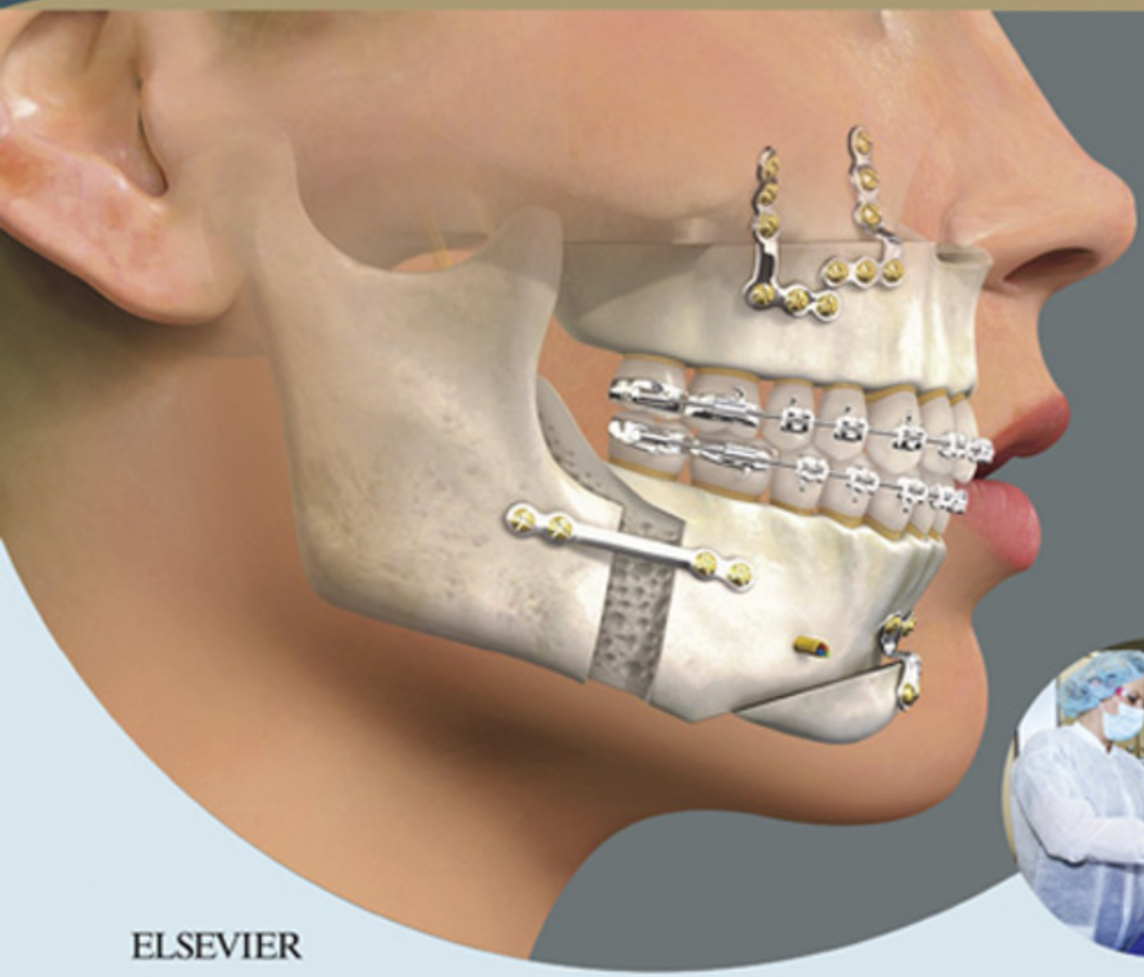
James R. Hupp | Edward Ellis III | Myron R. Tucker

CONTEMPORARY ORAL and MAXILLOFACIAL SURGERY

SEVENTH EDITION



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My contributions to this book are dedicated to my wonderfully supportive family:
Carmen, my wife, best friend, and the love of my life; our children,
Jamie, Justin, Joelle, and Jordan; our daughters and sons-in-law,
Natacha, Joe, Jordan, and Ted; and our precious grandchildren,
Peyton, Morgan, and Owen.

James R. Hupp

To all of the people I have worked with for the past 40 years
in oral and maxillofacial surgery, including my mentors,
partners in practice, residents, students,
and the staff that has offered me so much support.
You all know who you are.

Myron R. Tucker

To the many students and residents who have allowed
me to take part in their education.

Edward Ellis III

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Preface

The seventh edition of this internationally adopted and highly praised textbook, *Contemporary Oral and Maxillofacial Surgery,* is designed to provide both dental trainees and practicing dentists the fundamental principles of clinical evaluation, treatment planning, and surgical care for patients with diseases and deformities of the oral and maxillofacial region. This book provides great detail on the foundational techniques of evaluation, diagnosis, and care for clinical problems commonly managed by the general dental practitioner. The extensive number of illustrations make the surgical techniques readily understandable and also enhance readers' appreciation of the biologic basis and technical fundamentals, allowing them to manage routine surgical situations as well as those that go beyond "textbook cases."

There are two major purposes of the seventh edition of *Contemporary Oral and Maxillofacial Surgery*: (1) to present a comprehensive description of the basic oral surgery procedures that are performed by general practitioners, and (2) to provide information on advanced, more complex surgical evaluation and management of patients with problems that are typically managed by oral and maxillofacial surgeons but are commonly first seen and evaluated by other dental practitioners.

Whether you are a dental student, resident, or already in practice, the seventh edition of *Contemporary Oral and Maxillofacial Surgery* is an excellent resource to add to your professional library and regularly return to while providing patient care.

New to This Edition

Chapters 1 and 2, "Preoperative Health Status Evaluation" and "Prevention and Management of Medical Emergencies." These chapters have been completely updated.

Chapter 6, "Pain and Anxiety Control in Surgical Practice." This is an entirely new chapter providing succinct presentation of local anesthesia and nitrous oxide sedation as they relate to office-based oral surgery.

Chapter 8, "Principles of Routine Exodontia." New photographs and illustrations help enhance understanding of routine exodontic procedures.

Chapter 11, "Postextraction Patient Management." This chapter provides comprehensive information on preventing and managing the postoperative sequelae and complications of exodontia.

Chapter 12, "Medicolegal Considerations." This chapter has been updated with the most current HIPAA and Affordable Health Care Act information that affects dentistry and oral and maxillofacial surgery.

Chapter 15, "Implant Treatment: Advanced Concepts and Complex Cases." This chapter has been updated with the latest virtual planning options and new cases.

Chapter 20, "Odontogenic Diseases of the Maxillary Sinus." This chapter includes updated medical management and treatment with endoscopic procedures.

Chapter 21, "Diagnosis and Management of Salivary Gland Disorders." This chapter includes updates on imaging techniques and medical management.

Chapter 25, "Management of Facial Fractures." New cases have been added, with emphasis on the most recent imaging and navigation applications.

Chapter 26, "Correction of Dentofacial Deformities." The most current applications of computerized virtual surgical planning have been expanded. New illustrations using Dolphin Aquarium technology have been added to demonstrate surgical osteotomies, along with many new case reports.

Chapter 27, "Facial Cosmetic Surgery." This chapter has been rewritten by a new author emphasizing the full scope of facial cosmetic surgery, including surgical and nonsurgical treatment of the aging face.

Chapter 28, "Management of Temporomandibular Disorders." Updates on nonsurgical medical management have been addressed. The latest concepts of reconstruction of severe temporomandibular joint degeneration and the current technology for joint replacement have been augmented.

Chapter 29, "Surgical Reconstruction of Defects of the Jaws." This chapter includes new information on the use of a combination of bone morphogenetic protein, bone marrow aspirate cell concentrate, and allogeneic bone to reconstruct the jaws without the need for procurement of large autogenous bone grafts.

Acknowledgments

Thank you to Katie DeFrancesco for her patience and hard work managing the production of this seventh edition. I appreciate Makani Dollinger, Cameron McGee, Jordan White, and Alison Yeung for agreeing to pose for the new photographs in this edition, and for Steven Lichti for taking the photos. I also wish to express my gratitude to my faculty colleagues, Drs. Alison Yeung and Steven Thompson, for their support while I was preparing my contributions.

James R. Hupp

I thank my daughter, Ashley Tucker, for all the graphic design work she has done for my publications over the past 12 years.

Myron R. Tucker

I am indebted to all those who have furthered my education. That list includes my teachers, my colleagues, and my residents.

Edward Ellis III

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Contents

PART I

Principles of Surgery

Surgery is a discipline based on principles that have evolved from basic research and centuries of trial and error. These principles pervade every area of surgery, whether oral and maxillofacial, periodontal, or gastrointestinal. Part I provides information about patient health evaluation, managing medical emergencies, surgical concepts, principles of asepsis, and pain and anxiety control, which together form the necessary foundation for presentations of the specialized surgical techniques in succeeding chapters in this book.

Many patients have medical conditions that affect their ability to tolerate oral and maxillofacial surgery and anesthesia. Chapter 1 discusses the process of evaluating the health status of patients. This chapter also describes methods of modifying surgical treatment plans to safely accommodate patients with the most common medical problems.

Preventing medical emergencies in the patient undergoing oral and maxillofacial surgery or other forms of dentistry is always easier than managing emergencies should they occur. Chapter 2 discusses the means of recognizing and managing common medical emergencies in the dental office. Just as important, Chapter 2 also provides information about measures to lower the probability of emergencies.

Contemporary surgery is guided by a set of guiding principles, most of which apply no matter where in the body they are put into practice. Chapter 3 covers the most important principles for those practitioners who perform surgery of the oral cavity and maxillofacial regions.

Surgery always leaves a wound, whether one was initially present or not. Although obvious, this fact is often forgotten by the inexperienced surgeon, who may act as if the surgical procedure is complete once the final suture has been tied and the patient leaves. The surgeon's primary responsibility to the patient continues until the wound has healed; therefore an understanding of wound healing is mandatory for anyone who intends to create wounds surgically or manage accidental wounds. Chapter 4 presents basic wound healing concepts, particularly as they relate to oral surgery.

The work of Semmelweiss and Lister in the 1800s made clinicians aware of the microbial origin of postoperative infections, thereby changing surgery from a last resort to a more predictably successful endeavor. The advent of antibiotics designed to be used systemically further advanced surgical science, allowing elective surgery to be performed at low risk. However, pathogenic communicable organisms still exist, and when the epithelial barrier is breached during surgery, these can cause wound infections or systemic infectious diseases. The most serious examples are the hepatitis B virus and human immunodeficiency virus. In addition, microbes resistant to even to the most powerful antimicrobials today are emerging, making surgical asepsis more important than ever. Chapter 5 describes the means of minimizing the risk of significant wound contamination and the spread of infectious organisms among individuals. This includes thorough decontamination of surgical instruments, disinfection of the room in which surgery is performed, lowering of bacterial counts in the operative site, and adherence to infection control principles by the members of the surgical team—in other words, strict adherence to aseptic technique.

Finally, Chapter 6 covers the common methods used by those performing oral surgery to control pain and anxiety, primarily through the use of local anesthesia and nitrous oxide sedation.

1

Preoperative Health Status Evaluation

JAMES R. HUPP AND ALISON YEUNG

CHAPTER OUTLINE

The extent of the medical history, physical examination, and laboratory evaluation of patients requiring outpatient dentoalveolar surgery, under local anesthesia, nitrous oxide sedation, or both, differs substantially from that necessary for a patient requiring hospital admission and general anesthesia for surgical procedures. A patient's primary care physician typically performs periodic comprehensive history taking and physical examination of patients; it is therefore impractical and of little value for the dentist to duplicate this process. However, the dental professional must discover the presence or history of medical problems that may affect the safe delivery of the care she or he plans to provide, as well as any conditions specifically affecting the health of the oral and maxillofacial regions. This is particularly true for patients for which dentoalveolar surgery is planned. This is due to several factors such as the added physical stress surgery patient experience, the creation of a bleeding wound that then needs to heal, the invasive nature of surgery that typically introduces microorganisms into the patients tissues, and the common need for more elaborate pain and anxiety control measures and the use of more potent agents.

Dentists are educated in the basic biomedical sciences and the pathophysiology of common medical problems, particularly as they relate to the maxillofacial region. This special expertise in medical topics as they relate to the oral region makes dentists valuable resources on the community health care delivery team. The responsibility this carries is that dentists must be capable of recognizing and appropriately managing pathologic oral conditions. To maintain this expertise, a dentist must keep informed of new developments in medicine, be vigilant while treating patients, and be prepared to communicate a thorough but succinct evaluation of the oral health of patients to other health care providers.

Medical History

An accurate medical history is the most useful information a clinician can have when deciding whether a patient can safely undergo planned dental therapy. The dentist must be prepared to anticipate how a medical problem or problems might alter a patient's response to planned anesthetic agents and surgery. If the history taking is done well, the physical examination and laboratory evaluation of a patient usually play lesser roles in the presurgical evaluation. The standard format used for recording the results of medical histories and physical examinations is illustrated in Box 1.1. This general format tends to be followed even in electronic medical records.

The medical history interview and the physical examination should be tailored to each patient, taking into consideration the patient's medical problems, age, intelligence, and social

• BOX 1.1 Standard Format for Recording Results of History and Physical Examinations

1. Biographic data
2. Chief complaint and its history
3. Medical history
4. Social and family medical histories
5. Review of systems
6. Physical examination
7. Laboratory and imaging results

• BOX 1.2 Baseline Health History Database

1. Past hospitalizations, operations, traumatic injuries, and serious illnesses
2. Recent minor illnesses or symptoms
3. Medications currently or recently in use and allergies (particularly drug allergies)
4. Description of health-related habits or addictions, such as the use of ethanol, tobacco, and illicit drugs; and the amount and type of daily exercise
5. Date and result of last medical checkup or physician visit

circumstances; the complexity of the planned procedure; and the anticipated anesthetic methods.

Biographic Data

The first information to obtain from a patient is biographic data. These data include the patient's full name, home address, age, gender, and occupation, as well as the name of the patient's primary care physician. The clinician uses this information, along with an impression of the patient's intelligence and personality, to assess the patient's reliability. This is important because the validity of the medical history provided by the patient depends primarily on the reliability of the patient as a historian. If the identification data and patient interview give the clinician reason to suspect that the medical history may be unreliable, alternative methods of obtaining the necessary information should be tried. A reliability assessment should continue throughout the entire history interview and physical examination, with the interviewer looking for illogical, improbable, or inconsistent patient responses that might suggest the need for corroboration of information.

Chief Complaint

Every patient should be asked to state their chief complaint. This can be accomplished on a form the patient completes, or the patient's answers should be transcribed (preferably verbatim) into the dental record during the initial interview by a staff member or the dentist. This statement helps the clinician establish priorities during history taking and treatment planning. In addition, having patients formulate a chief complaint encourages them to clarify for themselves and the clinician why they desire treatment. Occasionally, a hidden agenda may exist for the patient, consciously or subconsciously. In such circumstances, subsequent information elicited from the patient interview may reveal the true reason the patient seeks care.

History of Chief Complaint

The patient should be asked to describe the history of the present complaint or illness, particularly its first appearance, any changes since its first appearance, and its influence on or by other factors. For example, descriptions of pain should include date of onset, intensity, duration, location, and radiation, as well as factors that worsen and mitigate the pain. In addition, an inquiry should be made about constitutional symptoms such as fever, chills, lethargy, anorexia, malaise, and any weakness associated with the chief complaint.

This portion of the health history may be straightforward, such as a 2-day history of pain and swelling around an erupting third molar. However, the chief complaint may be relatively involved, such as a lengthy history of a painful, nonhealing extraction site in a patient who received therapeutic irradiation. In this more complex case, a more detailed history of the chief complaint is important to obtain.

Medical History

Most dental practitioners find health history forms (questionnaires) to be an efficient means of initially collecting the medical history, whether obtained in writing or in an electronic format. When a credible patient completes a health history form, the dentist can use pertinent answers to direct the interview. Properly trained dental assistants can "red flag" important patient responses on the form (e.g., circling allergies to medications in red or electronically flagging them) to bring positive answers to the dentist's attention.

Health questionnaires should be written clearly, in nontechnical language, and in a concise manner. To lessen the chance of patients giving incomplete or inaccurate responses, and to comply with Health Insurance Portability and Accountability Act regulations, the form should include a statement that assures the patient of the confidentiality of the information and a consent line identifying those individuals the patient approves of having access to the dental record, such as the primary care physician and other clinicians in the practice. The form should also include a way (e.g., a signature line or pad) for the patient to verify that he or she has understood the questions and the accuracy of the answers. Numerous health questionnaires designed for dental patients are available from sources such as the American Dental Association and dental textbooks (Fig. 1.1).

Answers to the items listed in Box 1.2 (collected on a form via touch screen or verbally) help establish a suitable health history database for patients; if the data are collected verbally, subsequent written documentation of the results is important.

In addition to this basic information, it is helpful to inquire specifically about common medical problems that are likely to alter the dental management of the patient. These problems include angina, myocardial infarction (MI), heart murmurs, rheumatic heart disease, bleeding disorders (including anticoagulant use), asthma, chronic lung disease, hepatitis, sexually transmitted infections, diabetes, corticosteroid use, seizure disorder, stroke, and any implanted prosthetic device such as artificial joint or heart valve. Patients should be asked specifically about allergies to local anesthetics, aspirin, and penicillin. Female patients in the appropriate age group must be asked at each visit whether they are or may be pregnant.

A brief family history can be useful and should focus on relevant inherited diseases such as hemophilia (Box 1.3). The medical history should be regularly updated. Many dentists have their assistants specifically ask each patient at checkup appointments whether there has been any change in health since the last dental visit. The

MEDICAL HISTORY

Name _____ M _____ F _____ Date of Birth _____

Address _____

Telephone: (Home) _____ (Work) _____ Height _____ Weight _____

Today's Date _____ Occupation _____

Answer all questions by circling either YES or NO and fill in all blank spaces where indicated. Answers to the following questions are for our records only and are confidential.

1. My last medical physical examination was on (approximate) _____
2. The name & address of my personal physician is _____
   _____
3. Are you now under the care of a physician . . . . . YES NO
   If so, what is the condition being treated? _____
4. Have you had any serious illness or operation . . . . . YES NO
   If so, what was the illness or operation? _____
5. Have you been hospitalized within the past 5 years . . . . . YES NO
   If so, what was the problem? _____
6. Do you have or have you had any of the following diseases or problems:
   a. Rheumatic fever or rheumatic heart disease . . . . . YES NO
   b. Heart abnormalities present since birth . . . . . YES NO
   c. Cardiovascular disease (heart trouble, heart attack, angina, stroke, high blood pressure, heart murmur) . . . . . YES NO
      (1) Do you have pain or pressure in chest upon exertion . . . . . YES NO
      (2) Are you ever short of breath after mild exercise . . . . . YES NO
      (3) Do your ankles swell . . . . . YES NO
      (4) Do you get short of breath when you lie down, or do you require extra pillows when you sleep . . . . . YES NO
      (5) Have you been told you have a heart murmur . . . . . YES NO
   d. Asthma or hay fever . . . . . YES NO
   e. Hives or a skin rash . . . . . YES NO
   f. Fainting spells or seizures . . . . . YES NO
   g. Diabetes . . . . . YES NO
      (1) Do you have to urinate (pass water) more than six times a day . . . . . YES NO
      (2) Are you thirsty much of the time . . . . . YES NO
      (3) Does your mouth usually feel dry . . . . . YES NO
   h. Hepatitis, jaundice or liver disease . . . . . YES NO
   i. Arthritis or other joint problems . . . . . YES NO
   j. Stomach ulcers . . . . . YES NO
   k. Kidney trouble . . . . . YES NO
   l. Tuberculosis . . . . . YES NO
   m. Do you have a persistent cough or cough up blood . . . . . YES NO
   n. Venereal disease . . . . . YES NO
   o. Other (list) _____
      _____
      _____
7. Have you had abnormal bleeding associated with previous extractions, surgery, or trauma . . . . . YES NO
   a. Do you bruise easily . . . . . YES NO
   b. Have you ever required a blood transfusion . . . . . YES NO
   c. If so, explain the circumstances _____
      _____
8. Do you have any blood disorder such as anemia, including sickle cell anemia . . . . . YES NO
9. Have you had surgery or radiation treatment for a tumor, cancer, or other condition of your head or neck . . . . . YES NO

• **Fig. 1.1** Example of health history questionnaire useful for screening dental patients. (Modified from a form provided by the American Dental Association.)

MEDICAL HISTORY—cont'd

10. Are you taking any drug or medicine or herb . . . . . YES NO
    If so, what _____

11. Are you taking any of the following:
    a. Antibiotics or sulfa drugs . . . . . YES NO
    b. Anticoagulants (blood thinners) . . . . . YES NO
    c. Medicine for high blood pressure . . . . . YES NO
    d. Cortisone (steroids) (including prednisone) . . . . . YES NO
    e. Tranquilizers . . . . . YES NO
    f. Aspirin . . . . . YES NO
    g. Insulin, tolbutamide (Orinase) or similar drug for diabetes . . . . . YES NO
    h. Digitalis or drugs for heart trouble . . . . . YES NO
    i. Nitroglycerin . . . . . YES NO
    j. Antihistamine . . . . . YES NO
    k. Oral birth control drug or other hormonal therapy . . . . . YES NO
    l. Medicines for osteoporosis . . . . . YES NO
    m. Other _____

12. Are you allergic or have you reacted adversely to:
    a. Local anesthetics (procaine [Novocain]) . . . . . YES NO
    b. Penicillin or other antibiotics . . . . . YES NO
    c. Sulfa drugs . . . . . YES NO
    d. Aspirin . . . . . YES NO
    e. Iodine or x-ray dyes . . . . . YES NO
    f. Codeine or other narcotics . . . . . YES NO
    g. Other _____

13. Have you had any serious trouble associated with any previous dental treatment . . . . . YES NO
    If so, explain _____
    _____

14. Do you have any disease, condition, or problem not listed above that you think I should know about . . . . . YES NO
    If so, explain _____
    _____

15. Are you employed in any situation which exposes you regularly to x-rays or other ionizing radiation . . . . . YES NO

16. Are you wearing contact lenses . . . . . YES NO

WOMEN:

17. Are you pregnant or have you recently missed a menstrual period . . . . . YES NO

18. Are you presently breast-feeding . . . . . YES NO

Chief dental complaint (Why did you come to the office today?): _____
_____
_____
_____

_____
Signature of Patient (verifying accuracy of historical information)

_____
Signature of Dentist

• **Fig. 1.1, cont'd**

• BOX 1.3 Common Health Conditions to Inquire About Verbally or on a Health Questionnaire

- Allergies to antibiotics or local anesthetics
- Angina
- Anticoagulant use
- Asthma
- Bleeding disorders
- Breastfeeding
- Corticosteroid use
- Diabetes
- Heart murmurs
- Hepatitis
- Hypertension
- Implanted prosthetic devices
- Lung disease
- Myocardial infarction (i.e., heart attack)
- Osteoporosis
- Pregnancy
- Renal disease
- Rheumatic heart disease
- Seizure disorder
- Sexually transmitted diseases
- Tuberculosis

dentist is alerted if a change has occurred, and the changes are documented in the record.

Review of Systems

The medical review of systems is a sequential, comprehensive method of eliciting patient symptoms on an organ-by-organ basis. The review of systems may reveal undiagnosed medical conditions. This review can be extensive when performed by a physician for a patient with complicated medical problems. However, the review of systems conducted by the dentist before oral surgery should be guided by pertinent answers obtained from the history. For example, the review of the cardiovascular system in a patient with a history of ischemic heart disease includes questions concerning chest discomfort (during exertion, eating, or at rest), palpitations, fainting, and ankle swelling. Such questions help the dentist decide whether to perform surgery at all or to alter the surgical or anesthetic methods. If anxiety-controlling adjuncts such as intravenous (IV) and inhalation sedation are planned, the cardiovascular, respiratory, and nervous systems should always be reviewed; this can disclose previously undiagnosed problems that may jeopardize successful sedation. In the role of the oral health specialist, the dentist is expected to perform a quick review of the head, ears, eyes, nose, mouth, and throat on every patient, regardless of whether other systems are reviewed. Items to be reviewed are outlined in Box 1.4.

The need to review organ systems in addition to those in the maxillofacial region depends on clinical circumstances. The cardiovascular and respiratory systems commonly require evaluation before oral surgery or sedation (Box 1.5).

• BOX 1.4 Routine Review of Head, Neck, and Maxillofacial Regions

- *Constitutional:* Fever, chills, sweats, weight loss, fatigue, malaise, loss of appetite
- *Head:* Headache, dizziness, fainting, insomnia
- *Ears:* Decreased hearing, tinnitus (ringing), pain
- *Eyes:* Blurring, double vision, excessive tearing, dryness, pain
- *Nose and sinuses:* Rhinorrhea, epistaxis, problems breathing through nose, pain, change in sense of smell
- *Temporomandibular joint area:* Pain, noise, limited jaw motion, locking
- *Oral:* Dental pain or sensitivity, lip or mucosal sores, problems chewing, problems speaking, bad breath, loose restorations, sore throat, loud snoring
- *Neck:* Difficulty swallowing, change in voice, pain, stiffness

• BOX 1.5 Review of Cardiovascular and Respiratory Systems

Cardiovascular Review

Chest discomfort on exertion, when eating, or at rest; palpitations; fainting; ankle edema; shortness of breath (dyspnea) on exertion; dyspnea on assuming supine position (orthopnea or paroxysmal nocturnal dyspnea); postural hypotension; fatigue; leg muscle cramping

Respiratory Review

Dyspnea with exertion, wheezing, coughing, excessive sputum production, coughing up blood (hemoptysis)

Physical Examination

The physical examination of the dental patient focuses on the oral cavity and, to a lesser degree, on the entire maxillofacial region. Recording the results of the physical examination should be an exercise in accurate description rather than a listing of suspected medical diagnoses. For example, the clinician may find a mucosal lesion inside the lower lip that is 5 mm in diameter, raised and firm, and not painful to palpation. These physical findings should be recorded in a similarly descriptive manner; the dentist should not jump to a diagnosis and record only "fibroma on lower lip."

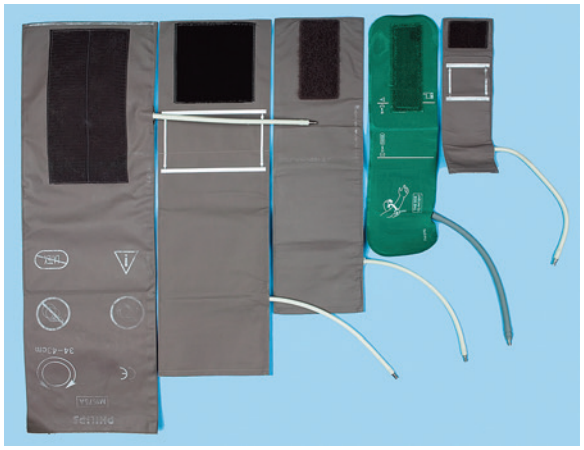
Any physical examination should begin with the measurement of vital signs. This serves as a screening device for unsuspected medical problems and as a baseline for future measurements. The techniques of measuring blood pressure and pulse rates are illustrated in Figs. 1.2 and 1.3.

The physical evaluation of various parts of the body usually involves one or more of the following four primary means of evaluation: (1) inspection, (2) palpation, (3) percussion, and (4) auscultation. In the oral and maxillofacial regions, inspection should always be performed. The clinician should note hair distribution and texture, facial symmetry and proportion, eye movements and conjunctival color, nasal patency on each side, the presence or absence of skin lesions or discoloration, and neck or facial masses. A thorough inspection of the oral cavity is necessary, including the oropharynx, tongue, floor of the mouth, and oral mucosa (Fig. 1.4).

Palpation is important when examining temporomandibular joint function, salivary gland size and function, thyroid gland size, presence or absence of enlarged or tender lymph nodes, and induration of oral soft tissues, as well as for determining pain or the presence of fluctuance in areas of swelling.

Physicians commonly use percussion during thoracic and abdominal examinations, and the dentist can use it to test teeth and paranasal sinuses. The dentist uses auscultation primarily for temporomandibular joint evaluation, but it is also used for cardiac, pulmonary, and gastrointestinal systems evaluations (Box 1.6). A

• **Fig. 1.2** (A) Measurement of systemic blood pressure. A cuff of proper size placed securely around the upper arm so that the lower edge of cuff lies 2 to 4 cm above the antecubital fossa. The brachial artery is palpated in the fossa, and the stethoscope diaphragm is placed over the artery and held in place with the fingers of the left hand. The squeeze-bulb is held in the palm of the right hand, and the valve is screwed closed with the thumb and the index finger of that hand. The bulb is then repeatedly squeezed until the pressure gauge reads approximately 220 mm Hg. Air is allowed to escape slowly from the cuff by partially opening the valve while the dentist listens through the stethoscope. Gauge reading at the point when a faint blowing sound is first heard is systolic blood pressure. Gauge reading when the sound from the artery disappears is diastolic pressure. Once the diastolic pressure reading is obtained, the valve is opened to deflate the cuff completely. (B) Pulse rate and rhythm most commonly are evaluated by using the tips of the middle and index fingers of the right hand to palpate the radial artery at the wrist. Once the rhythm has been determined to be regular, the number of pulsations that occur during 30 seconds is multiplied by 2 to get the number of pulses per minute. If a weak pulse or irregular rhythm is discovered while palpating the radial pulse, the heart should be auscultated directly to determine heart rate and rhythm.



• **Fig. 1.3** Blood pressure cuffs of varying sizes for patients with arms of different diameters (ranging from infants through obese adult patients). Use of an improper cuff size can jeopardize the accuracy of blood pressure results. Too small a cuff causes readings to be falsely high, and too large a cuff causes artificially low readings. Blood pressure cuffs typically are labeled as to the type and size of patient for whom they are designed.

• BOX 1.6 Physical Examination Before Oral and Maxillofacial Surgery

Inspection

- *Head and face:* General shape, symmetry, hair distribution
- *Ear:* Normal reaction to sounds (otoscopic examination if indicated)
- *Eye:* Symmetry, size, reactivity of pupil, color of sclera and conjunctiva, movement, test of vision
- *Nose:* Septum, mucosa, patency
- *Mouth:* Teeth, mucosa, pharynx, lips, tonsils
- *Neck:* Size of thyroid gland, jugular venous distention

Palpation

- *Temporomandibular joint:* Crepitus, tenderness
- *Paranasal:* Pain over sinuses
- *Mouth:* Salivary glands, floor of mouth, lips, muscles of mastication
- *Neck:* Thyroid gland size, lymph nodes

Percussion

- *Paranasal:* Resonance over sinuses (difficult to assess)
- *Mouth:* Teeth

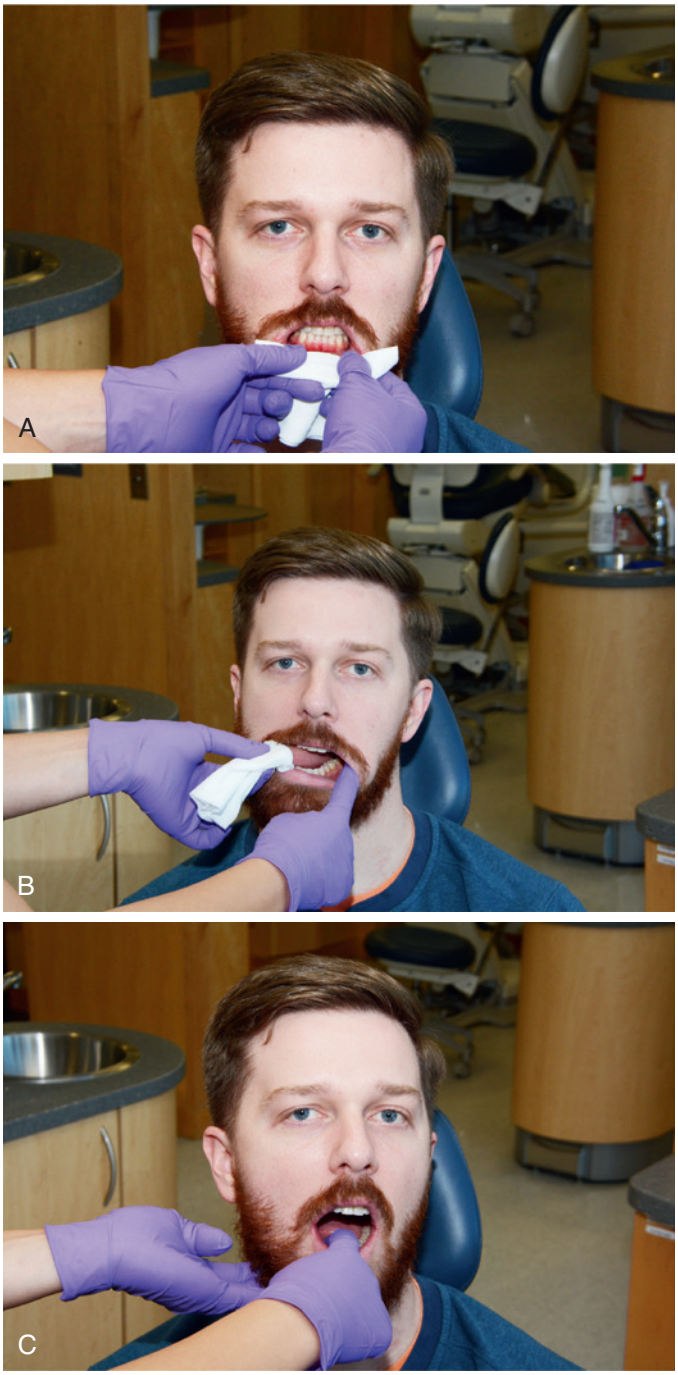
Auscultation

- *Temporomandibular joint:* Clicks, crepitus
- *Neck:* Carotid bruits

brief maxillofacial examination that all dentists should be able to perform is described in Box 1.7.

The results of the medical evaluation are used to assign a physical status classification. A few classification systems exist, but the one most commonly used is the American Society of Anesthesiologists' (ASA) physical status classification system (Box 1.8).

Once an ASA physical status class has been determined, the dentist can decide whether required treatment can be safely and routinely performed in the dental office. If a patient is not an ASA class I or a relatively healthy class II patient, the practitioner generally has the following four options: (1) modifying routine treatment plans by anxiety-reduction measures, pharmacologic anxiety-control techniques, more careful monitoring of the patient during treatment, or a combination of these methods (this is usually all that is necessary for ASA class II); (2) obtaining medical consultation for guidance



• **Fig. 1.4** (A) Lip mucosa examined by everting upper and lower lips. (B) Tongue examined by having the patient protrude it. The examiner then grasps the tongue with cotton sponge and gently manipulates it to examine the lateral borders. The patient also is asked to lift the tongue to allow visualization of the ventral surface and the floor of mouth. (C) Submandibular gland examined by bimanually feeling gland through floor of mouth and skin under floor of mouth.

in preparing patients to undergo ambulatory oral surgery (e.g., not fully reclining a patient with congestive heart failure [CHF], or hypertrophic cardiomyopathy [HCM]); (3) refusing to treat the patient in the ambulatory setting; or (4) referring the patient to an oral-maxillofacial surgeon. Modifications to the ASA system designed to be more specific to dentistry are available but are not yet widely used among health care professionals.

• BOX 1.7 Brief Maxillofacial Examination

While interviewing the patient, the dentist should visually examine the patient for general shape and symmetry of head and facial skeleton, eye movement, color of conjunctiva and sclera, and ability to hear. The clinician should listen for speech problems, temporomandibular joint sounds, and breathing ability.

Routine Examination

Temporomandibular Joint Region
- Palpate and auscultate joints.
- Measure range of motion of jaw and opening pattern.

Nose and Paranasal Region
- Occlude nares individually to check for patency.
- Inspect anterior nasal mucosa.

Mouth
- Take out all removable prostheses.
- Inspect oral cavity for dental, oral, and pharyngeal mucosal lesions. Look at tonsils and uvula.
- Hold tongue out of mouth with dry gauze while inspecting lateral borders.
- Palpate tongue, lips, floor of mouth, and salivary glands (check for saliva).
- Palpate neck for lymph nodes and thyroid gland size. Inspect jugular veins.

• BOX 1.8 American Society of Anesthesiologists (ASA) Classification of Physical Status

ASA I: A normal, healthy patient
ASA II: A patient with mild systemic disease or significant health risk factor
ASA III: A patient with severe systemic disease that is not incapacitating
ASA IV: A patient with severe systemic disease that is a constant threat to life
ASA V: A moribund patient who is not expected to survive without the operation
ASA VI: A declared brain-dead patient whose organs are being removed for donation purposes

Management of Patients With Compromising Medical Conditions

Patients with medical conditions sometimes require modifications of their perioperative care when oral surgery is planned. This section discusses those considerations for the major categories of health problems.

Cardiovascular Problems

Ischemic Heart Disease

Angina Pectoris

Narrowing of myocardial arteries is one of the most common health problems that dentists encounter. This condition occurs primarily in men older than age 40 years and is also prevalent in postmenopausal women. The basic disease process is a progressive narrowing or spasm (or both) of one or more of the coronary arteries. This leads to a mismatch between myocardial oxygen demand and the ability of the coronary arteries to supply oxygen-carrying blood. Myocardial oxygen demand can be increased, for example, by exertion or anxiety. Angina is a symptom of reversible ischemic heart disease produced when myocardial blood supply cannot be sufficiently increased to meet the increased oxygen requirements that result from coronary artery disease. The myocardium becomes ischemic, producing a heavy pressure or squeezing sensation in the patient's substernal region that can radiate into

the left shoulder and arm and even into the mandibular region. The patient may complain of an intense sense of being unable to breathe adequately. (The term *angina* is derived from the ancient Greek word meaning "a choking sensation.") Stimulation of vagal activity commonly occurs with resulting nausea, sweating, and bradycardia. The discomfort typically disappears once the myocardial work requirements are lowered or the oxygen supply to the heart muscle is increased.

The practitioner's responsibility to a patient with an angina history is to use all available preventive measures, thereby reducing the possibility that the surgical procedure will precipitate an anginal episode. Preventive measures begin with taking a careful history of the patient's angina. The patient should be questioned about the events that tend to precipitate the angina; the frequency, duration, and severity of angina; and the response to medications or diminished activity. The patient's physician can be consulted about the patient's cardiac status.

If the patient's angina arises only during moderately vigorous exertion and responds readily to rest and oral nitroglycerin administration, and if no recent increase in severity has occurred, ambulatory oral surgery procedures are usually safe when performed with proper precautions.

However, if anginal episodes occur with only minimal exertion, if several doses of nitroglycerin are needed to relieve chest discomfort, or if the patient has unstable angina (i.e., angina present at rest or worsening in frequency, severity, ease of precipitation, duration of attack, or predictability of response to medication), elective surgery should be postponed until a medical consultation is obtained. Alternatively, the patient can be referred to an oral-maxillofacial surgeon if emergency surgery is necessary.

Once the decision is made that ambulatory elective oral surgery can safely proceed, the patient with a history of angina should be prepared for surgery, and the patient's myocardial oxygen demand should be lowered or prevented from rising. The increased oxygen demand during ambulatory oral surgery is primarily the result of patient anxiety; thus an anxiety-reduction protocol should be used (Box 1.9). Profound local anesthesia is the best means of limiting patient anxiety. Although some controversy exists over the use of local anesthetics containing epinephrine in patients with angina, the benefits (i.e., prolonged and accentuated anesthesia) outweigh the risks. However, care should be taken to avoid excessive epinephrine administration by using proper injection techniques. Some clinicians also advise giving no more than 4 mL of a local anesthetic solution with a 1:100,000 concentration of epinephrine for a total adult dose of 0.04 mg in any 30-minute period.

Before and during surgery, vital signs should be monitored periodically. In addition, regular verbal contact with the patient should be maintained. The use of nitrous oxide or other conscious sedation methods for anxiety control in patients with ischemic heart disease should be considered. Fresh nitroglycerin should be nearby for use when necessary (Box 1.10).

The introduction of balloon-tipped catheters into narrowed coronary arteries for the purpose of reestablishing adequate blood flow and stenting arteries open is becoming commonplace. If the angioplasty has been successful (based on cardiac stress testing), oral surgery can proceed soon thereafter with the same precautions as those used for patients with angina.

Myocardial Infarction

MI occurs when ischemia (resulting from an oxygen demand-supply mismatch) is not relieved and causes myocardial cellular dysfunction and death. MI usually occurs when an area of coronary artery narrowing has a clot form that blocks all or most blood flow. The infarcted area of myocardium becomes nonfunctional and eventually necrotic and is surrounded by an area of usually reversibly ischemic myocardium that is prone to serve as a nidus for dysrhythmias. During the early hours and weeks after an MI, if thrombolytic treatment was tried but was unsuccessful, treatment would consist of limiting myocardial work requirements, increasing myocardial oxygen supply, and suppressing the production of dysrhythmias by irritable foci in ischemic tissue or by surgical bypass of the blocked vessels to promote revascularization. In addition, if any of the primary conduction pathways were involved in the infarcted area, pacemaker insertion may be necessary. If the patient survived the early weeks after an MI, the variably sized necrotic area would be gradually replaced with scar tissue, which is unable to contract or properly conduct electrical signals.

• BOX 1.9 General Anxiety-Reduction Protocol

Before Appointment

- Hypnotic agent to promote sleep on night before surgery (optional)
- Sedative agent to decrease anxiety on morning of surgery (optional)
- Morning appointment and schedule so that reception room time is minimized

During Appointment

Nonpharmacologic Means of Anxiety Control

- Frequent verbal reassurances
- Distracting conversation
- No surprises (clinician warns patient before doing anything that could cause anxiety)
- No unnecessary noise
- Surgical instruments out of patient's sight
- Relaxing background music

Pharmacologic Means of Anxiety Control

- Local anesthetics of sufficient intensity and duration
- Nitrous oxide
- Intravenous anxiolytics

After Surgery

- Succinct instructions for postoperative care
- Patient information on expected postsurgical sequelae (e.g., swelling or minor oozing of blood)
- Further reassurance
- Effective analgesics
- Patient information on who can be contacted if any problems arise
- Telephone call to patient at home during evening after surgery to check whether any problems exist

• BOX 1.10 Management of Patient With History of Angina Pectoris

1. Consult the patient's physician.
2. Use an anxiety-reduction protocol.
3. Have nitroglycerin tablets or spray readily available. Use nitroglycerin premedication, if indicated.
4. Ensure profound local anesthesia before starting surgery.
5. Consider the use of nitrous oxide sedation.
6. Monitor vital signs closely.
7. Consider possible limitation of amount of epinephrine used (0.04 mg maximum).
8. Maintain verbal contact with patient throughout the procedure to monitor status.

The management of an oral surgical problem in a patient who has had an MI begins with a consultation with the patient's physician. In general, it is recommended that elective major surgical procedures be deferred until at least 6 months after an infarction. This delay is based on statistical evidence that the risk of reinfarction after an MI drops to as low as it will ever be by about 6 months, particularly if the patient is properly supervised medically. The advent of thrombolytic-based treatment strategies and improved MI care make an automatic 6-month wait to do dental work unnecessary. Straightforward oral surgical procedures typically performed in the dental office may be performed less than 6 months after an MI if the procedure is unlikely to provoke significant anxiety and the patient had an uneventful recovery from the MI. In addition, other dental procedures may proceed if cleared by the patient's physician via a medical consult.

Patients with a history of MI should be carefully questioned concerning their cardiovascular health. An attempt to elicit evidence of undiagnosed dysrhythmias or CHF (HCM) should be made. Patients who have had an MI typically take aspirin or another antiplatelet or anticoagulant to decrease coronary thrombogenesis; details of this should be sought because it can affect surgical decision making.

If more than 6 months have elapsed or physician clearance is obtained, the management of the patient who has had an MI is similar to care of the patient with angina. An anxiety-reduction program should be used. Supplemental oxygen can be considered but is usually unnecessary. Prophylactic nitroglycerin should be administered only if directed by the patient's primary care physician, but nitroglycerin should be readily available. Local anesthetics containing epinephrine are safe to use if given in proper amounts using an aspiration technique. Vital signs should be monitored throughout the perioperative period (Box 1.11).

In general, with respect to major oral surgical care, patients who have had coronary artery bypass grafting (CABG) are treated in a manner similar to patients who have had an MI. Before major elective surgery is performed, 3 months are allowed to elapse. If major surgery is necessary earlier than 3 months after the CABG, the patient's physician should be consulted. Patients who have had CABG usually have a history of angina, MI, or both and therefore should be managed as previously described. Routine office surgical procedures may be safely performed in patients less than 6 months after CABG surgery if their recovery has been uncomplicated and anxiety is kept to a minimum.

• BOX 1.11 Management of Patient With a History of Myocardial Infarction

1. Consult the patient's primary care physician.
2. Check with the physician if invasive dental care is needed before 6 months since the myocardial infarction.
3. Check whether the patient is using anticoagulants (including aspirin).
4. Use an anxiety-reduction protocol.
5. Have nitroglycerin available; use it prophylactically if the physician advises.
6. Administer supplemental oxygen (optional).
7. Provide profound local anesthesia.
8. Consider nitrous oxide administration.
9. Monitor vital signs, and maintain verbal contact with the patient.
10. Consider possible limitation of epinephrine use to 0.04 mg.
11. Consider referral to an oral-maxillofacial surgeon.

Cerebrovascular Accident (Stroke)

Patients who have had a cerebrovascular accident (CVA) are always susceptible to further neurovascular accidents. These patients are often prescribed anticoagulants or antiplatelet medication depending on the cause of the CVA; if they are hypertensive, they are given blood pressure–lowering agents. CVAs are typically a result of an embolus from a history of atrial fibrillation, a thrombus due to a hypercoagulable state, or stenotic vessels. In the case of a patient having an embolic or thrombotic stroke, the patient is likely taking an anticoagulant as opposed to an ischemic stroke secondary to stenotic vessels, in which case the patient would be taking an antiplatelet medication. If such a patient requires surgery, clearance by the patient's physician is desirable, as is a delay until significant hypertensive tendencies have been controlled. The patient's baseline neurologic status should be assessed and documented preoperatively. The patient should be treated by a nonpharmacologic anxiety-reduction protocol and have vital signs carefully monitored during surgery. If pharmacologic sedation is necessary, low concentrations of nitrous oxide can be used. Techniques to manage patients taking anticoagulants are discussed later in this chapter.

Dysrhythmias

Cardiac dysrhythmias manifest as uncoordinated contractions of the chambers of the heart, secondary to the conduction deficits initiated by either problems with impulse initiation or impulse propagation. Dysrhythmias may occur in patients as a result of a history of chronic systemic illness such as prior cardiac disease, open heart surgery, valvulopathy, thyroid disease, metabolic syndrome, electrolyte abnormalities, or idiopathically. Atrial fibrillation is the most common dysrhythmia to occur in patients older than 50 years. Because patients who are prone to or who have cardiac dysrhythmias may have a history of ischemic heart disease, some dental management modifications may need to be considered. Many advocate limiting the total amount of epinephrine administration to 0.04 mg, but this should be balanced with the patient's overall risk for a cardiac event and your ability to obtain profound anesthesia to minimize intraoperative pain and anxiety. In addition, these patients may have been prescribed anticoagulants or may have a permanent cardiac pacemaker. Pacemakers pose no contraindications to oral surgery, and no evidence exists that shows the need for antibiotic prophylaxis in patients with pacemakers. Electrical equipment, such as electrocautery and microwaves, should not be used near the patient. As with other medically compromised patients, vital signs should be carefully monitored, and all other comorbid conditions should be considered.

Heart Abnormalities That Predispose to Infective Endocarditis

The internal cardiac surface, or endocardium, can be predisposed to infection when abnormalities of its surface allow pathologic bacteria to attach and multiply. A complete description of this process and recommended means of possibly preventing it are discussed in Chapter 18.

Congestive Heart Failure (Hypertrophic Cardiomyopathy)

CHF (HCM) occurs when a diseased myocardium is unable to deliver the cardiac output demanded by the body or when excessive demands are placed on a normal myocardium. The heart begins to have an increased end-diastolic volume that, in the case of the normal myocardium, increases contractility through the Frank-Starling mechanism. However, as the normal or diseased myocardium

• BOX 1.12 Management of the Patient With Congestive Heart Failure (Hypertrophic Cardiomyopathy)

1. Defer treatment until heart function has been medically improved and the patient's physician believes treatment is possible.
2. Use an anxiety-reduction protocol.
3. Consider possible administration of supplemental oxygen.
4. Avoid using the supine position.
5. Consider referral to an oral-maxillofacial surgeon.

further dilates, it becomes a less efficient pump, causing blood to back up into the pulmonary, hepatic, and mesenteric vascular beds. This eventually leads to pulmonary edema, hepatic dysfunction, and compromised intestinal nutrient absorption. The lowered cardiac output causes generalized weakness, and impaired renal clearance of excess fluid leads to vascular overload.

Symptoms of CHF include orthopnea, paroxysmal nocturnal dyspnea, and ankle edema. Orthopnea is a respiratory disorder that exhibits shortness of breath when the patient is supine. Orthopnea usually occurs as a result of the redistribution of blood pooled in the lower extremity when a patient assumes the supine position (as when sleeping). The heart is overwhelmed, trying to handle the increased cardiac preload, and blood backs up into the pulmonary circulation, inducing pulmonary edema. Patients with orthopnea usually sleep with their upper body supported on several pillows.

Paroxysmal nocturnal dyspnea is a symptom of CHF that is similar to orthopnea. The patient has respiratory difficulty 1 or 2 hours after lying down. The disorder occurs when pooled blood and interstitial fluid reabsorbed into the vasculature from the legs are redistributed centrally, overwhelming the heart and producing pulmonary edema. A while after lying down to sleep, patients suddenly awake, feeling short of breath, and are compelled to sit up to try to catch their breath.

Lower extremity edema, which usually appears as a swelling of the foot, the ankle, or both, is caused by an increase in interstitial fluid. Usually the fluid collects as a result of any problem that increases venous pressure or lowers serum protein, allowing increased amounts of plasma to remain in the tissue spaces of the feet. The edema is detected by pressing a finger into the swollen area for a few seconds; if an indentation in the soft tissue is left after the finger is removed, pedal edema is deemed to be present. Other symptoms of CHF include weight gain and dyspnea on exertion.

Patients with CHF who are under a physician's care are usually following low-sodium diets to reduce fluid retention and are receiving diuretics to reduce intravascular volume; cardiac glycosides such as digoxin to improve cardiac efficiency; and sometimes afterload-reducing drugs such as nitrates, β-adrenergic antagonists, or calcium channel antagonists to control the amount of work the heart is required to do. In addition, patients with chronic atrial fibrillation caused by HCM are usually prescribed anticoagulants to prevent atrial thrombus formation.

Patients with CHF that is well compensated through dietary and drug therapy can safely undergo ambulatory oral surgery. An anxiety-reduction protocol and supplemental oxygen are helpful. Patients with orthopnea should not be placed supine during any procedure. Surgery for patients with uncompensated HCM is best deferred until compensation has been achieved or procedures can be performed in the hospital setting (Box 1.12).

• BOX 1.13 Management of the Patient With Asthma

1. Defer dental treatment until the asthma is well controlled and the patient has no signs of a respiratory tract infection.
2. Listen to the chest with a stethoscope to detect any wheezing before major oral surgical procedures or sedation.
3. Use an anxiety-reduction protocol, including nitrous oxide, but avoid the use of respiratory depressants.
4. Consult the patient's physician about possible preoperative use of cromolyn sodium.
5. If the patient is or has been chronically taking corticosteroids, provide prophylaxis for adrenal insufficiency.
6. Keep a bronchodilator-containing inhaler easily accessible.
7. Avoid the use of nonsteroidal antiinflammatory drugs in susceptible patients.

Pulmonary Problems

Asthma

When a patient has a history of asthma, the dentist should first determine, through further questioning, whether the patient truly has asthma or has a respiratory problem such as allergic rhinitis that carries less significance for dental care. True asthma involves the episodic narrowing of inflamed small airways, which produces wheezing and dyspnea as a result of chemical, infectious, immunologic, or emotional stimulation or a combination of these. Patients with asthma should be questioned about precipitating factors, frequency and severity of attacks, medications used, and response to medications. The severity of attacks can often be gauged by the need for emergency room visits and hospital admissions. These patients should be questioned specifically about aspirin allergy because of the relatively high frequency of generalized nonsteroidal antiinflammatory drug (NSAID) allergy in those with asthma, chronic rhinitis, or sinusitis and the presence of nasal polyps, known as Samter's triad.

Physicians prescribe medications for patients with asthma according to the frequency, severity, and causes of their disease. Patients with severe asthma require xanthine-derived bronchodilators, such as theophylline, as well as inhaled corticosteroids or short courses of high-dose systemic corticosteroids. Cromolyn may be used to protect against acute attacks, but it is ineffective once bronchospasm occurs. Many patients carry sympathomimetic amines such as epinephrine or metaproterenol in an aerosol form that can be self-administered if wheezing occurs. Inhaled β-adrenergic agonists, such as albuterol, are typically prescribed for episodes of acute bronchospasm to promote immediate bronchodilation.

Oral surgical management of the patient with asthma involves recognition of the role of anxiety in bronchospasm initiation and of the potential adrenal suppression in patients receiving systemic corticosteroid therapy. Elective oral surgery should be deferred if a respiratory tract infection or wheezing is present. When surgery is performed, an anxiety-reduction protocol should be followed; if the patient takes steroids, the patient's primary care physician can be consulted about the possible need for corticosteroid augmentation during the perioperative period if a major surgical procedure is planned. Nitrous oxide is safe to administer to persons with asthma and is especially indicated for patients whose asthma is triggered by anxiety. They can promote some mild bronchodilatory effects. The patient's own inhaler should be available during surgery, and drugs such as injectable epinephrine, theophylline, and inhaled beta agonists should be kept in an emergency kit. The use of NSAIDs should be avoided because they often precipitate asthma attacks in susceptible individuals (Box 1.13).

• BOX 1.14 Management of Patient With Chronic Obstructive Pulmonary Disease

1. Defer treatment until lung function has improved and treatment is possible.
2. Listen to the chest bilaterally with stethoscope to determine adequacy of breath sounds.
3. Use an anxiety-reduction protocol, but avoid the use of respiratory depressants.
4. If the patient requires chronic oxygen supplementation, continue at the prescribed flow rate. If the patient does not require supplemental oxygen therapy, consult his or her physician before administering oxygen.
5. If the patient chronically receives corticosteroid therapy, manage the patient for adrenal insufficiency.
6. Avoid placing the patient in the supine position until you are confident that the patient can tolerate it.
7. Keep a bronchodilator-containing inhaler accessible.
8. Closely monitor respiratory rate and heart rate.
9. Schedule afternoon appointments to allow for clearance of secretions.

Chronic Obstructive Pulmonary Disease

Pulmonary diseases are usually grouped together under the headings of either obstructive (chronic obstructive pulmonary disease [COPD]) or restrictive pulmonary disease. In the past, the terms *emphysema* and *bronchitis* were used to describe clinical manifestations of COPD, but COPD has been recognized to be a spectrum of pathologic pulmonary problems. It is usually caused by long-term exposure to pulmonary irritants such as tobacco smoke that cause metaplasia of pulmonary airway tissue. Airways are inflamed and disrupted, lose their elastic properties, and become obstructed because of mucosal edema, excessive secretions, and bronchospasm, producing the clinical manifestations of COPD. Patients with COPD frequently become dyspneic during mild to moderate exertion. They have a chronic cough that produces large amounts of thick secretions, frequent respiratory tract infections, and barrel-shaped chests, and they may purse their lips to breathe and have audible wheezing during breathing. Patients may develop associated pulmonary hypertension and eventual right-sided heart failure.

Bronchodilators such as theophylline, inhaled beta agonists, or inhaled anticholinergics are usually prescribed for patients with significant COPD; in more severe cases, patients are given long-acting agents and inhaled corticosteroids or short courses of systemic corticosteroids. Only in the most severe chronic cases is supplemental portable oxygen used.

In the dental management of patients with COPD who are receiving corticosteroids, the dentist should consider the use of additional supplementation before major surgery. Sedatives, hypnotics, and narcotics that depress respiration should be avoided. Patients may need to be kept in an upright sitting position in the dental chair to enable them to better handle their commonly copious pulmonary secretions. Finally, supplemental oxygen greater than their usual rate should not be administered to patients with severe COPD during surgery unless the physician advises it. In contrast with healthy persons in whom an elevated arterial carbon dioxide level is the major stimulation to breathing, the patient with severe COPD becomes acclimated to elevated arterial carbon dioxide levels and comes to depend entirely on depressed arterial oxygen (O_2) levels to stimulate breathing. If the arterial O_2 concentration is elevated by the administration of O_2 in a high concentration, the hypoxia-based respiratory stimulation is removed, and the patient's respiratory rate may become critically slowed (Box 1.14).

• BOX 1.15 Management of Patient With Renal Insufficiency and Patient Receiving Hemodialysis

1. Avoid the use of drugs that depend on renal metabolism or excretion. Modify the dose if such drugs are necessary. Do not use an atrioventricular shunt for giving drugs or for taking blood specimens.
2. Avoid the use of nephrotoxic drugs such as nonsteroidal antiinflammatory drugs.
3. Defer dental care until the day after dialysis has been given.
4. Consult the patient's physician about the use of prophylactic antibiotics.
5. Monitor blood pressure and heart rate.
6. Look for signs of secondary hyperparathyroidism.
7. Consider screening for hepatitis B virus before dental treatment. Take the necessary precautions if unable to screen for hepatitis.

Renal Problems

Renal Failure

Patients with chronic renal failure require periodic renal dialysis. These patients need special consideration during oral surgical care. Chronic dialysis treatment typically requires the presence of an arteriovenous shunt, which is a large, surgically created junction between an artery and a vein. The shunt allows easy vascular access and heparin administration, permitting blood to move through the dialysis equipment without clotting. The dentist should never use the shunt for venous access except in a life-threatening emergency. The blood pressure cuff should never be used on the arm where an arteriovenous shunt is present.

Elective oral surgery is best undertaken the day after a dialysis treatment has been performed. This allows the heparin used during dialysis to disappear and the patient to be in the best physiologic status with respect to intravascular volume and metabolic byproducts.

Drugs that depend on renal metabolism or excretion should be avoided or used in modified doses to prevent systemic toxicity. Drugs removed during dialysis will also necessitate special dosing regimens. Relatively nephrotoxic drugs such as NSAIDs should also be avoided in patients with seriously compromised kidneys.

Because of the higher incidence of hepatitis in patients undergoing renal dialysis, dentists should take the necessary precautions. The altered appearance of bone caused by secondary hyperparathyroidism in patients with renal failure should also be noted. Radiolucencies that occur as a result of metabolic process should not be mistaken for dental disease (Box 1.15).

Renal Transplantation and Transplantation of Other Organs

The patient requiring surgery after renal or other major organ transplantation is usually receiving a variety of drugs to preserve the function of the transplanted tissue. These patients receive corticosteroids and may need supplemental corticosteroids in the perioperative period (see discussion on adrenal insufficiency later in this chapter).

Most of these patients also receive immunosuppressive agents that may cause otherwise self-limiting infections to become severe. Therefore a more aggressive use of antibiotics and early hospitalization for infections are warranted. The patient's primary care physician should be consulted about the need for prophylactic antibiotics.

Cyclosporine A, an immunosuppressive drug administered after organ transplantation, may cause gingival hyperplasia. The dentist

• BOX 1.16 Management of Patient With Renal Transplant

1. Defer treatment until the patient's primary care physician or transplant surgeon clears the patient for dental care.
2. Avoid the use of nephrotoxic drugs.[a]
3. Consider the use of supplemental corticosteroids.
4. Monitor blood pressure.
5. Consider screening for hepatitis B virus before dental care. Take necessary precautions if unable to screen for hepatitis.
6. Watch for presence of cyclosporine-A–induced gingival hyperplasia. Emphasize the importance of oral hygiene.
7. Consider use of prophylactic antibiotics, particularly in patients taking immunosuppressive agents.

[a]*In patients with other transplanted organs, the clinician should avoid the use of drugs toxic to that organ.*

Most of these recommendations also apply to patients with other transplanted organs.

• BOX 1.17 Management of Patient With Hypertension

Mild to Moderate Hypertension (Systolic >140 mm Hg; Diastolic >90 mm Hg)

1. Recommend that the patient seek the primary care physician's guidance for medical therapy of hypertension. It is not necessary to defer needed dental care.
2. Monitor the patient's blood pressure at each visit and whenever administration of epinephrine-containing local anesthetic surpasses 0.04 mg during a single visit.
3. Use an anxiety-reduction protocol.
4. Avoid rapid posture changes in patients taking drugs that cause vasodilation.
5. Avoid administration of sodium-containing intravenous solutions.

Severe Hypertension (Systolic >200 mm Hg; Diastolic >110 mm Hg)

1. Defer elective dental treatment until the hypertension is better controlled.
2. Consider referral to an oral-maxillofacial surgeon for emergent problems.

performing oral surgery should recognize this so as not to wrongly attribute gingival hyperplasia entirely to hygiene problems.

Patients who have received renal transplants occasionally have problems with severe hypertension. Vital signs should be obtained immediately before oral surgery is performed in these patients (Box 1.16), although the patient should be counseled to see their primary care physician.

Hypertension

Chronically elevated blood pressure for which the cause is unknown is called *essential* hypertension. Mild or moderate hypertension (i.e., systolic pressure <200 mm Hg or diastolic pressure <110 mm Hg) is usually not a problem in the performance of ambulatory oral surgical care, as long as the patient is not having signs or symptoms of end-organ involvement secondary to the elevated blood pressure.

Care of the poorly controlled hypertensive patient includes use of an anxiety-reduction protocol and monitoring of vital signs. Epinephrine-containing local anesthetics should be used cautiously; after surgery, patients should be advised to seek medical care for their hypertension.

• BOX 1.18 Management of Patient With Hepatic Insufficiency

1. Attempt to learn the cause of the liver problem; if the cause is hepatitis B, take usual precautions.
2. Avoid drugs requiring hepatic metabolism or excretion; if their use is necessary, modify the dose.
3. Screen patients with severe liver disease for bleeding disorders by using tests for determining platelet count, prothrombin time, partial thromboplastin time, and bleeding time.
4. Attempt to avoid situations in which the patient might swallow large amounts of blood.

Elective oral surgery for patients with severe hypertension (i.e., systolic pressure of ≥200 mm Hg or diastolic pressure of ≥110 mm Hg) should be postponed until the pressure is better controlled. Emergency oral surgery in severely hypertensive patients should be performed in a well-controlled environment or in the hospital so that the patient can be carefully monitored during surgery and acute blood pressure control can be subsequently arranged (Box 1.17).

Hepatic Disorders

The patient with severe liver damage resulting from infectious disease, ethanol abuse, or vascular or biliary congestion requires special consideration before oral surgery is performed. An alteration of dose or avoidance of drugs that require hepatic metabolism may be necessary.

The production of nearly all coagulation factors, as well as protein C and S, may be depressed in severe liver disease; therefore obtaining an international normalized ratio (INR; prothrombin time [PT]) or partial thromboplastin time may be useful before surgery in patients with more severe liver disease who are undergoing surgery with the potential for heavy blood loss. Portal hypertension caused by liver disease may also cause hypersplenism and the sequestering of platelets, causing a relative thrombocytopenia. Thrombopoietin is also produced in the liver, and decreased production of thrombopoietin may result in a true thrombocytopenia. Finding a prolonged bleeding time or low platelet count reveals this problem. Patients with severe liver dysfunction may require hospitalization for dental surgery because their decreased ability to metabolize the nitrogen in swallowed blood may cause encephalopathy. Finally, unless documented otherwise, a patient with liver disease of unknown origin should be presumed to carry the hepatitis virus (Box 1.18).

Endocrine Disorders

Diabetes Mellitus

Diabetes mellitus is caused by an underproduction of insulin, a resistance of insulin receptors in end organs to the effects of insulin, or both. Diabetes is commonly divided into insulin-dependent (type 1) and non–insulin-dependent (type 2) diabetes. Type 1 diabetes usually begins during childhood or adolescence. The major problem in this form of diabetes is an underproduction of insulin, which results in the inability of the patient to use glucose properly. The serum glucose rises above the level at which renal reabsorption of all glucose can take place, causing glycosuria. The osmotic effect of the glucose solute results in polyuria, stimulating thirst and causing polydipsia (frequent consumption of liquids) in the patient. In addition, carbohydrate metabolism is altered, leading to fat

breakdown and the production of ketone bodies. This can lead to ketoacidosis and its attendant tachypnea with somnolence and eventually coma.

Persons with type 1 diabetes must strike a balance with regard to caloric intake, exercise, and insulin dose. Any decrease in regular caloric intake or increase in activity, metabolic rate, or insulin dose can lead to hypoglycemia, and vice versa.

Patients with type 2 diabetes usually produce insulin but in insufficient amounts because of decreased insulin activity, insulin receptor resistance, or both. This form of diabetes typically begins in adulthood, is exacerbated by obesity, and does not usually require insulin therapy. This form of diabetes is treated by weight control, dietary restrictions, and the use of oral hypoglycemics. Insulin is required only if the patient is unable to maintain acceptable serum glucose levels using the usual therapeutic measures. Severe hyperglycemia in patients with type 2 diabetes rarely produces ketoacidosis but leads to a hyperosmolar state with altered levels of consciousness.

Short-term, mild-to-moderate hyperglycemia is usually not a significant problem for persons with diabetes. Therefore, when an oral surgical procedure is planned, it is best to err on the side of hyperglycemia rather than hypoglycemia; that is, it is best to avoid an excessive insulin dose and to give a glucose source. Ambulatory oral surgery procedures should be performed early in the day, using an anxiety-reduction program. Discussion with the patient's primary care physician is warranted if adjustments need to be made to the patient's medication regimen in light of dietary changes made for the day of surgery or in the immediate postoperative period. If IV sedation is not being used, the patient should be asked to eat a normal meal and take the usual morning amount of regular insulin and a half dose of neutral protamine Hagedorn insulin (Table 1.1). The patient's vital signs should be monitored. If signs of hypoglycemia—hypotension, hunger, drowsiness, nausea, diaphoresis, tachycardia, or mood change—occur, an oral or IV supply of glucose should be administered. Ideally, offices should have an electronic glucometer available with which the clinician or patient can readily determine serum glucose with a drop of the patient's blood. This device may help determine the need to treat the patient for mild hyperglycemia. The patient should be advised to monitor serum glucose closely for the first 24 hours postoperatively and adjust insulin accordingly.

TABLE 1.1 Types of Insulin

Onset and Duration of Action	Names	Peak Effect of Action (Hours After Injection)	Duration of Action (Hours)
Fast (F)	Regular	2–3	6
	Semilente	3–6	12
Intermediate (I)	Globin zinc	6–8	18
	NPH	8–12	24
	Lente	8–12	24
Long (L)	Protamine zinc	16–24	36
	Ultralente	20–30	36

Insulin sources are pork—F, I; beef—F, I, L; beef and pork—F, I, L; and recombinant DNA—F, I, L.
NPH, Neutral protamine Hagedorn.

If a patient must miss a meal before a surgical procedure, the patient should be told to omit any morning insulin and only resume insulin once a supply of calories can be received. Regular insulin should then be used, with the dose based on serum glucose monitoring, as directed by the patient's physician. Once the patient has resumed normal dietary patterns and physical activity, the usual insulin regimen can be restarted.

Persons with well-controlled diabetes are no more susceptible to infections than are persons without diabetes, but they have more difficulty containing infections. This is caused by altered leukocyte function or by other factors that affect the ability of the body to control an infection. Difficulty in containing infections is more significant in persons with poorly controlled diabetes. Therefore elective oral surgery should be deferred in patients with poorly controlled diabetes until control is accomplished. However, if an emergency situation or a serious oral infection exists in any person with diabetes, consideration should be given to hospital admission to allow for acute control of the hyperglycemia and aggressive management of the infection. Many clinicians also believe that prophylactic antibiotics should be given routinely to patients with diabetes undergoing any surgical procedure. However, this position is a controversial one (Box 1.19).

• BOX 1.19 Management of Patient With Diabetes

Insulin-Dependent (Type 1) Diabetes

1. Defer surgery until the diabetes is well controlled; consult the patient's physician.
2. Schedule an early-morning appointment; avoid lengthy appointments.
3. Use an anxiety-reduction protocol, but avoid deep sedation techniques in outpatients.
4. Monitor pulse, respiration, and blood pressure before, during, and after surgery.
5. Maintain verbal contact with the patient during surgery.
6. If the patient must not eat or drink before oral surgery and will have difficulty eating after surgery, instruct him or her not to take the usual dose of regular or NPH insulin; start intravenous administration of a 5% dextrose in water drip at 150 mL/h.
7. If allowed, have the patient eat a normal breakfast before surgery and take the usual dose of regular insulin but only half the dose of NPH insulin.
8. Advise patients not to resume normal insulin doses until they are able to return to usual level of caloric intake and activity level.
9. Consult the physician if any questions concerning modification of the insulin regimen arise.
10. Watch for signs of hypoglycemia.
11. Treat infections aggressively.

Non–Insulin-Dependent (Type 2) Diabetes

1. Defer surgery until the diabetes is well controlled.
2. Schedule an early-morning appointment; avoid lengthy appointments.
3. Use an anxiety-reduction protocol.
4. Monitor pulse, respiration, and blood pressure before, during, and after surgery.
5. Maintain verbal contact with the patient during surgery.
6. If the patient must not eat or drink before oral surgery and will have difficulty eating after surgery, instruct him or her to skip any oral hypoglycemic medications that day.
7. If the patient can eat before and after surgery, instruct him or her to eat a normal breakfast and to take the usual dose of hypoglycemic agent.
8. Watch for signs of hypoglycemia.
9. Treat infections aggressively.

NPH, *Neutral protamine Hagedorn.*

• BOX 1.20 Management of Patient With Adrenal Suppression Who Requires Major Oral Surgery

If the patient is currently taking corticosteroids:
1. Use an anxiety-reduction protocol.
2. Monitor pulse and blood pressure before, during, and after surgery.
3. Instruct the patient to double the usual daily dose on the day before, day of, and day after surgery.
4. On the second postsurgical day, advise the patient to return to a usual steroid dose.

If the patient is not currently taking steroids but has received at least 20 mg of hydrocortisone (cortisol or equivalent) for more than 2 weeks within the past year:
1. Use an anxiety-reduction protocol.
2. Monitor pulse and blood pressure before, during, and after surgery.
3. Instruct the patient to take 60 mg of hydrocortisone (or equivalent) the day before and the morning of surgery (or the dentist should administer 60 mg of hydrocortisone or equivalent intramuscularly or intravenously before complex surgery).
4. On the first 2 postsurgical days, the dose should be dropped to 40 mg and dropped to 20 mg for 3 days thereafter. The clinician can cease administration of supplemental steroids 6 days after surgery.

If a major surgical procedure is planned, the clinician should strongly consider hospitalizing the patient. The clinician should consult the patient's physician if any questions arise concerning the need for or the dose of supplemental corticosteroids.

Adrenal Insufficiency

Diseases of the adrenal cortex may cause adrenal insufficiency. Symptoms of primary adrenal insufficiency include weakness, weight loss, fatigue, and hyperpigmentation of skin and mucous membranes. However, the most common cause of adrenal insufficiency is chronic therapeutic corticosteroid administration (secondary adrenal insufficiency). Often, patients who regularly take corticosteroids have moon facies (moon-shaped face), buffalo (back) humps, and thin, translucent skin. Their inability to increase endogenous corticosteroid levels in response to physiologic stress may cause them to become hypotensive, syncopal, nauseated, and feverish during complex, prolonged surgery, which is consistent with an adrenal crisis.

If a patient with primary or secondary adrenal suppression requires complex oral surgery, the primary care physician should be consulted about the potential need for supplemental steroids. In general, minor procedures require only the use of an anxiety-reduction protocol. Thus supplemental steroids are not needed for most dental procedures; however, the practitioner should monitor the patient closely for any signs or symptoms of adrenal crisis. More complicated procedures, such as orthognathic surgery in an adrenally suppressed patient, usually necessitate steroid supplementation (Box 1.20).

Hyperthyroidism

The thyroid gland problem of primary significance in oral surgery is thyrotoxicosis because it is the only thyroid gland disease in which an acute crisis can occur. Thyrotoxicosis is the result of an excess of circulating triiodothyronine and thyroxine, which is caused most frequently by Graves disease, a multinodular goiter, or a thyroid adenoma. The early manifestations of excessive thyroid hormone production include fine and brittle hair, hyperpigmentation of skin, excessive sweating, tachycardia, palpitations, weight loss, and emotional lability. Patients frequently, although not invariably, have exophthalmos (a bulging forward of the globes caused by increases of fat in the orbit). If hyperthyroidism is not recognized early, the patient can suffer heart failure. The diagnosis is made by the demonstration of elevated circulating thyroid hormones, using direct or indirect laboratory techniques.

• BOX 1.21 Management of Patient With Hyperthyroidism

1. Defer surgery until the thyroid gland dysfunction is well controlled.
2. Monitor pulse and blood pressure before, during, and after surgery.
3. Limit the amount of epinephrine used.

Thyrotoxic patients are usually treated with agents that block thyroid hormone synthesis and release, with a thyroidectomy, or with both. However, patients left untreated or incompletely treated can have a thyrotoxic crisis caused by the sudden release of large quantities of preformed thyroid hormones. Early symptoms of a thyrotoxic crisis include restlessness, nausea, and abdominal cramps. Later signs and symptoms are a high fever, diaphoresis, tachycardia, and, eventually, cardiac decompensation. The patient becomes stuporous and hypotensive, with death resulting if no intervention occurs.

The dentist may be able to diagnose previously unrecognized hyperthyroidism by taking a complete medical history and performing a careful examination of the patient, including thyroid gland inspection and palpation. If severe hyperthyroidism is suspected from the history and inspection, the gland should not be palpated because that manipulation alone can trigger a crisis. Patients suspected of having hyperthyroidism should be referred for medical evaluation before oral surgery.

Patients with treated thyroid gland disease can safely undergo ambulatory oral surgery. However, if a patient is found to have an oral infection, the primary care physician should be notified, particularly if the patient shows signs of hyperthyroidism. Atropine and excessive amounts of epinephrine-containing solutions should be avoided if a patient is thought to have incompletely treated hyperthyroidism (Box 1.21).

Hypothyroidism

The dentist can play a role in the initial recognition of hypothyroidism. Early symptoms of hypothyroidism include fatigue, constipation, weight gain, hoarseness, headaches, arthralgia, menstrual disturbances, edema, dry skin, and brittle hair and fingernails. If the symptoms of hypothyroidism are mild, no modification of dental therapy is required.

Hematologic Problems

Hereditary Coagulopathies

Patients with inherited bleeding disorders are usually aware of their problems, allowing the clinician to take the necessary precautions before any surgical procedure. However, in many patients, prolonged bleeding after the extraction of a tooth may be the first evidence that a bleeding disorder exists. Therefore all patients should be questioned concerning prolonged bleeding after previous injuries and surgery. A history of epistaxis (nosebleeds), easy bruising, hematuria, heavy menstrual bleeding, and spontaneous bleeding should alert the dentist to the possible need for a presurgical

laboratory coagulation screening or hematologist consultation. A PT is used to test the extrinsic pathway factors, whereas a partial thromboplastin time is used to detect intrinsic pathway factors. To better standardize PT values within and between hospitals, the INR method was developed. This technique adjusts the actual PT for variations in agents used to run the test, and the value is presented as a ratio between the patient's PT and a standardized value from the same laboratory.

Platelet inadequacy usually causes easy bruising and is evaluated by a bleeding time and platelet count. If a coagulopathy is suspected, the primary care physician or a hematologist should be consulted about more refined testing to better define the cause of the bleeding disorder and to help manage the patient in the perioperative period.

The management of patients with coagulopathies who require oral surgery depends on the nature of the bleeding disorder. Specific factor deficiencies—such as hemophilia A, B, or C or von Willebrand disease—are usually managed by the perioperative administration of coagulation factor concentrates or desmopressin and by the use of an antifibrinolytic agent such as aminocaproic acid (Amicar). The physician decides the form in which factor replacement is given on the basis of the degree of factor deficiency and on the patient's history of factor replacement. Patients who receive factor replacement, although a rare occurrence, are at risk of contracting an infectious blood-borne disease. Universal precautions should be employed, as with all patients, to reduce the risk of transmission to all staff and health care providers.

Platelet problems may be quantitative or qualitative. Quantitative platelet deficiency may be a cyclic problem, and the hematologist can help determine the proper timing of elective surgery. Patients with a chronically low platelet count can be given platelet transfusions. Counts must usually dip below 50,000/mm^3 before abnormal postoperative bleeding occurs. If the platelet count is between 20,000/mm^3 and 50,000/mm^3, the hematologist may wish to withhold platelet transfusion until postoperative bleeding becomes a problem. However, platelet transfusions may be given to patients with counts higher than 50,000/mm^3 if a concurrent qualitative platelet problem exists. Qualitative platelet disorders are typically due to the administration of antiplatelet medications (such as aspirin or clopidogrel) but can be related to liver or splenic dysfunction as well. Platelet counts less than 20,000/mm^3 usually require presurgical platelet transfusion or a delay in surgery until platelet numbers rise. If a qualitative platelet disorder is suspected, platelet function tests can be ordered, and modification of the medication regimen should be weighed against the risk of postoperative complications. Local anesthesia should be given by local infiltration rather than by field blocks to lessen the likelihood of damaging larger blood vessels, which can lead to prolonged postinjection bleeding and hematoma formation. Consideration should be given to the use of topical coagulation-promoting substances in oral wounds, and the patient should be carefully instructed in ways to avoid dislodging blood clots once they have formed (Box 1.22). See Chapter 12 for additional means of preventing or managing postextraction bleeding.

Therapeutic Anticoagulation

Therapeutic anticoagulation is administered to patients with thrombogenic implanted devices such as prosthetic heart valves; with thrombogenic cardiovascular problems such as atrial fibrillation or MI; with prior history of inherited or obtained hypercoagulable states such as recurrent pulmonary emboli or deep vein thromboses; or with a need for extracorporeal blood flow such as for hemodialysis.

• BOX 1.22 Management of Patient With a Coagulopathy

1. Defer surgery until a hematologist is consulted about the patient's management.
2. Have baseline coagulation tests, as indicated (prothrombin time, partial thromboplastin time, bleeding time, platelet count), and screening for hepatitis performed.
3. Schedule the surgery in a manner that allows it to be performed soon after any coagulation-correcting measures have been taken (after platelet transfusion, factor replacement, or aminocaproic acid administration).
4. Augment clotting during surgery with the use of topical coagulation-promoting substances, sutures, and well-placed pressure packs.
5. Monitor the wound for 2 h to ensure that a good initial clot forms.
6. Instruct the patient on ways to prevent dislodgment of the clot and on what to do should bleeding restart.
7. Avoid prescribing nonsteroidal antiinflammatory drugs.
8. Take precautions against contracting hepatitis during surgery.

Patients with severe coagulopathies who require major surgery should be hospitalized.

Patients may also take drugs with antiplatelet properties, such as aspirin, for secondary effect.

When elective oral surgery is necessary, the need for continuous anticoagulation must be weighed against the need for hemostasis after surgery. This decision should be made in consultation with the patient's primary care physician. Drugs such as low-dose aspirin do not usually need to be withdrawn to allow routine surgery. Patients taking heparin usually can have their surgery delayed until the circulating heparin is inactive (6 hours if IV heparin is given, 24 hours if given subcutaneously). Protamine sulfate, which reverses the effects of heparin, can also be used if emergency oral surgery cannot be deferred until heparin is naturally inactivated.

Patients on warfarin for anticoagulation and who need elective oral surgery benefit from close cooperation between the patient's physician and the dentist. The therapeutic range for most conditions requiring warfarin administration is typically an INR of 2 to 3 and, in some cases, may be increased to 3.5. Warfarin has a 2- to 3-day delay in the onset of action; therefore alterations of warfarin anticoagulant effects appear several days after the dose is changed. The INR is used to gauge the anticoagulant action of warfarin. Most physicians will allow the INR to drop to about 2 during the perioperative period, which usually allows sufficient coagulation for safe surgery. Patients should stop taking warfarin 2 or 3 days before the planned surgery if cessation of the medication is necessary because of expected excessive surgical blood loss. On the morning of surgery, the INR value should be checked; if it is between 2 and 3, routine oral surgery can typically be performed with the use of in-office adjunctive measures. If the PT is still greater than 3 INR, surgery should be delayed until the PT approaches 3 INR. Surgical wounds should be dressed with thrombogenic substances, and the patient should be given instruction in promoting clot retention. Warfarin therapy can be resumed the day of surgery (Box 1.23).

The recent development of direct and indirect Xa inhibitors has made anticoagulant therapy more attainable for a greater population of patients. These medications do not require routine laboratory monitoring because INR values are ineffective at determining the efficacy of the drug. Typically these medications have a shorter half-life if cessation is necessary; however, in most cases, cessation of these medications before routine oral surgical procedures is not required. Appropriate adjunctive procedures

• BOX 1.23 Management of Patient Whose Blood Is Therapeutically Anticoagulated

Patients Receiving Aspirin or Other Platelet-Inhibiting Drugs

1. Consult the patient's physician to determine the safety of stopping the anticoagulant drug for several days.
2. Defer surgery until the platelet-inhibiting drugs have been stopped for 5 days.
3. Take extra measures during and after surgery to help promote clot formation and retention.
4. Restart drug therapy on the day after surgery if no bleeding is present.

Patients Receiving Warfarin (Coumadin)

1. Consult the patient's physician to determine the safety of allowing the prothrombin time (PT) to fall to 2.0–3.0 INR (international normalized ratio). This may take a few days.[a]
2. Obtain the baseline PT.
3. (a) If the PT is less than 3.1 INR, proceed with surgery and skip to step 6. (b) If the PT is more than 3.0 INR, go to step 4.
4. Stop warfarin approximately 2 days before surgery.
5. Check the PT daily, and proceed with surgery on the day when the PT falls to 3.0 INR.
6. Take extra measures during and after surgery to help promote clot formation and retention.
7. Restart warfarin on the day of surgery.

Patients Receiving Heparin

1. Consult the patient's physician to determine the safety of stopping heparin for the perioperative period.
2. Defer surgery until at least 6 h after the heparin is stopped or reverse heparin with protamine.
3. Restart heparin once a good clot has formed.

[a]If the patient's physician believes it is unsafe to allow the prothrombin time to fall, the patient must be hospitalized for conversion from warfarin to heparin anticoagulation during the perioperative period.

should be implemented to obtain and maintain stable hemostasis of all surgical sites.

The cessation of any anticoagulant or antiplatelet medication should not be taken lightly. In most routine oral surgical procedures, the expected intraoperative bleeding typically can be controlled with adjunctive hemostatic techniques if the patient's laboratory data are within the therapeutic range for that medication. Following any type of surgery, there is a natural systemic inflammatory response that promotes a local and systemic hypercoagulable state, which can predispose a patient to increased risk of clot formation elsewhere in the body with more severe clinical complications such as stroke, pulmonary embolism, or MI.

Neurologic Disorders

Seizure Disorders

Patients with a history of seizures should be questioned about the frequency, type, duration, and sequelae of seizures. Seizures can result from ethanol withdrawal, high fever, electrolyte imbalance, hypoglycemia, or traumatic brain damage, or they can be idiopathic. The dentist should inquire about medications used to control the seizure disorder, particularly about patient compliance and any recent measurement of serum levels. The patient's physician should be consulted concerning the seizure history and to establish whether oral surgery should be deferred for any reason. If the seizure disorder is well controlled, standard oral surgical care can

• BOX 1.24 Management of Patient With a Seizure Disorder

1. Defer surgery until the seizures are well controlled.
2. Consider having serum levels of antiseizure medications measured if patient compliance is questionable.
3. Use an anxiety-reduction protocol.
4. Take measures to avoid hypoglycemia and fatigue in the patient.

be delivered without any further precautions (except for the use of an anxiety-reduction protocol; Box 1.24). If good control cannot be obtained, the patient should be referred to an oral-maxillofacial surgeon for treatment under deep sedation in the office or hospital.

Ethanolism (Alcoholism)

Patients volunteering a history of ethanol abuse or in whom ethanolism is suspected and then confirmed through means other than history taking require special consideration before surgery. The primary problems ethanol abusers have in relation to dental care are hepatic insufficiency, ethanol and medication interaction, electrolyte abnormalities, and withdrawal phenomena. Hepatic insufficiency has already been discussed. Ethanol interacts with many of the sedatives used for anxiety control during oral surgery. The interaction usually potentiates the level of sedation and suppresses the gag reflex.

Ethanol abusers may undergo withdrawal phenomenon in the perioperative period if they have acutely lowered their daily ethanol intake before seeking dental care. This phenomenon may exhibit mild agitation and severe hypertension, which can progress to tremors, seizures, diaphoresis, or, rarely, delirium tremens with hallucinations, considerable agitation, and circulatory collapse.

Patients requiring oral surgery who exhibit signs of severe alcoholic liver disease or signs of ethanol withdrawal should be treated in the hospital setting. Liver function tests, a coagulation profile, and medical consultation before surgery are desirable. In patients who can be treated on an outpatient basis, the dose of drugs metabolized in the liver should be altered, and the patients should be monitored closely for signs of oversedation.

Management of Patients During and After Pregnancy

Pregnancy

Although not a disease state, pregnancy is still a situation in which special considerations are necessary when oral surgery is required to protect the mother and the developing fetus. The primary concern when providing care for a pregnant patient is the prevention of genetic damage to the fetus. Two areas of oral surgical management with the potential for creating fetal damage are (1) dental imaging and (2) drug administration. It is virtually impossible to perform an oral surgical procedure properly without using radiography or medications; therefore one option is to defer any elective oral surgery until after delivery to avoid fetal risk. Frequently, temporary measures can be used to delay surgery.

However, if surgery during pregnancy cannot be postponed, efforts should be made to lessen fetal exposure to teratogenic factors. In the case of imaging, the use of protective aprons and taking digital periapical films of only the areas requiring surgery

• **Fig. 1.5** A proper lead apron shield is used during dental radiography.

• BOX 1.25 Management of Patient Who Is Pregnant

1. Defer elective surgery until after delivery, if possible.
2. Consult the patient's obstetrician if surgery cannot be delayed.
3. Avoid dental radiographs unless information about tooth roots or bone is necessary for proper dental care. If radiographs must be taken, use proper lead shielding.
4. Avoid the use of drugs with teratogenic potential. Use local anesthetics when anesthesia is necessary.
5. Use at least 50% oxygen if nitrous oxide sedation is used, but avoid use during the first trimester.
6. Avoid keeping the patient in the supine position for long periods to prevent vena caval compression.
7. Allow the patient to take trips to the restroom as often as needed.

• BOX 1.26 Dental Medications to Avoid in Patients Who Are Pregnant

Aspirin and Other Nonsteroidal Antiinflammatory Drugs

- Carbamazepine
- Chloral hydrate (if chronically used)
- Chlordiazepoxide
- Corticosteroids
- Diazepam and other benzodiazepines
- Diphenhydramine hydrochloride (if chronically used)
- Morphine
- Nitrous oxide (if exposure is >9 h/wk, oxygen concentration is less than 50%, or pregnancy is in the first trimester)

Nonsteroidal Antiinflammatory Agents

- Pentazocine hydrochloride
- Phenobarbital
- Promethazine hydrochloride
- Tetracyclines

• BOX 1.27 Classification of Medications With Respect to Potential Fetal Risk

Category A: Controlled studies in women have failed to demonstrate a fetal risk in the first trimester (and there is no evidence of risk in later trimesters), and the possibility of fetal harm appears remote.

Category B: Either animal reproduction studies have not demonstrated a fetal risk and there are no controlled studies in pregnant women, or animal reproduction studies have shown an adverse effect (other than decreased fertility) that was not confirmed in controlled studies on women in the first trimester (and there is no evidence of a risk in later trimesters).

Category C: Either studies in animals have revealed adverse fetal effects and there are no controlled studies in human beings, or studies in women and animals are not available. Drugs in this category should only be given if safer alternatives are not available and if the potential benefit justifies the known fetal risk or risks.

Category D: Positive evidence of human fetal risk exists, but benefits for pregnant women may be acceptable despite the risk, as in life-threatening or serious diseases for which safer drugs cannot be used or are ineffective. An appropriate statement must appear in the "warnings" section of the labeling of drugs in this category.

Category X: Either studies in animals or human beings have demonstrated fetal abnormalities, or there is evidence of fetal risk based on human experience (or both); and the risk of using the drug in pregnant women clearly outweighs any possible benefit. The drug is contraindicated in women who are or may become pregnant. An appropriate statement must appear in the "contraindications" section of the labeling of drugs in this category.

From the United States Food and Drug Administration.

can accomplish this (Fig. 1.5). The list of drugs thought to pose little risk to the fetus is short. For purposes of oral surgery, the following drugs are believed least likely to harm a fetus when used in moderate amounts: lidocaine, bupivacaine, acetaminophen, codeine, penicillin, and cephalosporins. The use of NSAIDs, such as aspirin and ibuprofen, should not be given during pregnancy, especially late in the third trimester because of its antiplatelet properties and the potential for causing premature closure of the ductus arteriosus. All sedative drugs are best avoided in pregnant patients. Nitrous oxide should not be used during the first trimester but, if necessary, may be considered in the second and third trimesters as long as it is delivered with at least 50% oxygen and in consultation with the patient's obstetrician (Boxes 1.25 and 1.26). The U.S. Food and Drug Administration created a system of drug categorization based on the known degree of risk to the human fetus posed by particular drugs. When required to give a medication to a pregnant patient, the clinician should check that the drug falls into an acceptable risk category before administering it to the patient (Box 1.27).

Pregnancy can be emotionally and physiologically stressful; therefore an anxiety-reduction protocol is recommended. Patient vital signs should be obtained, with particular attention paid to any elevation in blood pressure (a possible sign of preeclampsia).

TABLE 1.2 Effect of Dental Medications in Lactating Mothers

No Apparent Clinical Effects in Breastfeeding Infants	Potentially Harmful Clinical Effects in Breastfeeding Infants
Acetaminophen	Ampicillin
Antihistamines	Aspirin
Cephalexin	Atropine
Codeine	Barbiturates
Erythromycin	Chloral hydrate
Fluoride	Corticosteroids
Lidocaine	Diazepam
Meperidine	Metronidazole
Oxacillin	Penicillin
Pentazocine	Tetracyclines

A patient nearing delivery may need special positioning of the chair during care because, if the patient is placed in the fully supine position, the uterine contents may cause compression of the inferior vena cava, compromising venous return to the heart and, thereby, cardiac output. The patient may need to be in a more upright position or have her torso turned slightly to the left side during surgery. Frequent breaks to allow the patient to void are commonly necessary late in pregnancy because of fetal pressure on the urinary bladder. Before performing any oral surgery on a pregnant patient, the clinician should consult the patient's obstetrician.

Postpartum

Special considerations should be taken when providing oral surgical care for the postpartum patient who is breastfeeding a child. Avoiding drugs that are known to enter breast milk and to be potentially harmful to infants is prudent (the child's pediatrician can provide guidance). Information about some drugs is provided in Table 1.2. However, in general, all the drugs common in oral surgical care are safe to use in moderate doses; the exceptions are corticosteroids, aminoglycosides, and tetracyclines, which should not be used.

2

Prevention and Management of Medical Emergencies

JAMES R. HUPP AND ALISON YEUNG

CHAPTER OUTLINE

Serious medical emergencies in the general dental office are, fortunately, rare. The primary reason for the limited frequency of emergencies in dental practice is the nature of dental education that prepares practitioners to recognize potential problems and manage them before they cause an emergency or refer unhealthy patients needing surgery to oral-maxillofacial surgeons. Dental practices serving patients in medically underserved communities may see a disproportionate number of individuals more prone to medical emergencies in the dental setting.

When oral surgical procedures are necessary, the increased mental and physiologic stress inherent in such care can push the patient with moderately or poorly compensated medical conditions into an emergency situation. Similarly, the advanced forms of pain and anxiety control frequently needed for oral surgery can predispose patients to emergent conditions. This chapter begins with a presentation of the various means of lowering the probability of medical emergencies in the dental office. The chapter also details ways to prepare for emergencies and discusses the clinical manifestations and the initial management of the types of medical emergencies most common in the dental office.

Prevention

An understanding of the relative frequency of emergencies and knowledge of those likely to produce serious morbidity and mortality is important when setting priorities for preventive measures. Studies reveal that hyperventilation, seizures, and suspected hypoglycemia are the most common emergency situations occurring in patients before, during, or soon after general dental care. These are followed in frequency by vasovagal syncope, angina pectoris, orthostatic hypotension, and hypersensitivity (allergic) reactions.

The incidence of medical emergencies is higher in patients receiving ambulatory oral surgery compared with those receiving nonsurgical care because of the following three factors: (1) surgery is more stress provoking, (2) a greater number of medications are typically administered during the perioperative period, and (3) longer appointments are often necessary when performing surgery. These factors are known to increase the likelihood of medical emergencies. Other factors that increase the potential for emergencies are the age of the patient (very young and old patients being at greater risk), the increasing ability of the medical profession to keep relatively unhealthy persons ambulatory, and the large variety of drugs dentists administer in their offices.

Prevention is the cornerstone of management of medical emergencies. The first step is risk assessment. This begins with a careful medical evaluation in the dental office, which requires taking an accurate medical history, including a review of systems guided by pertinent positive responses in the patient's history. Vital signs should be recorded, and a physical examination (tailored to the patient's medical history and present problems) should be performed and regularly updated. Techniques for this are described in Chapter 1.

Although any patient could have a medical emergency at any time, certain medical conditions predispose patients to medical emergencies in the dental office. These conditions are more likely to turn into an emergency when the patient is physiologically or emotionally stressed. The most common conditions affected or precipitated by anxiety are listed in Box 2.1. Once those patients who are likely to have medical emergencies are recognized, the practitioner can prevent most problems from occurring by modifying the manner in which oral surgical care is delivered.

• BOX 2.1 Medical Emergencies Commonly Provoked by Anxiety

- Angina pectoris
- Thyroid storm
- Myocardial infarction
- Insulin shock
- Asthmatic bronchospasm
- Hyperventilation
- Adrenal insufficiency (acute)
- Epilepsy
- Severe hypertension

• BOX 2.2 Preparation for Medical Emergencies

1. Personal continuing education in emergency recognition and management
2. Auxiliary staff education in emergency recognition and management
3. Establishment and periodic testing of a system to access medical assistance readily when an emergency occurs
4. Equipping office with supplies necessary for emergency care

• BOX 2.3 Basic Life Support

ABCs

- A—Airway
- B—Breathing
- C—Circulation

Airway Obtained and Maintained by a Combination of the Following:

1. Extending head at the neck by pushing upward on the chin with one hand and pushing the forehead back with other hand
2. Pushing mandible forward by pressure on the mandibular angles
3. Pulling mandible forward by pulling on anterior mandible
4. Pulling tongue forward, using suture material or instrument to grasp anterior part of tongue

Breathing Provided by One of the Following:

1. Mouth-to-mask ventilation
2. Resuscitation bag ventilation

Circulation Provided by External Cardiac Compressions

Preparation

Preparedness is the second most important factor (after prevention) in the management of medical emergencies. Preparation to handle emergencies includes four specific actions: (1) ensuring that the dentist's own education about emergency management is adequate and up to date, (2) having the office staff trained to assist in medical emergencies, (3) establishing a system to gain ready access to other health care providers able to assist during emergencies, and (4) equipping the office with equipment and supplies necessary to initially care for patients having serious problems (Box 2.2).

Continuing Education

In dental school, clinicians are trained in ways to assess patient risk and manage medical emergencies. However, because of the rarity of these problems, practitioners should seek continuing education in this area, not only to refresh their knowledge but also to learn new concepts concerning medical evaluation and management of emergencies. An important feature of continuing education is to maintain certification in basic life support (BLS), including the use of automated external defibrillator units (Box 2.3). Some recommend that continuing education in medical emergency management be obtained annually, with a BLS skills update and review obtained biannually. Dentists who deliver parenteral sedatives other than nitrous oxide are wise to obtain certification in advanced cardiac life support and to have the drugs and equipment necessary for advanced cardiac life support available.

Office Staff Training

The dentist must ensure that all office personnel are trained to assist in the recognition and management of emergencies. This should include reinforcement by regular emergency drills in the office and by annual BLS skills renewal by all staff members. The office staff should be preassigned specific responsibilities so that in the event of an emergency, each person knows what will be expected of him or her.

Access to Help

The ease of access to other health care providers varies from office to office. Preidentifying individuals with training that would make them useful during a medical emergency is helpful. If the dental practice is located near other professional offices, prior arrangements should be made to obtain assistance in the event of an emergency. Not all physicians are well versed in the management of emergencies, and dentists must be selective in the physicians they contact for help during an emergency. Oral-maxillofacial surgeons are a good resource, as are most general surgeons, internists, and anesthesiologists. Ambulances carrying emergency medical technicians are useful to the dentist facing an emergency situation, and communities provide easy telephone access (911) to a rapid-response emergency medical service team. Finally, it is important to identify a nearby hospital or freestanding emergency care facility with well-trained emergency care experts.

Once the dentist has established who can be of assistance in the event of an emergency, the appropriate telephone numbers should be kept readily available. Easily identified lists can be placed on each telephone, or telephone numbers can be entered into the memory of an automatic-dial telephone and/or added to cellphone contacts. The numbers should be called periodically to test their accuracy.

Emergency Supplies and Equipment

The final means of preparing for emergencies is by ensuring that appropriate emergency drugs, supplies, and equipment are available in the office. One basic piece of equipment is the dental chair that should facilitate placing the patient in the supine position or, even better, in the head-down, feet-raised position. In addition, it should be possible to lower the chair close to the floor to allow BLS to be performed properly, or standing stools should be kept readily available. Operatories should be large enough to allow a patient to be placed on the floor for BLS performance and should provide enough room for the dentist and others to deliver emergency care. If the operatory is too small to allow the patient to be placed on the floor, specially designed boards that are available can be placed

under the patient's thorax to allow effective BLS administration in the dental chair.

Frequently, equipment used for respiratory assistance and the administration of injectable drugs is needed during office emergencies. Equipment for respiratory assistance includes oral and nasal airways, large suction tips, connector tubing that allows the use of high-volume suction, and resuscitation bags (e.g., air mask bag unit [AMBU bags]) with clear facemasks. Laryngoscopes and endotracheal tubes for tracheal intubation may be helpful to dentists trained in their proper use or for others called into the office to assist during an emergency.

Useful drug administration equipment includes syringes and needles, tourniquets, intravenous (IV) solutions, indwelling catheters, and IV tubing (Table 2.1). Emergency kits containing a variety of drugs are commercially available (Fig. 2.1). If dentists have made arrangements for help from nearby professionals, they may also want to include drugs in their kits that the assisting individuals suggest may be helpful. The drugs and any equipment in the kit must be clearly labeled and checked frequently for completeness and to ensure that no drugs have passed their expiration date. Labeling should include not only the drug name but also situations in which the drug is most commonly used. A list of drugs that should be in a dental office emergency kit is provided in Table 2.2.

One emergency item that must be available in dental offices is oxygen. Many dentists use oxygen supplied in a portable tank. The dentist should be properly trained to be capable of delivering the oxygen under positive pressure to the patient. Establishing a system to check periodically that a sufficient supply of oxygen is always available is important. Dentists who use a central oxygen system also need to have portable oxygen available for use outside of the operatory, such as in the waiting room or during transport to an emergency facility.

TABLE 2.1 Emergency Supplies for the Dental Office

Use	Supplies
Establishment and maintenance of intravenous access	Plastic indwelling catheter, metal indwelling catheter, intravenous tubing with flow valve, tourniquet, 1-inch wide plastic tape, crystalloid solution (normal saline, 5% dextrose in water)
High-volume suction	Large-diameter suction tip, tonsillar suction tip, extension tubing, connectors to adapt tubing to office suction
Drug administration	Plastic syringes (5 and 10 mL), needles (18 and 21 gauge)
Oxygen administration	Clear facemask, resuscitation bag (air mask bag unit), extension oxygen tubing (with and without nasal catheters), oxygen cylinder with flow valve, oral and nasal airways,[a] endotracheal tube,[a] demand valve oxygen mask[a]

[a]For use by dentists with appropriate training or by those called to give medical assistance.

Medical Emergencies

A brief description of the pathophysiology, clinical manifestations, and acute management of several emergency situations is presented in the following section. The section has been organized into a combination of specific problems such as hypersensitivity reactions as well as symptom-oriented problems such as chest discomfort.

Hypersensitivity Reactions

Several of the drugs administered to patients undergoing oral surgery can act as antigenic stimuli, triggering allergic reactions. Of the four basic types of hypersensitivity reactions, only type 1 (immediate hypersensitivity) can cause an acute, life-threatening condition. Type 1 allergic reactions are mediated primarily by immunoglobulin E antibodies. As with all allergies, initiation of a type 1 response requires exposure to an antigen previously encountered by the immune system. Reexposure to the antigen triggers a cascade of events that are then exhibited locally, systemically, or both in varying

A B

• **Fig. 2.1** (A) Example of commercially available emergency kit of appropriate size and complexity for dental office. (B) Office emergency response systems are available to help guide the dentist and staff during emergencies and drills. (B, Courtesy Institute of Medical Emergency Preparedness (IMEP), Virginia Beach, VA.)

TABLE 2.2 Emergency Drugs for the Dental Office

General Drug Group	Common Examples
Parenteral Preparations	
Analgesic	Morphine sulfate
Anticonvulsant	Diazepam, midazolam
Antihistamine	Diphenhydramine (Benadryl), chlorpheniramine (Chlor-Trimeton)
Antihypoglycemic	50% dextrose in water, glucagon
Corticosteroid	Methylprednisolone (Solu-Medrol), dexamethasone (Decadron), hydrocortisone (Solu-Cortef)
Narcotic antagonist/ benzodiazepine antagonist	Naloxone (Narcan) Flumazenil (Romazicon)
Sympathomimetic	Epinephrine
Vagolytic	Atropine
Oral Preparations	
Antihistamine	Diphenhydramine (Benadryl), chlorpheniramine (Chlor-Trimeton)
Antihypoglycemic	Candy (containing sugar), fruit juice, sugar cubes, glucose gel
Antiplatelet	Aspirin
Vasodilator	Nitroglycerine (Nitrostat, Nitrolingual)
Inhaled Preparations	
Bronchodilator	Metaproterenol (Alupent), epinephrine bitartrate (Medihaler-Epi) albuterol
Oxygen	—
Respiratory stimulant	Aromatic ammonia

degrees of severity mainly in response to significant mast cell degranulation and the widespread release of histamine. Table 2.3 details the manifestations of type 1 hypersensitivity reactions and their management.

The least severe manifestation of type 1 hypersensitivity is dermatologic. Skin or mucosal reactions include localized areas of pruritus, erythema, urticaria (wheals consisting of slightly elevated areas of epithelial tissue that are erythematous and indurated), and angioedema (large areas of swollen tissue generally with little erythema or induration). Although skin and mucosal reactions are not in themselves dangerous, they may be the first indication of more serious allergic manifestations that will soon follow. Skin lesions usually take anywhere from minutes to hours to appear; however, those appearing and progressing rapidly after administration of an antigenic drug are the most menacing and concerning for progression to the more life-threatening clinical presentations.

Allergic reactions affecting the respiratory tract are more serious and require more aggressive intervention. The involvement of small airways occurs with wheezing, as constriction of bronchial smooth muscle (bronchospasm) and airway mucosal inflammation occurs. The patient will complain of dyspnea and may eventually become cyanotic. The patient may be using accessory muscles to assist in breathing. Involvement of the larger airways usually first occurs at the narrowest portion of those air passages—the vocal cords in the larynx. Angioedema of the vocal cords causes partial or total airway obstruction. The patient is usually unable to speak and produces high-pitched crowing sounds (stridor) as air passes through constricted cords. As the edema worsens, total upper airway obstruction may eventually occur, presenting an immediate threat to life.

Generalized anaphylaxis is the most dramatic hypersensitivity reaction, usually occurring within seconds or minutes after the parenteral administration of the antigenic medication; a more delayed onset occurs after oral or topical drug administration. Many signs and symptoms of anaphylaxis exists, but the most important with respect to early management are those resulting from cardiovascular and respiratory tract disturbances.

An anaphylactic reaction typically begins with a patient complaining of malaise or a feeling of impending doom. Skin manifestations soon appear, including flushing, urticaria, and pruritus on the face and trunk. Nausea and vomiting, abdominal cramping, and urinary incontinence may occur. Symptoms of respiratory compromise soon follow, accompanied with dyspnea and wheezing. Cyanosis of nail beds and mucosa appear next if air exchange becomes insufficient. Finally, total upper airway obstruction occurs, which causes the patient quickly to become unconscious. Disordered cardiovascular function initially occurs with tachycardia and palpitations. Blood pressure tends to fall because of decreasing cardiac output secondary to peripheral vasodilation, and cardiac dysrhythmias appear. Cardiac output eventually may be compromised to a degree sufficient to cause loss of consciousness and cardiac arrest. Despite the potentially severe cardiovascular disturbances, the usual cause of death in patients having an anaphylactic reaction is laryngeal obstruction caused by vocal cord edema.

As with any potential emergency condition, prevention is the best strategy. During the initial interview and subsequent recall visits, patients should be questioned about their history of drug allergies. In addition, dentists should ask patients specifically about medications they intend to use during the planned oral surgical care. If a patient claims to have an allergy to a particular drug, the clinician should question the patient further about the way in which the allergic reaction has exhibited and what was necessary to manage the problem. Many patients will claim an allergy to local anesthetics; however, before subjecting patients to alternative forms of anesthesia, the clinician should try to ensure that an allergy to the local anesthetic does indeed exist. Many patients have been told they had an allergic reaction when, in fact, they experienced a vasovagal hypotensive episode or mild palpitations secondary to epinephrine sensitivity. If an allergy is truly possible, the patient may require referral to a physician who can perform hypersensitivity testing. After it is determined that a patient does have a drug allergy, the information should be displayed prominently on the patient's record in a way to alert care providers but still protect patient confidentiality.

Management of allergic reactions depends on the severity of the signs and symptoms. The initial response to any sign of untoward reaction to a drug being given parenterally should be to cease its administration. If the allergic reaction is confined to the skin or mucosa, IV or intramuscular (IM) antihistamine should be administered. Diphenhydramine hydrochloride 50 mg or chlorpheniramine maleate 10 mg are commonly used antihistamines.*

*All doses given in this chapter are those recommended for an average adult. Doses will vary for children, for older adults, and for those with debilitating diseases. The clinician should consult a drug reference book for additional information.

TABLE 2.3 Manifestations and Management of Hypersensitivity (Allergic) Reactions

Manifestations	Management
Skin Signs	
Delayed-onset skin signs: erythema, urticaria, pruritus, angioedema	1. Stop administration of all drugs presently in use. 2. Administer IV or IM Benadryl[a] 50 mg or Chlor-Trimeton[b] 10 mg. 3. Refer to physician. 4. Prescribe oral antihistamine such as Benadryl 50 mg q6h or Chlor-Trimeton 10 mg q6h. 5. Can prescribe tapering dose of an oral corticosteroid (prednisone or methylprednisolone dose pack).
Immediate-onset skin signs: erythema, urticaria, pruritus	1. Stop administration of all drugs presently in use. 2. Administer antihistamine IM or IV Benadryl 50 mg or Chlor-Trimeton 10 mg. 3. Consider administering 100 mg of hydrocortisone, 8 mg of dexamethasone, or 125 mg of methylprednisolone. 4. Monitor vital signs. 5. Consult patient's physician. 6. Observe in office for 1 hour. 7. Prescribe Benadryl 50 mg q6h or Chlor-Trimeton 10 mg q6h. 8. Prescribe tapering dose of an oral corticosteroid.
Respiratory Tract Signs With or Without Cardiovascular or Skin Signs	
Wheezing, mild dyspnea	1. Stop administration of all drugs presently in use. 2. Place patient in sitting position. 3. Administer 2 puffs of inhaled β-agonist, repeat up to 3 doses if no cardiovascular compromise is present. 4. Consider administering 100 mg of hydrocortisone, 8 mg of dexamethasone, or 125 mg of methylprednisolone. 5. Administer epinephrine if signs of cardiovascular compromise or airway obstruction are present.[c] 6. Provide IV access. 7. Consult patient's physician or emergency department physician. 8. Observe in office for at least 1 hour. 9. Prescribe antihistamine.
Stridorous breathing (i.e., crowing sound), moderate to severe dyspnea	1. Stop administration of all drugs presently in use. 2. Sit the patient upright, and have someone summon medical assistance. 3. Administer epinephrine.[a] 4. Give oxygen (6 L/min) by facemask or nasally. 5. Monitor vital signs frequently. 6. Administer antihistamine and corticosteroid. 7. Provide IV access; if signs worsen, treat as for anaphylaxis. 8. Consult patient's physician or emergency room physician; prepare for transport to emergency department if signs do not improve rapidly.
Anaphylaxis (with or without skin signs): malaise, wheezing, stridor, cyanosis, total airway obstruction, nausea and vomiting, abdominal cramps, urinary incontinence, tachycardia, hypotension, cardiac dysrhythmias, cardiac arrest	1. Stop administration of all drugs. 2. Position patient supine on back board or on floor and have someone summon assistance. 3. Administer epinephrine.[a] 4. Initiate basic life support and monitor vital signs. 5. Consider cricothyrotomy if trained to perform and if laryngospasm is not quickly relieved with epinephrine. 6. Provide IV access. 7. Give oxygen at 6 L/min. 8. Administer antihistamine IV or IM. 9. Prepare for transport.

[a]Brand of diphenhydramine.
[b]Brand of chlorpheniramine.
[c]As described in "Immediate Onset" section.
IM, Intramuscular; *IV*, intravenous; *SC*, subcutaneous.

The antihistamine is then continued in an oral form (diphenhydramine [Benadryl] 50 mg or chlorpheniramine [Chlor-Trimeton] 8 mg) every 6 to 8 hours for 24 to 48 hours to ensure that the drug has been eliminated from the body. Immediate, severe urticarial reactions warrant immediate parenteral (IV or IM) administration of a corticosteroid containing solution such as 100 mg of hydrocortisone, 8 mg of dexamethasone, or 125 mg of methylprednisolone, followed by an antihistamine. The patient's vital signs should be monitored frequently for 1 hour; if the patient is stable, he or she should be referred to a physician or an emergency care facility for further evaluation.

If a patient begins to show signs of lower respiratory tract involvement (i.e., wheezing during an allergic reaction), several actions should be initiated. Outside emergency assistance should be summoned immediately. The patient should be placed in a semi-reclined position, and nasal oxygen should be begun. If the patient is dyspneic but stable cardiovascularly, two puffs of albuterol may be administered followed by two more doses if improvement is noted. If the patient is showing significant respiratory distress, the clinician should not hesitate to administer epinephrine by IM injection of 0.3 mL of a 1:1000 solution or with an aerosol inhaler (e.g., Medihaler-Epi, each inhalation of which delivers 0.3 mg). Epinephrine is short acting; if symptoms recur or continue, the dose can be repeated within 5 minutes. Antihistamines, such as diphenhydramine or chlorpheniramine, as well as corticosteroids, are then given. The patient should be immediately transferred to the nearest emergency facility for further management.

If a patient shows signs of laryngeal obstruction (i.e., stridor), epinephrine (0.3 mL of 1:1000 solution given IM) should be given as quickly as possible, and oxygen should be administered. If a patient loses consciousness and attempts made to ventilate the patient's lungs fail, an emergency cricothyrotomy or intubation may be required to bypass the laryngeal obstruction.* A description of the technique of cricothyrotomy or tracheotomy is beyond the scope of this book, but these techniques may be lifesaving in an anaphylactic reaction. It should be noted that the true emergency airway is the cricothyrotomy because the tracheostomy procedure must be done in a controlled well-lit environment (such as an operating room) to ensure the preservation of vital structures. Once an airway is reestablished, an antihistamine and further doses of epinephrine should be given. Vital signs should be monitored, and steps necessary to maintain the patient should be taken until emergency assistance is available.

Patients who show signs of cardiovascular system compromise should be closely monitored for the appearance of hypotension and bradycardia, which may necessitate initiation of BLS if cardiac output falls below the level necessary to maintain viability or if cardiac arrest occurs (see Box 2.3).

Chest Discomfort

The appearance of chest discomfort in the perioperative period in a patient who may have ischemic heart disease calls for rapid identification of the cause so that appropriate measures can be taken (Box 2.4). Discomfort from cardiac ischemia is frequently described as a squeezing sensation, with a feeling of heaviness on the chest (Box 2.5). Discomfort usually begins in a retrosternal location, radiating to the left shoulder and arm. Patients with documented heart disease who have had such discomfort in the past will usually be able to confirm that the discomfort is their angina. For patients who are unable to remember such a sensation in the past or who have been assured by their physician that such discomfort does not represent heart disease, further information is useful before assuming a cardiac origin of the symptom. The patient should be asked to describe the exact location of the discomfort and any radiation, how the discomfort is changing with time, and if postural position affects the discomfort. Pain resulting from gastric reflux into the esophagus because of chair position should improve when the patient sits up and is given an antacid. Discomfort caused by costochondritis or pulmonary conditions should vary with respirations or be stimulated by manual pressure on the thorax. The only other common condition that can occur with chest discomfort is anxiety, which may be difficult to differentiate from cardiogenic problems without the use of monitoring devices not commonly present in the dental office.

If chest discomfort is suspected to be caused by myocardial ischemia, or if that possibility cannot be ruled out, measures should be instituted that decrease myocardial work and increase myocardial oxygen supply. All dental care must be stopped, even if the surgery is only partially finished. The patient should be reassured that everything is under control while vital signs are being obtained, oxygen administration is started, and nitroglycerin is administered sublingually or by oral spray. The nitroglycerin dose should be 0.4 mg dissolved sublingually and repeated (if necessary) every 5

*Cricothyrotomy is the surgical creation of an opening into the cricothyroid membrane just below the thyroid cartilage to create a path for ventilation that bypasses the vocal chords.

• BOX 2.4 Clinical Characteristics of Chest Pain Caused by Myocardial Ischemia or Infarction as Described by Patients

1. Squeezing, bursting, pressing, burning, choking, or crushing (not typically sharp or stabbing)
2. Substernally located, with variable radiation to left shoulder, arm, or left side (or a combination of these areas) of neck and mandible; occasionally may manifest as severe pain in the back between the shoulder blades
3. Frequently associated at the onset with exertion, heavy meal, anxiety, or on assuming horizontal posture
4. Relieved by vasodilators such as nitroglycerin, or rest (in the case of angina)
5. Accompanied by dyspnea, nausea, weakness, palpitations, perspiration, or a feeling of impending doom (or a combination of these symptoms)

• BOX 2.5 Differential Diagnosis of Acute-Onset Chest Pain

Common Causes

- *Cardiovascular system:* Angina pectoris, myocardial infarction
- *Gastrointestinal tract:* Dyspepsia (i.e., heartburn), hiatal hernia, reflux esophagitis, gastric ulcers
- *Musculoskeletal system:* Intercostal muscle spasm, rib or chest muscle contusions
- *Psychological:* Hyperventilation

Uncommon Causes

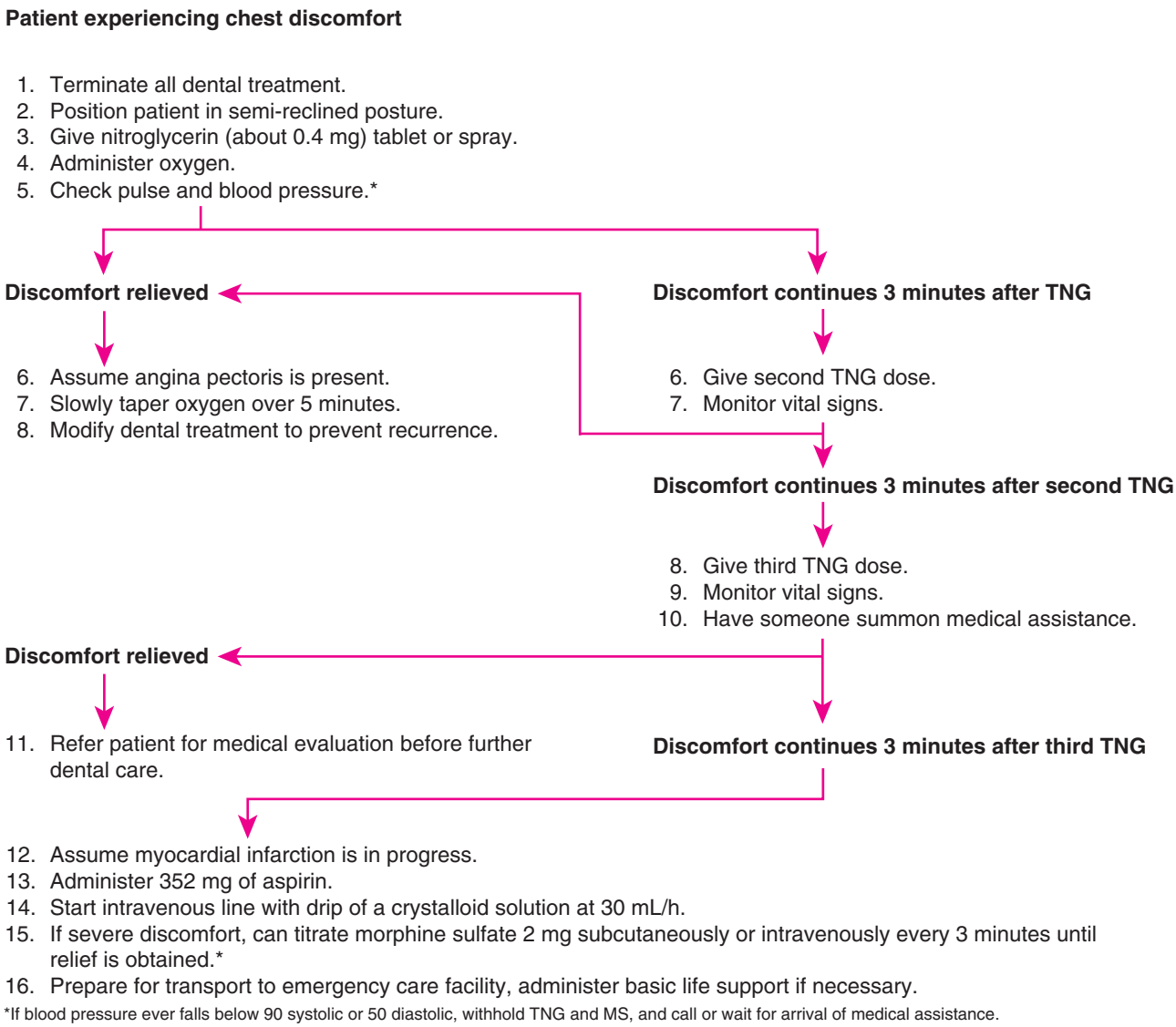
- *Cardiovascular system:* Pericarditis, dissecting aortic aneurysm
- *Respiratory system:* Pulmonary embolism, pleuritis, tracheobronchitis, mediastinitis, pneumothorax
- *Gastrointestinal tract:* Esophageal rupture, achalasia
- *Musculoskeletal system:* Osteochondritis, chondrosternitis
- *Psychological:* Psychogenic chest pain (i.e., imagined chest pain)

minutes for up to a maximum of three doses as long as systolic blood pressure is at least 90 mm Hg. If vital signs remain normal, the chest discomfort is relieved, and the amount of nitroglycerin that was required to relieve the discomfort was not more than normally necessary for that patient, the patient should be discharged with plans for future surgery to be done in an oral-maxillofacial surgery office or in a hospital after conferring with the patient's physician (Fig. 2.2).

Some circumstances do require transport to an emergency facility. If the pulse is irregular, rapid, or weak, or if the blood pressure is found to be below baseline, outside emergency help should be summoned while the patient is placed in an almost supine position with the legs raised, and then oxygen and nitroglycerin therapy are started. Venous access should be initiated and a slow 5% dextrose in normal saline IV drip should be begun, if possible, for use by emergency personnel. Another serious situation requiring transfer to a hospital is a case in which the patient's discomfort is not relieved after 20 minutes of appropriate therapy. In this case, it should be presumed that a myocardial infarction is in progress. Such a patient is especially prone to the appearance of serious cardiac dysrhythmias or cardiac arrest; therefore vital signs should be monitored frequently, and BLS should be instituted, if indicated. Aspirin may be administered in the case of a suspected myocardial infarction, 325 mg chewed and swallowed, to aid in decreasing thrombus progression by its antiplatelet effects. Morphine sulfate (4 to 6 mg) may be administered IM or subcutaneously to help relieve the discomfort and reduce anxiety. Morphine also provides a beneficial effect for patients who are developing pulmonary edema; however, care should be taken to avoid significant hypotension (see Fig. 2.2). Transfer to a hospital should be expedited because therapy may be initiated in the form of thrombolytic agents, an angioplasty, stenting procedure, or coronary artery bypass grafting, which may be able to preserve some or all of the ischemic myocardium.

Respiratory Difficulty

Many patients are predisposed to respiratory problems in the dental setting; these include patients with asthma or chronic obstructive pulmonary disease (COPD), extremely anxious patients, patients who are atopic, and those in whom a noninhalation sedative



• **Fig. 2.2** Management of patient having chest discomfort while undergoing dental surgery. *MS,* Morphine sulfate; *TNG,* trinitroglycerine.

technique using respiratory depressant drugs is to be used. Special precautions should be taken to help prevent the occurrence of emergencies. If these patients are not treated promptly, the situation may become life-threatening.

Asthma

Patients with a history of asthma can be a particular challenge to manage safely if emotional stress or certain pharmacologic agents easily trigger their respiratory problems. Most patients with asthma are aware of the symptoms that signal the onset of their bronchospasm. Patients will complain of shortness of breath and want to sit erect. Wheezing is usually audible; tachypnea and tachycardia begin, and patients start using their accessory muscles of respiration. As bronchospasm progresses, patients may become hypoxic and cyanotic, with eventual loss of consciousness (Box 2.6).

Management should start with placing patients in an upright or almost-upright position. Patients should then self-administer bronchodilators, using their own inhalers or one provided from the office emergency supply. The inhaler may contain epinephrine, isoproterenol, metaproterenol, or albuterol. Repeated doses should be administered cautiously to avoid overdosing. Oxygen administration should follow, using nasal prongs or a facemask, if high-flow oxygen is required. In more severe asthmatic episodes or when aerosol therapy is ineffective, epinephrine (0.3 mL of a 1:1000 dilution) may be injected subcutaneously or IM. When patients have severe respiratory distress, it may be necessary to obtain outside emergency medical assistance (Fig. 2.3).

Respiratory problems caused by drug allergy may be difficult to differentiate from those resulting from asthma. However, management of the respiratory problems is the same in either case.

Hyperventilation

The most frequent cause of respiratory difficulty in the dental setting is anxiety that manifests as hyperventilation, usually seen in patients in their teens, 20s, and 30s; it can frequently be prevented through anxiety control. Dentists should be attuned to the signs of patient apprehension and, through the health interview, should encourage patients to express their concerns. Patients with extreme

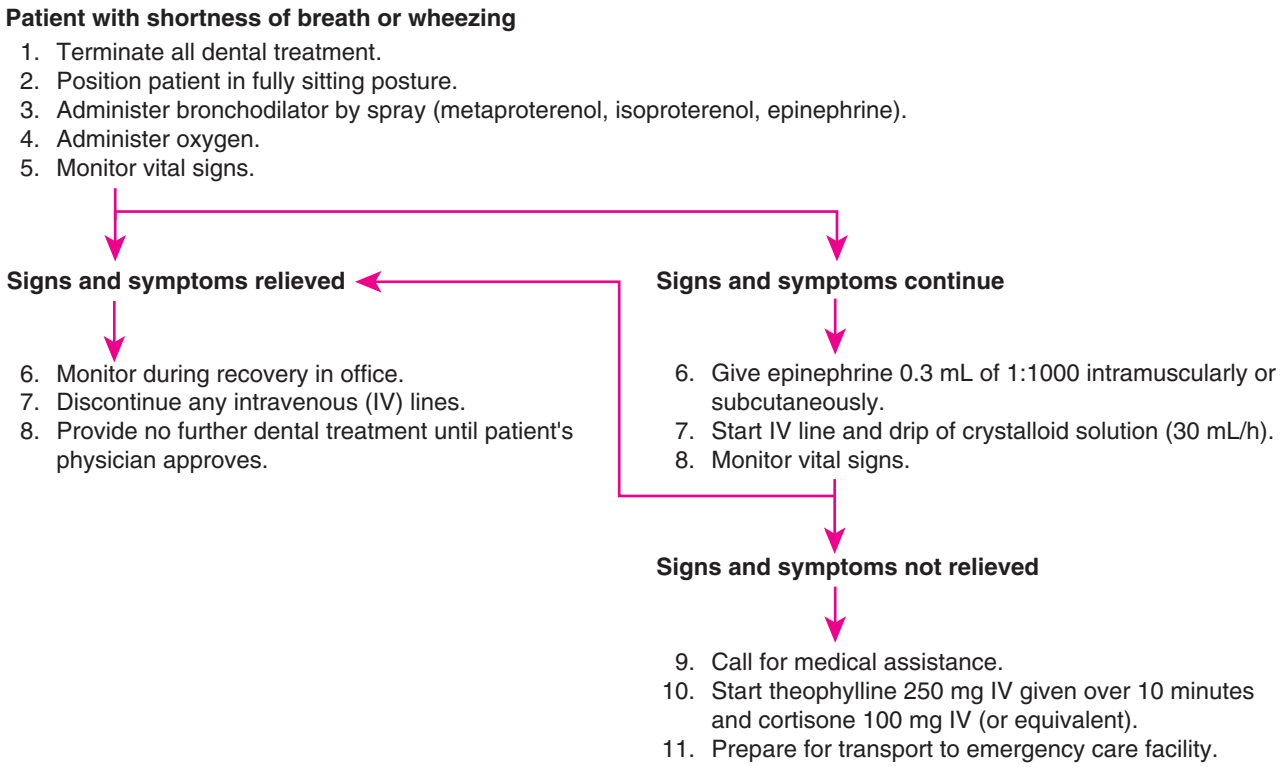
• BOX 2.6 Manifestations of an Acute Asthmatic Episode

Mild to Moderate

- Wheezing (audible with or without stethoscope)
- Dyspnea (i.e., labored breathing)
- Tachycardia
- Coughing
- Anxiety

Severe

- Intense dyspnea with flaring of nostrils and use of accessory muscles of respiration
- Cyanosis of mucous membranes and nail beds
- Minimal breath sounds on auscultation
- Flushing of face
- Extreme anxiety
- Mental confusion
- Perspiration



• **Fig. 2.3** Management of acute asthmatic episode occurring during dental surgery.

anxiety should be managed with an anxiety-reduction protocol. In addition, pharmacologic anxiolysis may be necessary.

The first manifestation of hyperventilation syndrome is frequently a complaint of an inability to get enough air. The patient breathes rapidly (tachypnea) and becomes agitated. The rapid ventilation increases elimination of carbon dioxide (CO_2) through the lungs. The patient soon becomes alkalotic; may complain of becoming light-headed and of having a tingling sensation in the fingers, toes, and perioral region; and may even develop muscle twitches or convulsions. Eventually, a loss of consciousness occurs (Box 2.7).

Management of a hyperventilating patient involves terminating the surgical procedure, positioning the patient in a semi-upright position, and providing reassurance. If symptoms of alkalosis occur, the patient should be forced to breathe in and out of a small bag to return CO_2 to proper levels. Oxygen-enriched air is not indicated. If hyperventilation continues, the clinician may need to administer 2 to 4 mg of a sedative, such as midazolam, given IM or by IV titration until hyperventilation ceases or the patient is sedated. Once hyperventilation stops, the patient should be rescheduled, with plans to use preoperative anxiolytics or intraoperative sedation (or both) in future visits (Box 2.8).

Chronic Obstructive Pulmonary Disease

Patients with well-compensated COPD can have difficulty during oral surgery. Many of these patients depend on maintaining an upright posture to breathe adequately. In addition, they become accustomed to having high arterial CO_2 levels and use a low level of blood oxygen (hypoxia) as the primary stimulus to drive respirations. Many of these patients experience difficulty if placed in an almost supine position or if given high-flow nasal oxygen. Patients with COPD often rely on their accessory muscles of respiration to breathe. The supine position interferes with the use of these accessory muscles; therefore patients will usually ask or struggle to sit up before problems resulting from positioning occur. Excessive lung secretions that are more difficult to clear when supine also accompany COPD.

If excessive oxygen is administered to a patient susceptible to COPD, the respiratory rate will fall, which produces cyanosis, and apnea may eventually occur. The treatment for such a problem is to discontinue oxygen administration before the patient becomes apneic. The respiratory rate should soon improve. If apnea occurs and the patient loses consciousness, BLS must be initiated and emergency assistance summoned.

All patients with a history of COPD are at risk for respiratory issues during an acute exacerbation. Patients exhibiting signs of respiratory difficulty (use of accessory muscles, tachypnea) should be queried regarding increased cough frequency or characteristic change in sputum production. If an acute exacerbation is suspected, elective surgery should be postponed until the patient receives appropriate medical attention. In the case of emergency surgery, care should be taken to optimize the airways with the use of a prophylactic dose of a bronchodilator, and referral to an oral-maxillofacial surgeon should be considered.

Foreign Body Aspiration

Aspiration of foreign bodies into the airway is always a potential problem during oral surgical and other dental procedures. This is especially true if the patient is positioned supine or semi-upright in the chair or is sufficiently sedated to dull the gag reflex. Objects that fall into the hypopharynx are frequently swallowed and usually pass harmlessly through the gastrointestinal tract. Even if the clinician feels confident that the material was swallowed, chest and abdominal radiographs should be obtained to eliminate the possibility of asymptomatic aspiration into the respiratory tract. Occasionally, the foreign object is aspirated into the larynx, where, in the lightly sedated or nonsedated patient, violent coughing will ensue that may expel the aspirated material. The patient can usually still talk and breathe. However, larger objects that are aspirated may obstruct the airway and become lodged in such a manner that coughing is ineffective because the lungs cannot be filled with air before the attempted cough. In this situation, the patient usually cannot produce any vocalizations and becomes extremely anxious. Cyanosis soon appears, followed by loss of consciousness (Box 2.9).

The manner in which aspirated foreign bodies are managed depends primarily on the degree of airway obstruction. Patients with an intact gag reflex and a partially obstructed airway should be allowed to attempt to expel the foreign body by coughing. If the material will not come up, the patient should be given supplemental oxygen and transported to an emergency facility for

• BOX 2.7 Manifestations of Hyperventilation Syndrome

Neurologic
- Dizziness
- Syncope
- Tingling or numbness of fingers, toes, or lips

Respiratory
- Chest pain
- Feeling of shortness of breath
- Increased rate and depth of breaths
- Xerostomia

Cardiac
- Palpitations
- Tachycardia

Musculoskeletal
- Muscle spasm
- Myalgia
- Tetany
- Tremor

Psychological
- Extreme anxiety

• BOX 2.8 Management of Hyperventilation Syndrome

1. Terminate all dental treatment, and remove foreign bodies from mouth.
2. Position patient in chair in almost fully upright position.
3. Attempt to calm patient verbally.
4. Have patient breathe carbon dioxide–enriched air, such as in and out of a small bag or cupped hands.
5. If symptoms persist or worsen, administer diazepam 10 mg intramuscularly or titrate slowly intravenously until anxiety is relieved, or administer midazolam 5 mg intramuscularly or titrate slowly intravenously until anxiety is relieved.
6. Monitor the vital signs.
7. Perform all further dental surgery using anxiety-reducing measures.

• BOX 2.9 Acute Manifestations of Aspiration Into the Lower Respiratory Tract

Large Foreign Body

- Coughing
- Choking sensation
- Stridorous breathing (i.e., crowing sounds)
- Severe dyspnea
- Feeling of something caught in throat
- Inability to breathe
- Cyanosis
- Loss of consciousness

Gastric Contents

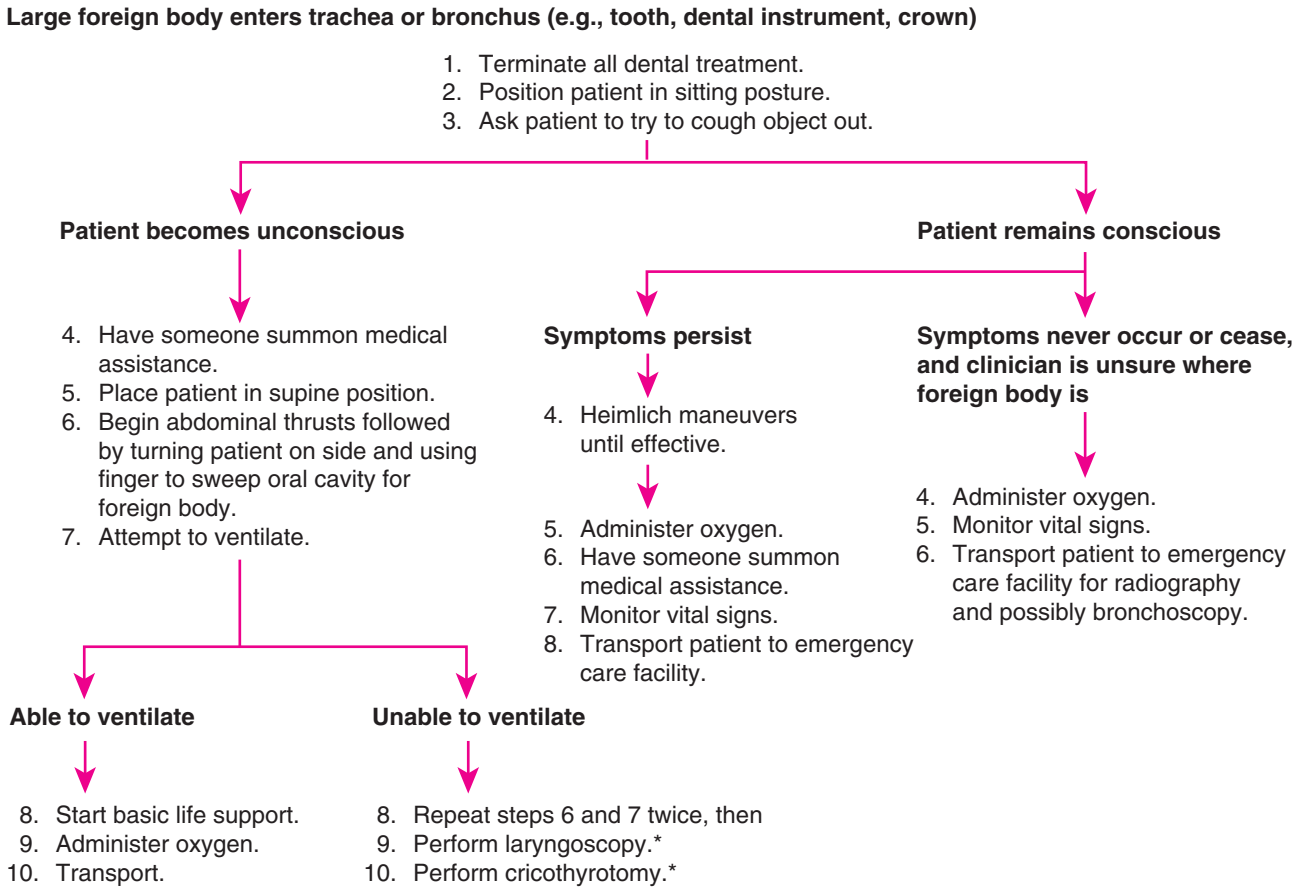
- Coughing
- Stridorous breathing
- Wheezing or rales (i.e., cracking sound) on chest auscultation
- Tachycardia
- Hypotension
- Dyspnea
- Cyanosis

laryngoscopy or bronchoscopy to be performed. The completely obstructed but awake adult patient should have abdominal thrusts or Heimlich maneuvers performed until successful expulsion of the object occurs or consciousness is lost (Fig. 2.4). If a patient has a diminished gag reflex as a result of sedation or has a completely obstructed airway and loses consciousness, abdominal thrusts should be performed with the patient in a supine position. After each volley of thrusts, the patient should be quickly turned onto the side, and the clinician should finger sweep the mouth to remove any object that may have been forced out. If the patient is not exchanging air, BLS should be started. If air cannot be blown into the lungs, additional abdominal thrusts should be attempted, followed by oral finger sweeps and BLS. Dentists trained in laryngoscopy can look into the larynx and use Magill forceps to try to remove any foreign material; however, time should not be wasted trying to retrieve a foreign object if it prolongs hypoxia. If several attempts to relieve the obstruction fail, an emergency cricothyrotomy may be necessary (Fig. 2.5).

Gastric Contents Aspiration

Aspiration of gastric contents into the lower respiratory tract presents another situation that frequently leads to serious respiratory difficulties. The particulate matter in gastric contents causes physical obstruction of pulmonary airways, but it is usually the high acidity of gastric material that produces more serious problems. The low pH of gastric juice quickly necrotizes the pulmonary tissue it contacts, and a respiratory distress syndrome soon follows, with transudation of fluid into pulmonary alveoli and a loss of functioning lung tissue. The patient with an intact gag reflex rarely aspirates gastric contents during vomiting. Rather, it is the patient with a diminished gag reflex caused by sedation, unconsciousness, or topical anesthesia in the oropharynx who is at greatest risk for gastric aspiration. The sedated or unconscious patient who aspirates a significant amount of gastric material will first show signs of respiratory difficulty such as tachypnea and wheezing. Tachycardia and hypotension may soon occur, and as ventilatory capability worsens, cyanosis appears. Eventually, respiratory failure that is refractory to BLS occurs, and intubation and the delivery of high concentrations of oxygen are required.

• Fig. 2.4 (A) Method of performing abdominal thrusts for an unconscious patient with a foreign body obstructing the airway. The chair is first placed in the recumbent position. The heel of the dentist's right palm is placed on the abdomen just below the xiphoid process with the elbow kept locked and the left hand placed over the right for further delivery of force. Arms are quickly thrust into the patient's abdomen, directing force down and superiorly. (B) Proper positioning for the Heimlich maneuver is shown. The rescuer approaches the patient from behind and positions hands on the patient's abdomen, just below the rib cage. The rescuer's hands are then quickly pulled into the abdominal area in an attempt to have any residual air in the lungs dislodge the obstruction from the airway.



• **Fig. 2.5** Management of respiratory tract foreign body aspiration in patient undergoing dental surgery.

• BOX 2.10 Signs of Imminent Vomiting

- Nausea
- Feeling of warmth
- Frequent swallowing
- Feeling of anxiety
- Perspiration
- Gagging

Prevention of gastric aspiration involves instruction to patients to avoid eating or drinking for 8 hours before any oral surgery appointment during which they are to be moderately or deeply sedated.

A deeply sedated or unconscious patient who begins to vomit should be immediately placed into a head-down, feet-raised position and turned onto their side to encourage oral drainage of vomitus. Box 2.10 lists several symptoms exhibited by patients preparing to vomit. High-volume suction should be used to assist removal of vomitus from the oral cavity. If the clinician suspects that gastric material may have entered the lower respiratory tract, emergency assistance should be contacted immediately. The patient should be placed on supplemental oxygen and vital signs monitored. If possible, the dentist should gain venous access (i.e., start an IV line) and be prepared to administer crystalloid solution (e.g., normal saline or 5% dextrose in normal saline) to help treat a falling blood pressure and allow emergency technicians to administer IV bronchodilators, if necessary. Immediate transportation to an emergency facility is mandatory (Fig. 2.6).

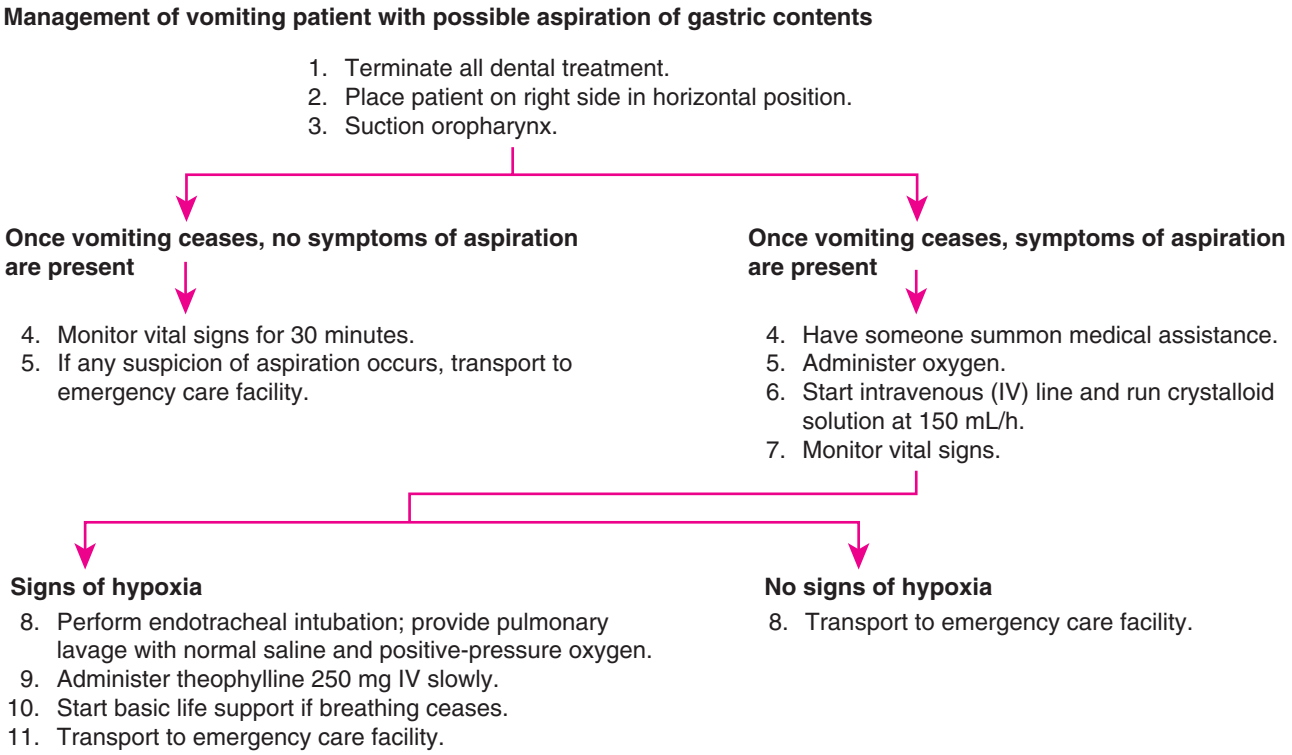
Altered Consciousness

An alteration in a patient's level of consciousness may result from a large variety of medical problems. The altered state can range from mild light-headedness to a complete loss of consciousness. Without attempting to include all possible causes of altered consciousness, a discussion of commonly occurring conditions that may lead to an acutely altered state of consciousness before or while patients are undergoing oral surgical procedures is presented here.

Vasovagal Syncope

The most common cause of a transient loss of consciousness in the dental office is vasovagal syncope. This generally occurs because of a series of cardiovascular events triggered by emotional stress brought on by the anticipation of or delivery of dental care. The initial event in a vasovagal syncopal episode is the stress-induced increase in amounts of catecholamines that, via reflexive maneuvers, cause a decrease in peripheral vascular resistance secondary to vasodilation, vagally mediated bradycardia, and sweating. The patient may complain of feeling generalized warmth, as well as nausea and palpitations. As blood pools in the periphery, a drop in the arterial blood pressure appears with a corresponding decrease in cerebral blood flow. The patient may then complain of feeling dizzy or weak. Once the blood pressure drops below levels necessary to sustain consciousness, syncope occurs (Fig. 2.7).

If cerebral ischemia is sufficiently slow to develop, the patient may first develop seizures. The syncopal episode and any accompanying seizure usually end rapidly once the patient assumes or is placed



• **Fig. 2.6** Management of vomiting with possible aspiration of gastric contents.

in a horizontal (supine) position with the feet elevated (Trendelenburg position) (Fig. 2.8). Once consciousness is regained, the patient may have pallor, nausea, and weakness for several minutes.

Prevention of vasovagal syncopal reactions involves proper patient preparation. The extremely anxious patient should be treated by using an anxiety-reduction protocol and, if necessary, should be given anxiolytic drugs before treatment. Oral surgical care should be provided while the patient is in a semi-supine or fully supine position. Any signs of an impending syncopal episode should be quickly treated by placing the patient in a fully supine position or a position in which the legs are elevated above the level of the heart and by placing a cool, moist towel on the forehead. If the patient is hypoventilating and is slow to recover consciousness, a respiratory stimulant, such as aromatic ammonia, may be useful. If the return of consciousness is delayed for more than a minute, an alternative cause for depressed consciousness other than vasovagal syncope should be considered. After early recovery from the syncopal episode, the patient should be allowed to recover in the office and then be discharged with an escort. Future office visits by the patient will require preoperative sedation and other anxiety-reducing measures.

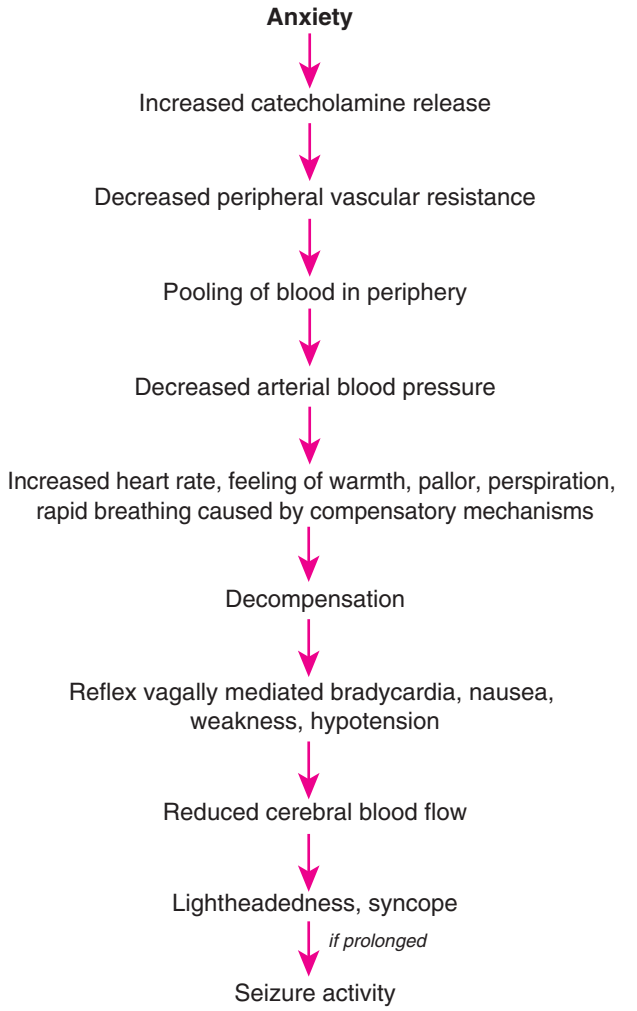
Orthostatic Hypotension

Another common cause of a transient altered state of consciousness in the dental setting is orthostatic (or postural) hypotension. This problem occurs because of pooling of blood in the periphery that is not remobilized quickly enough via peripheral vasoconstriction and increased heart rate to prevent cerebral ischemia when a patient rapidly assumes an upright posture. Therefore the patient will feel light-headed or become syncopal. Patients with orthostatic hypotension who remain conscious will usually complain of palpitations and generalized weakness. Most individuals who are not hypovolemic or have orthostatic hypotension resulting from the pharmacologic effects of drugs such as antihypertensive agents will quickly recover by reassuming the reclined position. Once symptoms disappear, the patient can generally sit up (although this should be done slowly on the edge of the chair for a few moments before standing). Blood pressure can be taken in each position and allowed to return to normal before a more upright posture is allowed (Box 2.11).

• BOX 2.11 Management of Orthostatic Hypotension

1. Terminate all dental treatment.
2. Place the patient in the supine position with legs raised above the level of the head.
3. Monitor the vital signs.
4. Once blood pressure improves, slowly return the patient to the sitting position.
5. Discharge the patient home once the vital signs are normal and stable.
6. Obtain medical consultation before any further dental care.

Some patients have a predisposition to orthostatic hypotension. In the ambulatory population, this is usually encountered in patients receiving the following medications: drugs that produce intravascular depletion such as diuretics; drugs that produce peripheral vasodilation such as most nondiuretic antihypertensives, narcotics, and many psychiatric drugs; and drugs that prevent the heart rate from increasing reflexively such as β-sympathetic antagonist medications (e.g., propranolol). Patients with a predisposition to postural hypotension can usually be managed by allowing a much longer period to attain the standing position (i.e., by stopping at several increments while becoming upright to allow reflex cardiovascular compensation to occur). If the patient was sedated by using long-acting narcotics, an antagonist such as naloxone may be necessary. Patients with severe problems with postural hypotension as a result of drug therapy should be referred to their physician for possible modification of their drug regimen.



• **Fig. 2.7** Pathophysiology and manifestations of vasovagal syncope.

Seizure

Idiopathic seizure disorders are exhibited in many ways, ranging from grand mal seizures with their frightening display of clonic contortions of the trunk and extremities to petit mal seizures that may occur with only episodic absences (e.g., blank stare). Although rare, some seizure disorders, such as those resulting from injury-induced brain damage or damage from ethanol abuse, have a known cause. Usually, the patient will have had the seizure disorder previously diagnosed and will be receiving antiseizure medications, such as phenytoin (Dilantin) or levitiracetam (Keppra). Therefore the dentist should find out, through the medical interview, the degree of the patient's seizure control to decide whether oral surgery can be safely performed. The patient should be asked to describe what witnesses have said occurs just before, during, and after the patient's seizures. Discovery of any factors that seem to precipitate the seizure, the patient's compliance with antiseizure drugs, and the recent frequency of seizure episodes is helpful. Patients with seizure disorders who appear to have good control of their disease, that is, infrequent episodes that are brief and are not easily precipitated by anxiety, are usually able to undergo oral surgery safely in the ambulatory setting. (See Chapter 1 for recommendations.)

The occurrence of a seizure while a patient is undergoing care in the dental office, although usually creating great concern among the office staff, is rarely an emergency that calls for actions other than simply protecting the patient from self-injury. However, management of the patient during and after a seizure varies, based on the type of seizure that occurs. The patient's ability to exchange air must be monitored by close observation. If it appears that the airway is obstructed, measures to reopen it by placing the head in moderate extension (chin pulled away from the chest) and moving the mandible away from the pharynx must be taken. If the patient vomits or seems to be having problems keeping secretions out of the airway, the patient's head must be turned to the side to allow obstructing materials to drain out of the mouth. If possible,

Management of patient showing symptoms or signs of syncope

Prodrome:
1. Terminate all dental treatment.
2. Position patient in supine posture with legs raised above level of head.
3. Attempt to calm patient.
4. Place cool towel on patient's forehead.
5. Monitor vital signs.

Syncopal episode:
1. Terminate all dental treatment.
2. Position patient in supine posture with legs raised.
3. Check for breathing.

If absent:
4. Start basic life support.
5. Have someone summon medical assistance.
6. Consider other causes of syncope, including hypoglycemia, cerebral vascular accident, or cardiac dysrhythmia.

If present:
4. Crush ammonia ampule under nose, administer O_2.
5. Monitor vital signs.
6. Have patient escorted home.
7. Plan anxiety control measures during future dental care.

• **Fig. 2.8** Management of vasovagal syncope and its prodrome.

high-volume suction should be used to evacuate materials from the pharynx. Brief periods of apnea that may occur require no treatment other than ensuring a patent airway. However, apnea lasting more than 30 seconds demands that BLS be initiated. Although frequently described as being important, the placement of objects between teeth in an attempt to prevent tongue biting is hazardous and, therefore, should be avoided.

Continuous or repeated seizures without periods of recovery between them are known as *status epilepticus*. This problem warrants notification of outside emergency assistance because it is the most common type of seizure disorder to cause mortality. Therapy includes instituting measures already described for self-limiting seizures; in addition, administration of a benzodiazepine is indicated. Injectable water-insoluble benzodiazepines, such as diazepam, must be given intravenously to allow predictability of results, which may be difficult in the patient having seizures if venous access is not already available. Injectable water-soluble benzodiazepines, such as midazolam, provide a better alternative because an IM injection will give a more rapid response. However, the health care provider administering benzodiazepines for a seizure must be prepared to provide BLS because patients may experience a period of apnea after receiving a large, rapid dose of benzodiazepines.

After seizures have ceased, most patients will be left either somnolent or unconscious. Vital signs should be monitored carefully during this time, and the patient should not be allowed to leave the office until fully alert and in the company of an escort. The patient's primary care physician should be notified to decide whether medical evaluation is necessary and whether ambulatory dental care is advisable in the future (Fig. 2.9).

Tremors, palpitations, and extreme anxiety usually precede seizures caused by ethanol withdrawal. Therefore the appearance of these signs in a patient should warn the clinician to defer treatment until proper medical care for the patient's condition is instituted. Control is usually obtained by the use of benzodiazepines, which are used until the untoward effects of abstinence from ethanol cease. Seizures that occur in ethanol-abusing patients are treated in a similar manner as other seizures.

Local Anesthetic Toxicity

Local anesthetics, when properly used, are a safe and effective means of providing pain control during dentoalveolar surgery (see Chapter 6). However, as with all medications, toxicity reactions occur if the local anesthetic is given in an amount or in a manner that produces an excessive serum concentration.

Prevention of a toxicity reaction to local anesthetics generally involves several factors. First, the dose to be used should be the least amount of local anesthetic necessary to produce the intensity and duration of pain control required to successfully complete the

Management of a seizing patient

Manifestations	Acute management
Isolated, brief seizure	1. Terminate all dental treatment. 2. Place in supine position. 3. Protect from nearby objects.
Tonic-clonic movements of trunk and extremities, loss of consciousness, vomiting, airway obstruction, loss of urinary and anal sphincter control	**After seizure**
	Patient is unconscious 4. Have someone summon medical assistance. 5. Place patient on side and suction airway. 6. Monitor vital signs. 7. Initiate basic life support (BLS), if necessary. 8. Administer oxygen. 9. Transport to emergency care facility.
	Patient is conscious 4. Suction airway, if necessary. 5. Monitor vital signs. 6. Administer oxygen. 7. Consult physician. 8. Observe patient in office for 1 hour. 9. Have patient escorted home.
Repeated or sustained seizure (status epilepticus)	1. Administer diazepam 5 mg/min intravenously (IV) up to 10 mg or midazolam 3 mg/min IV or intramuscularly up to 6 mg* titrated until seizures stop.
(as above)	2. Have someone summon medical assistance. 3. Protect patient from nearby objects.
	Once seizure ceases 4. Place patient on side and suction airway. 5. Monitor vital signs. 6. Initiate BLS, if necessary. 7. Administer oxygen. 8. Transport to emergency care facility.

*Total dose can be doubled if no signs of respiratory depression occur. Total dose should be halved in children and older patients.

• **Fig. 2.9** Manifestations and acute management of seizures.

TABLE 2.4 Suggested Maximum Dose of Local Anesthetics

Drug	Common Brand	Concentration	Maximum Dose (mg/kg)	Maximum Number of 1.8-mL Cartridges
Lidocaine	Xylocaine	2%	4	10
Lidocaine with epinephrine[a]	Xylocaine with epinephrine	2% lidocaine 1:100,000 epinephrine	7	10
Mepivacaine	Carbocaine	3%	5	6
Mepivacaine with levonordefrin	Carbocaine with Neo-Cobefrin	2% mepivacaine 1:20,000 levonordefrin	5	8
Prilocaine	Citanest	4%	5	6
Bupivacaine with epinephrine	Marcaine with epinephrine	0.5% bupivacaine 1:200,000 epinephrine	1.5	10
Etidocaine with epinephrine	Duranest with epinephrine	1.5% etidocaine 1:200,000 epinephrine	8	15

[a]Maximum dose of epinephrine is 0.2 mg per appointment.
Maximum doses are those for normal healthy individuals.

planned surgical procedure. The patient's age, lean body mass, liver function, and history of problems with local anesthetics must be considered when choosing the dose of local anesthesia. The second factor to consider in preventing a local anesthetic overdose reaction is the manner of drug administration. The dentist should give the required dose slowly, avoiding intravascular injection, and use vasoconstrictors to slow the entry of local anesthetics into blood. It must be remembered that topical use of local anesthetics in wounds or on mucosal surfaces allows rapid entry of local anesthetics into the systemic circulation. The choice of local anesthetic agents is the third important factor to consider in attempting to reduce the risk of a toxicity reaction. Local anesthetics vary in their lipid solubility, vasodilatory properties, protein binding, and inherent toxicity. Therefore the dentist must be knowledgeable about the various local anesthetics available to make a rational decision when choosing which drug to administer and in what amounts (Table 2.4; also see Chapter 6).

The clinical manifestations of a local anesthetic overdose vary, depending on the severity of the overdose, how rapidly it occurs, and the duration of the excessive serum concentrations. Signs of a mild toxicity reaction may be limited to increased patient confusion, talkativeness, anxiety, and slurring of speech. As the severity of the overdose increases, the patient may display stuttering speech, nystagmus, and generalized tremors. Symptoms such as headache, dizziness, blurred vision, and drowsiness may also occur. The most serious manifestations of local anesthetic toxicity are the appearance of generalized tonic-clonic seizures and cardiac depression leading to cardiac arrest (Table 2.5).

Mild local anesthetic overdose reactions are managed by monitoring vital signs, instructing the patient to hyperventilate moderately with or without administering oxygen, and gaining venous access. If signs of anesthetic toxicity do not rapidly disappear, a slow 2.5 mg to 5 mg IV dose of diazepam should be given. Medical assistance should also be summoned if signs of toxicity do not rapidly resolve or progressively worsen.

If convulsions occur, patients should be protected from hurting themselves. BLS measures are instituted as needed, and venous access is gained, if possible, for the administration of anticonvulsants. Medical assistance should be obtained. If venous access is available, diazepam should be slowly titrated until the seizures stop (5 to 25 mg is the usual effective range). Vital signs should be checked frequently.

TABLE 2.5 Manifestations and Management of Local Anesthetic Toxicity

Manifestations	Management
Mild toxicity: talkativeness, anxiety, slurred speech, confusion	• Stop administration of local anesthetics. • Monitor all vital signs. • Observe in office for 1 hour.
Moderate toxicity: stuttering speech, nystagmus, tremors, headache, dizziness, blurred vision, drowsiness	• Stop administration of all local anesthetics. • Place in supine position. • Monitor vital signs. • Administer oxygen. • Observe in office for 1 hour.
Severe toxicity: seizure, cardiac dysrhythmia or arrest	• Place in supine position. • If seizure occurs, protect patient from nearby objects; suction contents of oral cavity if vomiting occurs. • Have someone summon medical assistance. • Monitor all vital signs. • Administer oxygen. • Start an intravenous line. • Administer diazepam 5–10 mg slowly or midazolam 2–6 mg slowly. • Institute basic life support, if necessary. • Transport to emergency care facility.

Diabetes Mellitus

Diabetes mellitus is a metabolic disease in which the patient's long-term prognosis appears to depend on keeping serum glucose levels close to normal. A person with untreated insulin-dependent

diabetes constantly runs the risk of developing ketoacidosis (type 1 patients) or a hyperosmolar state (type 2 patients) and their attendant alteration of consciousness, requiring emergency treatment. Although a patient with compliant type 1 diabetes may suffer long-term problems because of relatively high serum glucose levels, the more common emergency situation is hypoglycemia resulting from a mismatch of insulin dose and serum glucose. Severe hypoglycemia is the emergency situation dentists are most likely to face when providing oral surgery for a patient with diabetes.

Serum glucose concentration in the patient with diabetes represents a balancing of administered insulin, glucose placed into the serum from various sources, and glucose use. The two primary sources of glucose are dietary and gluconeogenesis from adipose tissue, muscle, and glycogen stores. Physical activity is the principal means by which serum glucose is lowered. Therefore, serum glucose levels can fall because of any or all of the following:

1. Increasing administered insulin
2. Decreasing dietary caloric intake
3. Increasing metabolic use of glucose (e.g., exercise, infection, or emotional stress)

Problems with hypoglycemia during dental care usually arise because the patient has acutely decreased caloric intake, has an infection, or has an increased metabolic rate caused by considerable anxiety. If the patient has not compensated for this diminution of available glucose by decreasing the usual dose of insulin, hypoglycemia results. Although patients taking oral hypoglycemics also can have problems with hypoglycemia, their swings in serum glucose levels are usually less pronounced than those taking insulin, so they are much less likely to quickly become severely hypoglycemic.

Many patients with diabetes are well informed about their disease and are capable of diagnosing their own hypoglycemia before it becomes severe. The patient may feel hunger, nausea, or lightheadedness or may develop a headache. The dentist may notice the patient becoming irritable or lethargic, with decreased spontaneity of conversation and ability to concentrate. As hypoglycemia worsens, the patient may become diaphoretic or have tachycardia, piloerection, or increased anxiety and may exhibit unusual behavior. The patient may soon become stuporous or lose consciousness (Box 2.12).

Severe hypoglycemia in patients with diabetes usually can be avoided through measures designed to keep serum glucose levels on the high side of normal or even temporarily above normal.

• BOX 2.12 Manifestations of Acute Hypoglycemia

Mild

- Hunger
- Nausea
- Mood change (irritability)
- Weakness

Moderate

- Anxiety
- Behavior change: belligerence, confusion, uncooperativeness
- Pallor
- Perspiration
- Tachycardia

Severe

- Hypotension
- Seizures
- Unconsciousness

During the health history interview, the dentist should get a clear idea of the degree of control of the patient's diabetes.

If patients do not regularly check their own serum glucose or if they are aware of their HgbA1c level, their physician should be contacted to determine whether routine dental care can be performed safely. Before any planned procedures, measures discussed in Chapter 1 concerning the patient with diabetes should be taken.

If a patient with diabetes indicates a feeling of low blood sugar or if signs or symptoms of hypoglycemia appear, the procedure being performed should be stopped and the patient should be allowed to consume a high-caloric carbohydrate such as a few packets of sugar, a glass of fruit juice, or other sugar-containing oral agent (glucose gel or paste). If the patient fails to improve rapidly, becomes unconscious, or is otherwise unable to take a glucose source by mouth, venous access should be gained and an ampule (50 mL) of 50% glucose (dextrose) in water should be administered intravenously over 2 to 3 minutes. If venous access cannot be established, 1 mg of glucagon can be given intramuscularly. If 50% glucose and glucagon are unavailable, a 0.5-mL dose of 1:1000 epinephrine can be administered subcutaneously and repeated every 15 minutes as needed (Fig. 2.10).

A patient who seems to have recovered from a hypoglycemic episode should remain in the office for at least 1 hour, and further symptoms should be treated with oral glucose sources. It should be ensured that the patient is escorted home with instructions on how to avoid a hypoglycemic episode during the next dental appointment.

Thyroid Dysfunction

Hyperthyroidism and hypothyroidism are slowly developing disorders that can produce an altered state of consciousness but rarely cause emergencies. The most common circumstance in which an ambulatory, relatively healthy-appearing patient develops an emergency from thyroid dysfunction is when a *thyroid storm* (crisis) occurs.

Thyroid storm is a sudden, severe exacerbation of hyperthyroidism that may or may not have been previously diagnosed. It can be precipitated by infection, surgery, trauma, pregnancy, or any other physiologic or emotional stress. Patients predisposed to thyroid crisis frequently have signs of hyperthyroidism such as tremor, tachycardia, weight loss, hypertension, irritability, intolerance to heat, and exophthalmos; they may even have received therapy for the thyroid disorder.

The clinician should consult the primary care physician of a patient with known hyperthyroidism before any oral surgical procedure. A determination of the adequacy of control of excessive thyroid hormone production should be obtained from the patient's physician, and if necessary, the patient should receive antithyroid drugs and iodide treatment preoperatively. If clearance for ambulatory surgery is given, the patient should be managed as shown in the outline in Chapter 1.

The first sign of a developing thyroid storm is an elevation of temperature and heart rate. Most of the usual signs and symptoms of untreated hyperthyroidism occur in an exaggerated form. The patient becomes irritable, delirious, or even comatose. Hypotension, vomiting, and diarrhea also occur.

Treatment of thyrotoxic crisis begins with the termination of any procedure and notification of those outside the office able to give emergency assistance. Venous access should be obtained, a crystalloid solution should be started at a moderate rate, and the patient should be kept as calm as possible. Attempts may be made to cool the patient until transported to a hospital, where

Management of acute hypoglycemia

1. Terminate all dental treatment

Signs and symptoms of mild hypoglycemia

2. Administer glucose source such as sugar or fruit by mouth.
3. Monitor vital signs.
4. Before further dental care, consult physician if unsure whether or why hypoglycemia has occurred.

Signs and symptoms of moderate hypoglycemia

2. Orally administer glucose source, such as sugar or fruit juice.
3. Monitor vital signs.
4. If symptoms do not rapidly improve, administer 50 mL 50% glucose or 1 mg glucagon intravenously (IV) or intramuscularly (IM).
5. Consult physician before further dental care.

Signs and symptoms of severe hypoglycemia

2. Administer 50 mL 50% glucose IV or IM or 1 mg glucagon.
3. Have someone summon medical assistance.
4. Monitor vital signs.
5. Administer oxygen.
6. Transport to emergency care facility.

• **Fig. 2.10** Management of acute hypoglycemia.

• BOX 2.13 Manifestations and Management of Acute Thyroid Storm

Manifestations

- Abdominal pains
- Cardiac dysrhythmias
- Hyperpyrexia (i.e., fever)
- Nausea and vomiting
- Nervousness and agitation
- Palpitations
- Partial or complete loss of consciousness
- Tachycardia
- Tremor
- Weakness

Management

1. Terminate all dental treatment.
2. Have someone summon medical assistance.
3. Administer oxygen.
4. Monitor all vital signs.
5. Initiate basic life support, if necessary.
6. Start an intravenous line with drip of crystalloid solution (150 mL/h).
7. Transport the patient to an emergency care facility.

antithyroid and sympathetic blocking drugs can be administered safely (Box 2.13).

Adrenal Insufficiency

Primary adrenocortical insufficiency (Addison disease) or other medical conditions in which the adrenal cortex has been destroyed are rare. However, adrenal insufficiency resulting from exogenous corticosteroid administration is common because of the multitude of clinical conditions for which therapeutic corticosteroid administration is given. Patients with adrenal insufficiency are frequently not informed concerning their potential need for supplemental medication, and those with secondary adrenal insufficiency may fail to inform the dentist that they are taking corticosteroids. This is not a problem, provided the patient is not physiologically or emotionally stressed.

However, should the patient be stressed, adrenal suppression that results from exogenous corticosteroids may prevent the normal release of endogenous glucocorticoids in amounts needed to help the body meet the elevated metabolic demands. Patients at risk for acute adrenal insufficiency as a result of adrenal suppression are generally those who take at least 20 mg of cortisol (or its equivalent) daily for at least 2 weeks any time during the year preceding the planned major oral surgical procedure (Table 2.6). However, in most straightforward oral surgical procedures done under local anesthesia or nitrous oxide plus local anesthesia, administration of supplemental corticosteroids is unnecessary. When significant adrenal suppression is suspected, the steps discussed in Chapter 1 should be followed.

• BOX 2.14 Manifestations of Acute Adrenal Insufficiency

- Abdominal pain
- Confusion
- Feeling of extreme fatigue
- Hypotension
- Myalgia
- Nausea
- Partial or total loss of consciousness
- Weakness

Early clinical manifestations of acute adrenal insufficiency crisis include mental confusion, nausea, fatigue, and muscle weakness. As the condition worsens, the patient develops more severe mental confusion; pain in the back, abdomen, and legs; vomiting; and hypotension. Without treatment the patient will eventually begin to drift in and out of consciousness, with coma indicating the preterminal stage (Box 2.14).

Management of an adrenal crisis begins by stopping all dental treatment and taking vital signs. If the patient is found to be hypotensive, the patient must be placed immediately in the head-down, legs-elevated position. Medical assistance should be summoned. Oxygen should be administered and venous access gained. A 100-mg dose of hydrocortisone sodium succinate or its equivalent in dexamethasone or methylprednisolone should be given intravenously (or intramuscularly, if necessary). IV fluids should be rapidly administered until hypotension improves. Vital signs should be measured frequently while therapeutic measures are performed. Should the patient lose consciousness, the need for the initiation of BLS measures should be evaluated (Box 2.15).

TABLE 2.6 Equivalency of Commonly Used Glucocorticosteroids

Relative Duration of Action	Generic Name	Common Brand Name	Relative Glucocorticoid Potency	Relative Glucocorticoid Dose (mg)
Short	Cortisol (hydrocortisone)	Solu-Cortef	1	20
	Cortisone	—	0.8	25
	Prednisone	Deltasone	4	5
	Prednisolone	Delta-Cortef	4	5
	Methylprednisolone sodium succinate	Solu-Medrol	5	4
Intermediate	Triamcinolone	Kenalog	5	4
Long	Betamethasone	Celestone	25	0.6
	Dexamethasone	Decadron	30	0.75
	Methylprednisolone acetate	Depo-Medrol	5	4

• BOX 2.15 Management of Acute Adrenal Insufficiency

1. Terminate all dental treatment.
2. Place the patient in the supine position with legs raised above head level.
3. Have someone summon medical assistance.
4. Administer corticosteroid (100 mg hydrocortisone intramuscular or intravenous or its equivalent).
5. Administer oxygen.
6. Monitor all vital signs.
7. Start an intravenous line and a drip of crystalloid solution.
8. Start basic life support, if necessary.
9. Transport the patient to an emergency care facility.

• BOX 2.16 Manifestations of Cerebrovascular Compromise in Progress

- Headache that can range from mild to the worst the patient has ever experienced
- Unilateral weakness or paralysis of extremities or facial muscles or both
- Slurring of speech or inability to speak
- Difficulty breathing or swallowing or both
- Loss of bladder and bowel control
- Seizures
- Visual disturbance
- Dizziness
- Partial or total loss of consciousness

Cerebrovascular Compromise

Alterations in cerebral blood flow can be compromised in three principal ways: (1) embolization of particulate matter from a distant site, (2) formation of a thrombus in a cerebral vessel, or (3) rupture of a vessel. Material that embolizes to the brain comes most frequently from thrombi in the left side of the heart, from the carotid artery, or from bacterial vegetations on infected heart surfaces. Cerebrovascular thrombi generally form in areas of atherosclerotic changes. Finally, vascular rupture can occur because of rare congenital defects in the vessel, such as berry aneurysms or arteriovenous malformations.

The effect on the level of consciousness of a cerebrovascular problem depends on the severity of the cerebral lesion. If the problem rapidly resolves, as happens with transient ischemic attacks, the symptoms of cerebral vascular compromise may last only a few seconds or minutes. However, if ischemia is severe enough, an infarction may occur in an area of the brain, leaving a neurologic deficit.

A transient ischemic attack that occurs during dental care requires that the procedure be terminated. However, little must be done for the patient other than reassurance because most patients experience only a temporary numbness or weakness of both of the extremities on one side of the body and a speech or visual disturbance. Consciousness is usually unaltered. Transient ischemic attacks frequently precede a cerebral infarction, so immediate physician referral is important.

Cerebrovascular compromise that results from embolism usually occurs first with a mild headache, followed by the appearance of other neurologic symptoms such as vertigo, dizziness, or weakness in an extremity. However, cerebral hemorrhage typically has the abrupt onset of a severe headache, followed in several hours by nausea, dizziness, vertigo, and diaphoresis. The patient may eventually lose consciousness (Box 2.16).

• BOX 2.17 Management of Cerebrovascular Compromise in Progress

1. Terminate all dental treatment.
2. Have someone summon medical assistance.
3. Place the patient in the supine position with head slightly raised.
4. Monitor all vital signs.
5. If loss of consciousness occurs, administer oxygen and institute basic life support, as necessary.
6. Transport the patient to an emergency care facility.

If symptoms are present only briefly (i.e., transient ischemic attacks), terminate dental treatment, monitor vital signs, and consult the patient's physician concerning the safety of further dental care.

If signs or symptoms of a cerebrovascular compromise arise and are not transient, a major problem affecting the cerebral vasculature may be occurring. The procedure should be stopped, and frequent monitoring of vital signs should be begun. Medical help should be called to assist in the event the patient becomes hypotensive or unconscious and to transport the patient to a hospital where neurosurgical intervention or thrombolytic therapy can be initiated, as indicated. If the patient develops respiratory difficulty, oxygen should be administered. However, oxygen is otherwise contraindicated in patients with cerebrovascular insufficiency. Any narcotics that the patient has been administered should be reversed. If consciousness is lost, vital signs should be monitored frequently, and BLS should be started, if necessary (Box 2.17).

3

Principles of Surgery

JAMES R. HUPP

CHAPTER OUTLINE

Human tissues have genomically predetermined characteristics that define normal responses to injury. Because the response to injury is predictable, principles of surgery have evolved to help optimize the wound-healing environment guided by basic and clinical research. This chapter presents the evidence-based principles of surgical practice that have been found to be successful not only for oral surgery, but also for surgery in all sites of the body.

Developing a Surgical Diagnosis

The important decisions concerning a surgical procedure should be made well before the administration of anesthesia commences. The decision to perform surgery should be the result of careful patient examination. In the critical thinking analytic approach the surgeon first identifies the various signs and symptoms and relevant historical information; then, using available patient and diagnostic data and logical reasoning based on clinical experience, the surgeon establishes the relationship between the individual problems for which surgical intervention may be indicated.

The initial step in the presurgical evaluation is the collection of accurate and relevant data. This occurs through patient interviews and physical, laboratory, and imaging examinations. It may include the use of consultants. Patient interviews and physical examinations should be performed in an unhurried, careful manner. The surgeon should not be willing to accept incomplete data such as a poor-quality radiograph, especially when it is probable that additional data might alter decisions concerning surgery.

For proper analysis, diagnostic data must be organized into a form that allows for hypothesis testing; that is, the dentist should be able to consider a list of possible diseases and eliminate those unsupported by the patient data, disease frequencies, and evidence-based science. By using this method, along with the knowledge of disease probabilities, the surgeon is usually able to reach a decision about whether surgery is indicated and what procedure to perform.

Clinicians must also be thoughtful observers. Whenever a procedure is performed, they should reflect on all aspects of its outcome to advance their surgical knowledge and to improve future surgical results. This procedure should also be followed whenever a clinician is learning about a new technique. In addition, a clinician should practice evidence-based dentistry by evaluating the purported results of any new technique by weighing the scientific merit of studies used to investigate the technique. Frequently, scientific methods are violated by the unrecognized introduction of a placebo effect, observer bias, patient variability, or use of inadequate control groups.

Basic Necessities for Surgery

Little difference exists between the basic necessities required for oral surgery and those required for the proper performance of other aspects of dentistry. The two principal requirements are (1) adequate visibility and (2) assistance.

Although visibility may seem too obvious to mention as a requirement for performing surgery, clinicians often underestimate its importance, especially when the unexpected occurs. Adequate visibility depends on the following three factors: (1) adequate access, (2) adequate light, and (3) a surgical field free of excess blood and other fluids and debris.

Adequate access not only requires the patient's ability to open the mouth widely but also may require surgically created increased exposure. Retraction of tissues away from the operative field provides much of the necessary access. (Proper retraction also protects tissues being retracted from being accidentally injured, such as by sharp instruments.) Improved access is gained by the creation of surgical flaps, which are discussed later in this chapter.

Adequate light is another obvious necessity for surgery. However, clinicians often forget that many surgical procedures place the surgeon or assistant in positions that block chair-based light sources. To correct this problem, the light source must continually be repositioned, or the surgeon or assistant must avoid obstructing

the light. The availability of more than one overhead light or using a headlight greatly improves illumination of the operative site.

A surgical field free of fluids and debris is also necessary for adequate visibility. High-volume suctioning with a relatively small tip can quickly remove blood and other fluids from the field.

As in other types of dentistry, a properly trained and focused assistant provides invaluable help during oral surgery. The assistant should be sufficiently familiar with the procedures being performed to anticipate the surgeon's needs. Successful surgery is difficult to accomplish with poor or no assistance.

Aseptic Technique

Aseptic technique is used to minimize wound contamination by pathogenic microbes. This important surgical principle is discussed in detail in Chapter 5.

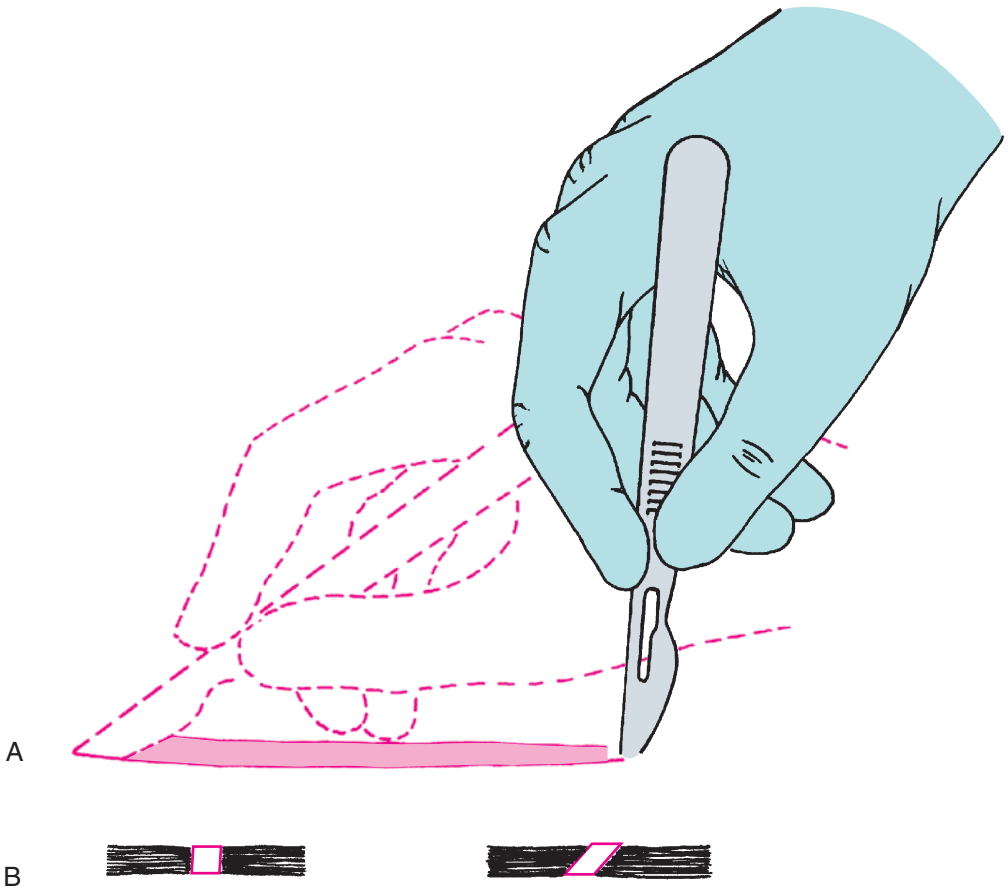
Incisions

Many oral and maxillofacial surgical procedures necessitate incisions. A few basic principles are important to remember when performing incisions.

The first principle is that a sharp blade of the proper size and shape should be used. A sharp blade allows the surgeon to make incisions precisely, without causing unnecessary injury caused by repeated strokes. The rate at which a blade dulls depends on the resistance of tissues through which the blade cuts. Bone and ligamental tissues dull blades much more rapidly than does buccal mucosa. Therefore the surgeon should change the blade whenever the scalpel does not seem to be incising easily.

The second principle is that a firm, continuous stroke should be used when incising. Repeated, tentative strokes increase the amount of damaged tissue within a wound and the amount of bleeding; these impair wound healing and visibility. Long, continuous strokes are preferable to short, interrupted ones (Fig. 3.1A).

The third principle is that the surgeon should carefully avoid accidentally cutting important structures when incising. Each patient's microanatomy is unique. Therefore to avoid unintentionally cutting large vessels or nerves, the surgeon must incise only deeply enough to define the next major layer when making incisions close to where major vessels, ducts, and nerves run. Vessels can be more easily controlled before they are completely divided, and important nerves can usually be freed from adjacent tissue and retracted away



• **Fig. 3.1** (A) Proper method of making incision using No. 15 scalpel blade. Note the scalpel motion is made by moving the hand at the wrist and not by moving the entire forearm. (B) When creating a tissue layer that is to be sutured closed, the blade should be kept perpendicular to the tissue surface to create squared wound edges. Holding the blade at any angle other than 90 degrees to the tissue surface creates an oblique cut that is difficult to close properly and compromises blood supply to the wound edge. (Modified from Clark HB Jr. *Practical Oral Surgery*. 3rd ed. Philadelphia: Lea & Febiger; 1965.)

from the area to be incised. In addition, when using a scalpel, the surgeon must remain focused on the location of the blade to avoid inadvertently cutting structures such as the lips when moving the scalpel into and out of the mouth.

The fourth principle is that incisions through epithelial surfaces that the surgeon plans to reapproximate should be made with the blade held perpendicular to the epithelial surface. This angle produces squared wound edges that are easier to reorient properly during suturing and are less susceptible to necrosis of the wound edges as a result of wound edge ischemia (see Fig. 3.1B).

The fifth principle is that incisions in the oral cavity should be properly placed. Incisions through attached gingiva and over healthy bone are more desirable than those through unattached gingiva and over unhealthy or missing bone. Properly placed incisions allow the wound margins to be sutured over intact, healthy bone that is at least a few millimeters away from the damaged bone, thereby providing support for the healing wound. Similarly, when possible, incisions over prominences such as the canine eminence are best to avoid because the pressure on the closed wound from the prominence may interfere with wound healing. Incisions placed near the teeth for extractions should be made in the gingival sulcus, unless the clinician thinks that it is necessary to excise the marginal gingiva or to leave the marginal gingiva untouched.

Flap Design

Surgical flaps are made to gain surgical access to an area or to move tissue from one place to another. Several basic principles of flap design must be followed to prevent the primary complications of flap surgery: necrosis, dehiscence, and tearing.

Prevention of Flap Necrosis

Flap necrosis can be prevented if the surgeon attends to four basic flap design principles: (1) The height of a flap should never be greater than the base, unless a major artery is present in the base. Preferably, flaps should have sides that run parallel to each other or converge moving from the base to the apex of the flap. (2) Generally, the height of a flap should be no more than twice the width of the base. The width of the base should preferably be greater than the height of the flap (Fig. 3.2). Strict adherence to this principle is less critical in the oral cavity due to the robust vascularization of oral mucosa, but in general, the length of the flap should never exceed the width. (3) When possible, an axial blood supply should be included in the base of the flap. For example, a flap in the palate should be based toward the greater palatine artery, when possible. (4) The base of flaps should not be excessively twisted, stretched, or grasped with anything that might damage vessels because these maneuvers could compromise the blood supply feeding and draining the flap, as well as delicate lymphatics.

Prevention of Flap Dehiscence

Flap margin dehiscence (separation leading to opening of a sutured incision) is prevented by approximating the edges of the flap over healthy bone, by gently handling the edges of the flap, and by not placing the edges of the flap under tension. One should not need to use any significant force to pull tissues together while suturing a wound. Dehiscence exposes underlying bone and other tissues, producing pain, bone loss, and increased scarring.

Prevention of Flap Tearing

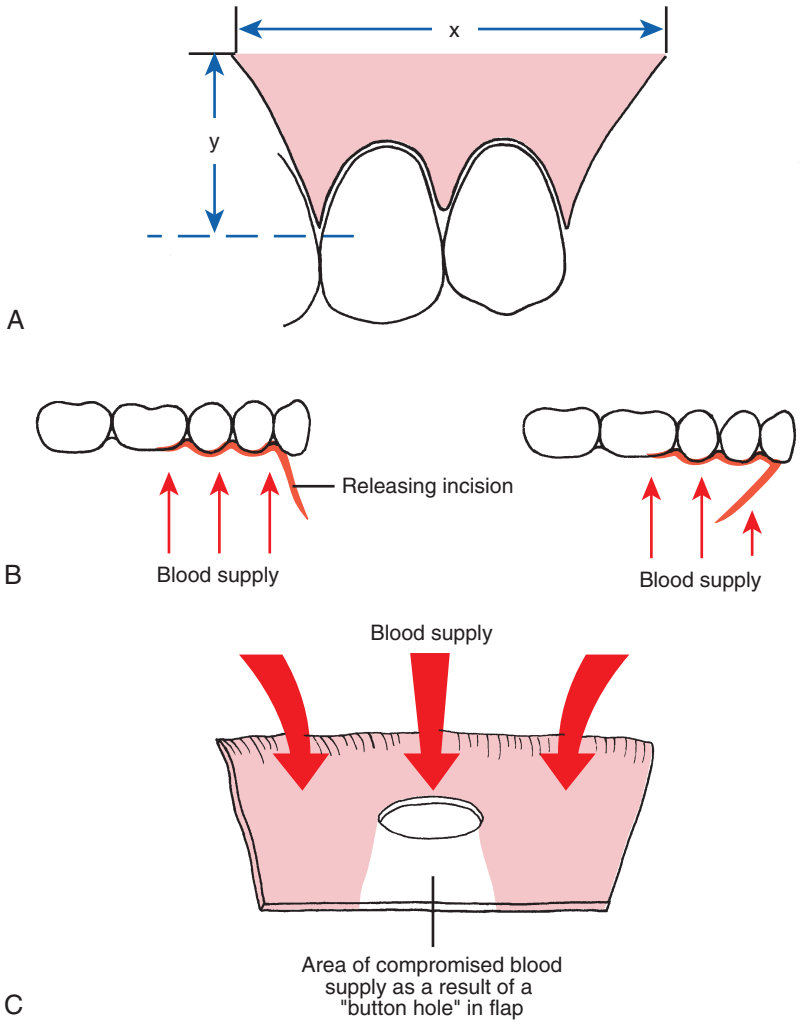
Tearing of a flap is a common complication of the novice surgeon who attempts to perform a procedure using a flap that provides insufficient access. Because a properly repaired long incision heals just as quickly as a short one, it is preferable to create a flap at the onset of surgery that is large enough for the surgeon to avoid tearing it or interrupting surgery to lengthen. Envelope flaps are those created by incisions that produce a one-sided flap. An example is an incision made around the necks of several teeth to expose alveolar bone without any vertical releasing incisions. However, if an envelope flap does not provide sufficient access, it should be lengthened or another (a releasing) incision should be made to prevent it from tearing (Fig. 3.3). Vertical (oblique) releasing incisions should generally be placed one full tooth anterior to the area of any anticipated bone removal. The incision is generally started at the line angle of a tooth or in the adjacent interdental papilla and is carried obliquely apically into the unattached gingiva. A need for more than one releasing incision is uncommon when using a flap to gain routine oral surgical access.

Tissue Handling

The difference between an acceptable and an excellent surgical outcome often rests on how the surgeon handles the tissues. The use of proper incision and flap design techniques plays a role; however, tissue also must be handled carefully. Excessive pulling or crushing, extremes of temperature, desiccation, or the use of unphysiologic chemicals easily damages tissue. Therefore the surgeon should use care whenever touching tissue. When tissue forceps are used, they should not be pinched together too tightly; rather, they should be used to delicately hold tissue. When possible, toothed forceps or tissue hooks should be used to hold tissue (Fig. 3.4). In addition, tissues should not be overaggressively retracted to gain greater surgical access. This includes not pulling excessively to retract the cheeks or the tongue during surgery. Note that overretraction is uncomfortable for patients even if the cheeks or tongue are locally anesthetized. When bone is cut, copious amounts of irrigation should be used to decrease the amount of bone damage from frictional heat. Soft tissue should also be protected from frictional heat or direct trauma from drilling equipment. Tissue should not be allowed to desiccate; open wounds should be frequently moistened or covered with a damp sponge if the surgeon will not be working on them for a while. Finally, only physiologic substances should come in contact with living tissue. For example, tissue forceps used to place a specimen into formalin during a biopsy procedure should not be returned to the wound until any contaminating formalin is thoroughly removed. The surgeon who handles tissue gently and physiologically is rewarded with grateful patients whose wounds heal with less frequent complications.

Hemostasis

Prevention of excessive blood loss during surgery is important for preserving a patient's oxygen-carrying capacity. However, maintaining meticulous hemostasis during surgery is necessary for other important reasons. One is the decreased visibility that uncontrolled bleeding creates. Even high-volume suctioning cannot keep a surgical field completely dry, particularly in the well-vascularized oral and maxillofacial regions. Another problem bleeding causes is the formation of hematomas (collections of blood under soft tissue). Hematomas place pressure on wounds, decreasing vascularity; they



• **Fig. 3.2** (A) Principles of flap design. In general, flap base dimension *(x)* must not be less than height dimension *(y)* and should preferably be approximately $x = 2y$. (B) When a releasing incision is used to reflect a two-sided flap, the incision should be designed to maximize flap blood supply by leaving a wide base. The design on the left is correct; the design on the right is incorrect. (C) When a "buttonhole" occurs near the free edge of the flap, blood supply to the flap tissue on the side of the hole away from the flap base is compromised.

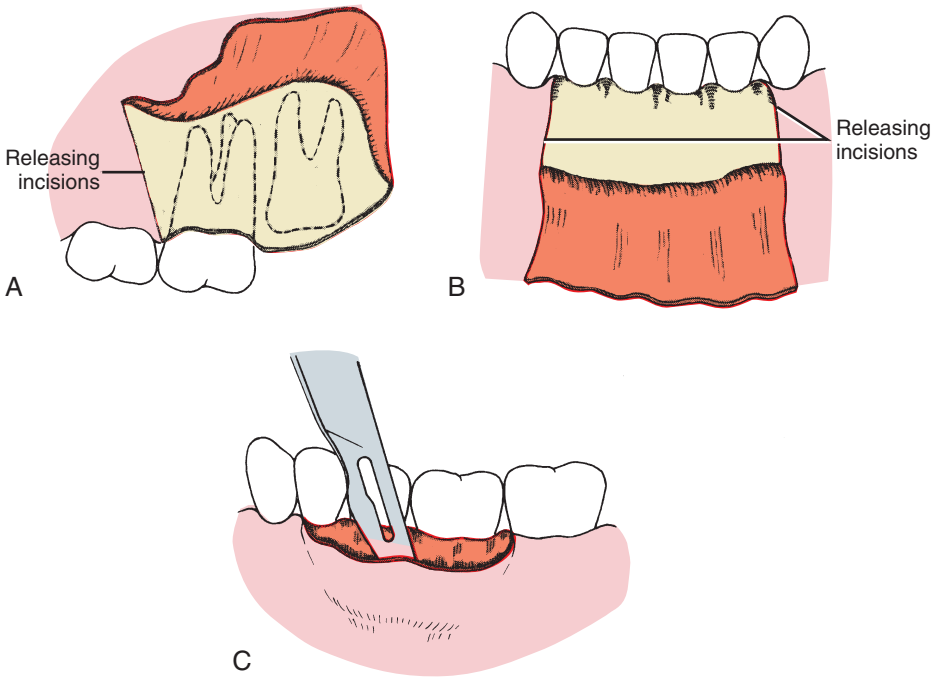
increase tension on the wound edges; and they act as culture media, potentiating the development of wound infections.

Means of Promoting Wound Hemostasis

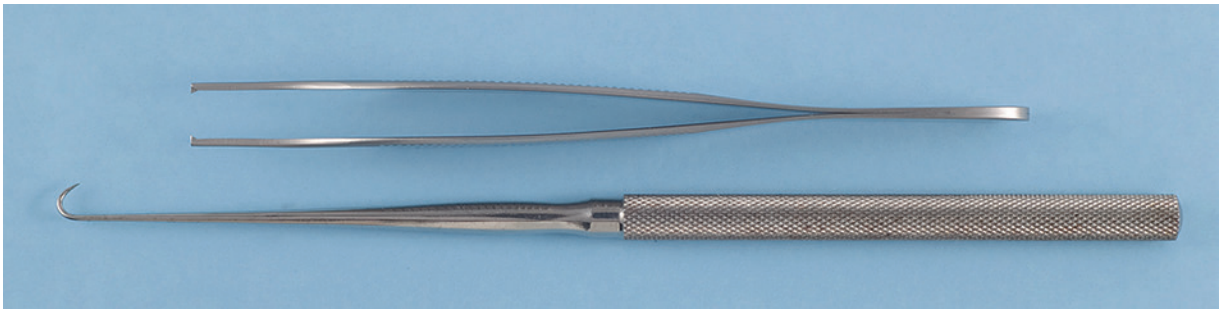
Wound hemostasis can be obtained in four ways. The first is by assisting natural hemostatic mechanisms. This is usually accomplished by using a gauze sponge to place pressure on bleeding vessels or placing a hemostat on a vessel. Both methods cause stasis of blood in vessels, which promotes coagulation. A few small vessels generally require pressure for only 20 to 30 seconds, whereas larger vessels require 5 to 10 minutes of continuous pressure. The surgeon and assistants should blot, rather than wipe, the wound with gauze sponges to remove extravasated blood. Wiping is more likely to reopen vessels that are already plugged by clotted blood.

A second means of obtaining hemostasis is by the use of heat to cause the ends of cut vessels to fuse (thermal coagulation). Heat is usually applied via an electrical current that the surgeon concentrates on the bleeding vessel by holding the vessel with a metal instrument such as a hemostat or by touching the vessel directly with an electrocautery tip. Three conditions should be created for proper use of thermal coagulation: (1) The patient must be grounded, to allow the current to enter the body; (2) the cautery tip and any metal instrument the cautery tip contacts cannot touch the patient at any point other than the site of the bleeding vessel, as otherwise, the current may follow an undesirable path and create a burn; and (3) the third necessity for thermal coagulation is the removal of any blood or fluid that has accumulated around the vessel to be cauterized. Fluid acts as an energy sump and thus prevents a sufficient amount of heat from reaching the vessel to cause closure.

The third means of providing surgical hemostasis is by suture ligation. If a sizable vessel is severed, each end is grasped with a hemostat. The surgeon then ties a nonresorbable suture around



• **Fig. 3.3** Three types of properly designed oral soft tissue flaps. (A) Horizontal and single vertical incisions used to create a two-sided flap. (B) Horizontal and two vertical incisions used to create a three-sided flap. (C) Single horizontal incision used to create a single-sided (envelope) flap.



• **Fig. 3.4** Instruments used to minimize damage while holding soft tissue. *Top,* Fine-toothed tissue forceps (pickups). *Bottom,* Soft tissue (skin) hook.

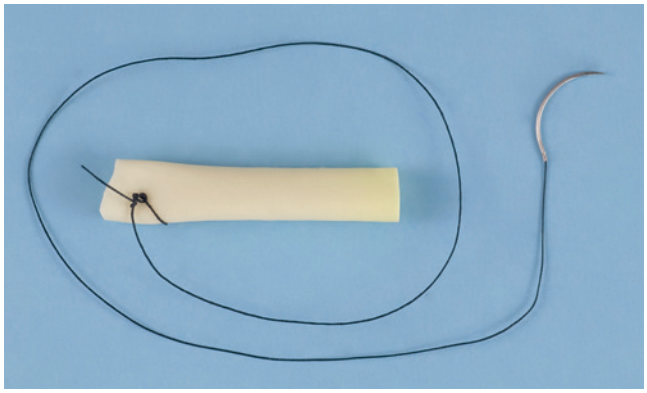
the vessel. If a vessel can be dissected free of surrounding connective tissue before it is cut, two hemostats can be placed on the vessel with enough space left between them to cut the vessel. Once the vessel is severed, sutures are tied around each end and the hemostats removed.

The fourth means of promoting hemostasis is by placing vasoconstrictive substances such as epinephrine in the wound or by applying procoagulants such as commercial thrombin or collagen on the wound. Epinephrine serves as a vasoconstrictor most effectively when placed in the site of desired vasoconstriction at least 7 minutes before surgery begins. Epinephrine is ineffective for promoting local hemostasis if administered after bleeding has started.

Dead Space Management

Dead space in a wound is any area that remains devoid of tissue after closure of the wound. Dead space is created by removing tissue in the depths of a wound and by not reapproximating all tissue planes during closure. Dead space in a wound usually fills with blood, which creates a hematoma with a high potential for infection.

Dead space can be eliminated in four ways: (1) The first is by suturing tissue planes together to minimize the postoperative void. (2) A second method is to place a pressure dressing over the sutured wound. The dressing compresses tissue planes together until they are bound by fibrin or pressed together by surgical edema (or both). This usually takes about 12 to 18 hours. (3) The third way to eliminate dead space is to place packing into the void until bleeding has stopped and then to remove the packing. This technique is usually used when the surgeon is unable to suture tissue together or to place pressure dressings (e.g., when a bony cavity remains after cyst removal). The packing material is impregnated with an antibacterial medication to lessen the chance of infection. (4) The fourth means of preventing dead space is through the use of drains, by themselves or in addition to pressure dressings. Suction drains



• **Fig. 3.5** Example of nonsuction drain. This Penrose drain is made of flexible, rubberized material that can be placed into wound during closure, or after incision and drainage of abscess, to prevent premature sealing of wound before blood or pus collections can drain to the surface. Draining material runs along and through the drain. In this example, a suture has been tied to the drain and it is ready for insertion into the wound. The needled end of the suture will be used to attach the drain to the wound edge to hold it in place.

continually remove any blood that accumulates in a wound until the bleeding stops and the tissues bind together, eliminating any dead space. Nonsuction drains allow any bleeding to drain to the surface rather than to form a hematoma (Fig. 3.5). In most routine oral surgical procedures performed by dentists, dead space creation is not a major problem.

Decontamination and Debridement

Bacteria invariably contaminate all wounds that are open to the external or oral environment. Because the risk of infection rises with the increased size of an inoculum, one way to lessen the chance of wound infection is to decrease the bacterial count. This is easily accomplished by repeatedly irrigating the wound during surgery and closure. Irrigation, particularly when delivered under pressure, dislodges bacteria and other foreign materials and rinses them out of the wound. Irrigation can be achieved by forcing large volumes of fluid under pressure on the wound. Although solutions containing antibiotics can be used, most surgeons simply use sterile saline or sterile water.

Wound debridement is the careful removal of necrotic and severely ischemic tissue and foreign material from injured tissue that would impede wound healing. In general, debridement is used only during care of traumatically incurred wounds or for severe tissue damage caused by a pathologic condition such as an infection.

Inflammation Control

Edema occurs after surgery as a result of tissue injury. Edema is an accumulation of fluid in the interstitial space because of fluid transudation from damaged vessels and lymphatic obstruction by fibrin. Two variables help determine the degree of postsurgical edema: (1) The greater the amount of tissue injury, the greater is the amount of edema and (2) the looser the connective tissue that is contained in the injured region, the more edema that occurs. For example, attached gingiva has little loose connective tissue, so it exhibits little tendency toward edema; however, the lips and floor of the mouth contain large amounts of loose connective tissue and can swell significantly.

The dentist can control the amount of postsurgical edema by performing surgery in a manner that minimizes tissue damage. Some believe that ice applied to a freshly wounded area decreases vascularity and thereby diminishes transudation and edema. However, no controlled study has verified the effectiveness of this practice. Patient positioning in the early postoperative period is also used to decrease edema by having the patient try to keep the head elevated above the rest of the body as much as possible during the first few postoperative days. Short-term, high-dose systemic corticosteroids, which have an impressive ability to lessen inflammation and transudation (and thus edema), can be administered to the patient. However, corticosteroids are useful for edema control only if administration is begun before tissue is damaged.

Patient General Health and Wound Healing

Proper wound healing depends on a patient's ability to resist infection, to provide essential nutrients for use as building materials, and to carry out reparative cellular processes. Numerous medical conditions impair a patient's ability to resist infection and heal wounds. These include conditions that establish a catabolic state of metabolism, that impede oxygen or nutrient delivery to tissues, or that require administration of drugs or physical agents that interfere with immunologic or wound-healing cells. Examples of diseases that induce a catabolic metabolic state include poorly controlled type 1 diabetes mellitus, end-stage renal or hepatic disease, and malignant diseases. Conditions that interfere with the delivery of oxygen or nutrients to wounded tissues include severe chronic obstructive pulmonary disease, poorly compensated congestive heart failure, and drug addictions such as ethanolism. Diseases requiring the administration of drugs that interfere with host defenses or wound-healing capabilities include autoimmune diseases for which long-term corticosteroid therapy is given and malignancies for which cytotoxic agents and irradiation are used.

The surgeon can help improve the patient's chances of having normal healing of an elective surgical wound by evaluating and optimizing the patient's general health status before surgery. For malnourished patients, this includes improving the nutritional status so that the patient is in a positive nitrogen balance and an anabolic metabolic state.

4

Wound Repair

JAMES R. HUPP

CHAPTER OUTLINE

An important aspect of any surgical procedure is the preparation of the wound for proper healing. A thorough understanding of the biology of normal tissue repair is therefore valuable for individuals intending to perform surgery.

Tissue injury can be caused by pathologic conditions or by traumatic events. The dental surgeon has some control over pathologic tissue damage such as the likelihood of a wound infection. In addition, the surgeon can favorably or unfavorably alter the amount and severity of traumatically induced tissue injury and thus contribute to promoting or impeding wound healing.

This chapter discusses the ways in which perioperative tissue injury occurs and the events normally occurring during the healing of soft and hard tissues.

Causes of Tissue Damage

Traumatic injuries can be caused by physical or chemical insults (Box 4.1). Physical means of producing tissue damage include incision or crushing, extremes of temperature or irradiation, desiccation, and obstruction of arterial inflow or venous outflow. Chemicals able to cause injury include those with unphysiologic pH or tonicity, those that disrupt protein integrity, and those that cause ischemia by producing vascular constriction or thrombosis.

Wound Repair

Epithelialization

Injured epithelium has a genetically programmed regenerative ability that allows it to reestablish its integrity through proliferation, migration, and a process known as *contact inhibition*. In general, any edge of normal epithelium will begin and continue to migrate (by proliferation of germinal epithelial cells that advance the free edge forward) until it comes into contact with another free edge of epithelium, where it is signaled to stop growing laterally. Note that the other epithelium can be a different type of epithelium.

Although it is theorized that chemical mediators (released from epithelial cells that have lost contact with other epithelial cells circumferentially) regulate this process, no definitive evidence for this is yet available. Wounds in which only the surface epithelium is injured (i.e., abrasions) heal by proliferation of epithelium across the wound bed from the epithelium contained in rete pegs and adnexal tissues. Because epithelium does not normally contain blood vessels, the epithelium in wounds in which the subepithelial tissue is also damaged proliferates across whatever vascularized tissue bed is available and stays under the portion of the superficial blood clot that desiccates (i.e., forms a scab) until it reaches another epithelial margin. Once the wound is fully epithelialized, the scab loosens and eventually dislodges.

An example of the sometimes detrimental effect of the process of contact inhibition controlling epithelialization occurs when an opening is accidentally made into a maxillary sinus during tooth extraction (see Chapter 11). If the epithelium of both the sinus wall and the oral mucosa is injured, it begins to proliferate in both areas. In this case, the first free epithelial edge the sinus epithelium may contact is oral mucosa, thereby creating an oroantral fistula (i.e., an epithelialized tract between the oral cavity and the maxillary sinus).

The process of reepithelialization (i.e., secondary epithelialization) is sometimes used therapeutically by oral-maxillofacial surgeons during certain preprosthetic surgical procedures in which an area of oral mucosa is denuded of epithelium (i.e., unattached gingiva) and then left to epithelialize by adjacent epithelium (i.e., attached gingiva) creeping over the wound bed.

Stages of Wound Healing

Regardless of the cause of nonepithelial tissue injury, a stereotypical process is initiated and, if able to proceed unimpeded, works to restore tissue integrity. This process is called *wound healing*. The process has been divided into basic stages that, although not mutually exclusive, take place in this sequence. These three basic stages are (1) inflammatory, (2) fibroplastic, and (3) remodeling.

• BOX 4.1 Causes of Tissue Damage

Physical

- Compromised blood flow
- Crushing
- Desiccation
- Incision
- Irradiation
- Overcooling
- Overheating

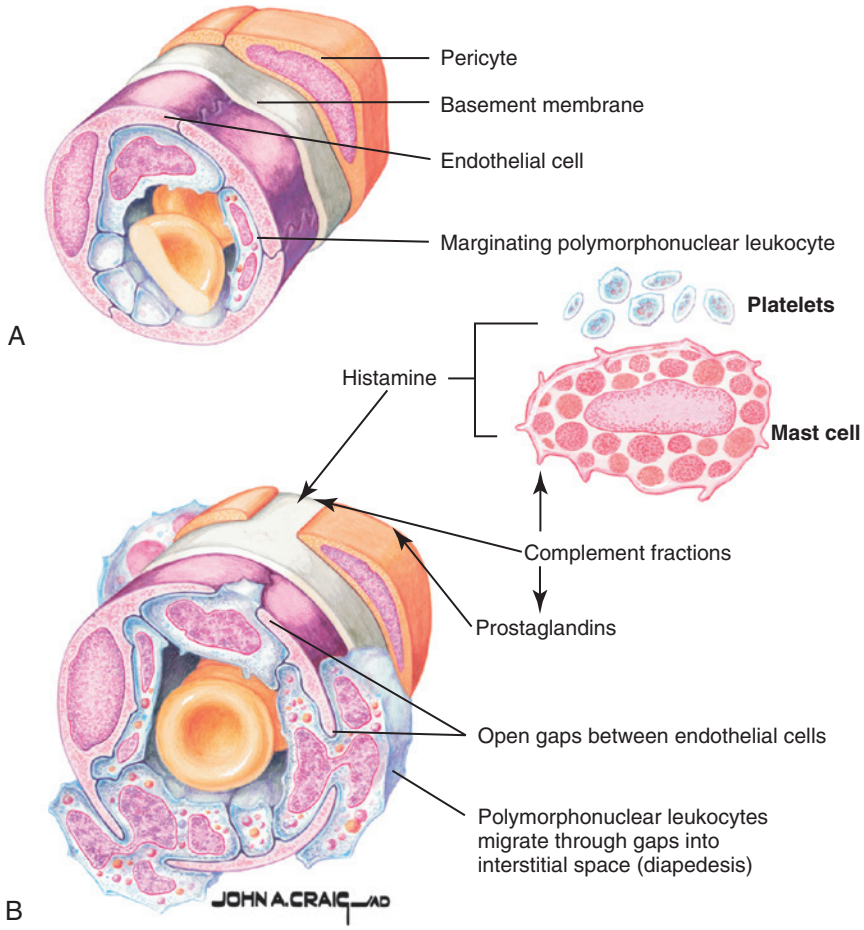
Chemical

- Agents with unphysiologic pH
- Agents with unphysiologic tonicity
- Proteases
- Vasoconstrictors
- Thrombogenic agents

Inflammatory Stage

The inflammatory stage begins the moment tissue injury occurs and, in the absence of factors that prolong inflammation, lasts 3 to 5 days. The inflammatory stage has two phases: (1) vascular and (2) cellular. The vascular events set in motion during inflammation begin with an initial vasoconstriction of disrupted vessels as a result of normal vascular tone. The vasoconstriction slows blood flow into the area of injury, promoting blood coagulation. Within minutes, histamine and prostaglandins E_1 and E_2, elaborated by white blood cells, cause vasodilation and open small spaces between endothelial cells, which allows plasma to leak and leukocytes to migrate into interstitial tissues. Fibrin from the transudated plasma causes lymphatic obstruction, and the transudated plasma—aided by obstructed lymphatic vessels—accumulates in the area of injury, functioning to dilute contaminants. This fluid collection is called *edema* (Fig. 4.1).

The cardinal signs of inflammation are redness (i.e., erythema) and swelling (i.e., edema), with warmth and pain—*rubor et tumour cum calore et dolore* (Celsius, 30 BC–AD 38)—and loss of function—*functio laesa* (Virchow, 1821–1902). Warmth and



• **Fig. 4.1** Early vascular responses to injury. Initial transient vasoconstriction (A) is soon followed by vasodilation (B). Vasodilation is caused by the actions of histamine, prostaglandins, and other vasodilatory substances. Dilation causes intercellular gaps to occur, which allows egress of plasma and emigration of leukocytes. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)

erythema are caused by vasodilation; swelling is caused by transudation of fluid; and pain and loss of function are caused by histamine, kinins, and prostaglandins released by leukocytes, as well as by pressure from edema.

The cellular phase of inflammation is triggered by the activation of serum complement by tissue trauma. Complement-split products, particularly C_{3a} and C_{5a}, act as chemotactic factors and cause polymorphonuclear leukocytes (neutrophils) to stick to the side of blood vessels (margination) and then migrate through the vessel walls (diapedesis). Once in contact with foreign materials (e.g., bacteria), the neutrophils release the contents of their lysosomes (degranulation). The lysosomal enzymes (consisting primarily of proteases) work to destroy bacteria and other foreign materials and to digest necrotic tissue. Clearance of debris is also aided by monocytes such as macrophages, which phagocytize foreign and necrotic materials. With time, lymphocytes accumulate at the site of tissue injury.

The inflammatory stage is sometimes referred to as the *lag phase*, because this is the period during which no significant gain in wound strength occurs (because little collagen deposition is taking place). The principal material holding a wound together during the inflammatory stage is fibrin, which possesses little tensile strength (Fig. 4.2).

Fibroplastic Stage

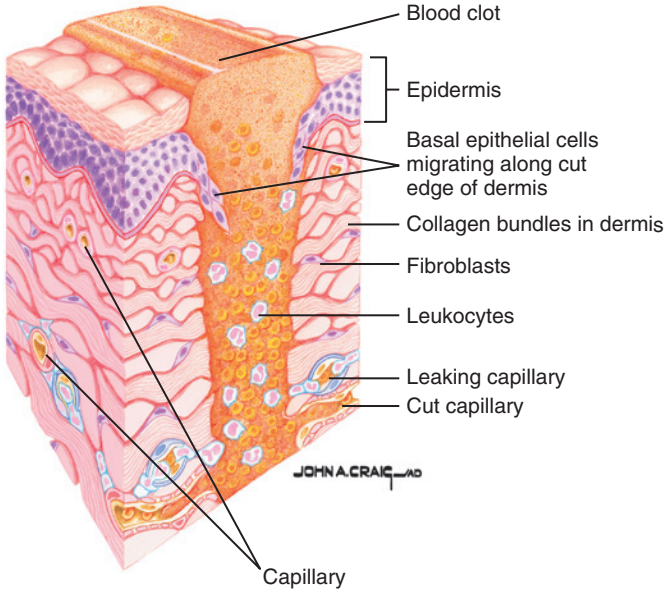
The strands of fibrin, which are derived from blood coagulation, crisscross wounds forming a latticework on which fibroblasts begin laying down ground substance and tropocollagen. This is the fibroplastic stage of wound repair. The ground substance consists of several mucopolysaccharides, which act to cement collagen fibers together. The fibroblasts transform local and circulating pluripotential mesenchymal cells that begin tropocollagen production on the third or fourth day after tissue injury. Fibroblasts also secrete fibronectin, a protein that performs several functions. Fibronectin helps stabilize fibrin, assists in recognizing foreign material that should be removed by the immune system, acts as a chemotactic factor for fibroblasts, and helps guide macrophages along fibrin strands for eventual phagocytosis of fibrin by macrophages.

The fibrin network is also used by new capillaries, which bud from existing vessels along the margins of the wound and run along fibrin strands to cross the wound. As fibroplasia continues, with increasing ingrowth of new cells, fibrinolysis occurs, which is caused by plasmin brought in by the new capillaries to remove the fibrin strands that have become superfluous (Fig. 4.3).

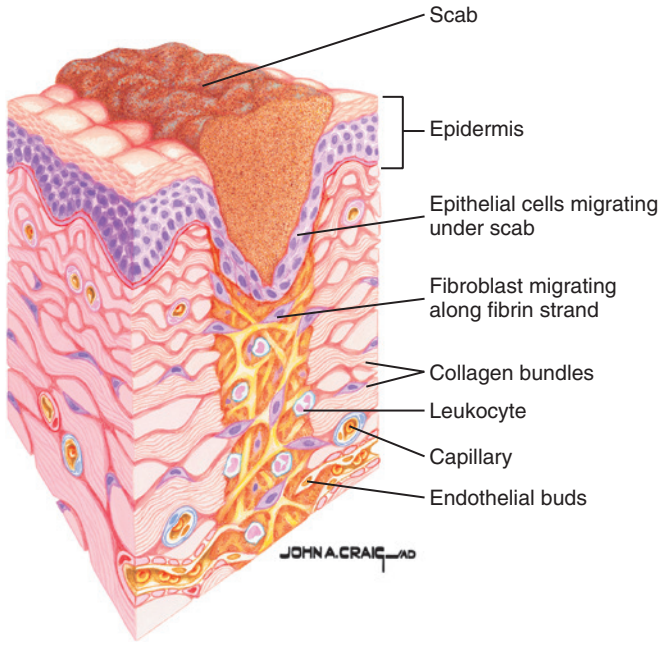
Fibroblasts deposit tropocollagen, which undergoes cross-linking to produce collagen. Initially, collagen is produced in excessive amounts and is laid down in a haphazard manner. The poor orientation of fibers decreases the effectiveness of a given amount of collagen to produce wound strength, so an overabundance of collagen is necessary to strengthen the healing wound early on. Despite the poor organization of collagen, wound strength rapidly increases during the fibroplastic stage, which normally lasts 2 to 3 weeks. If a wound is placed under tension at the beginning of fibroplasia, it tends to pull apart along the initial line of injury. However, if the wound were to be placed under tension near the end of fibroplasia, it would open along the junction between old collagen previously on the edges of the wound and newly deposited collagen. Clinically, the wound at the end of the fibroplastic stage will be stiff because of an excessive amount of collagen, erythematous because of the high degree of vascularization, and able to withstand 70% to 80% as much tension as uninjured tissue (Fig. 4.4).

Remodeling Stage

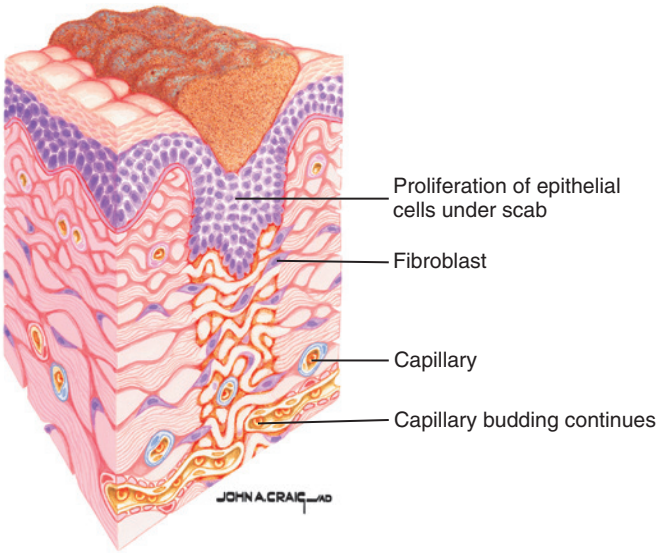
The final stage of wound repair, which continues indefinitely, is known as the *remodeling stage*, although some use the term *wound*



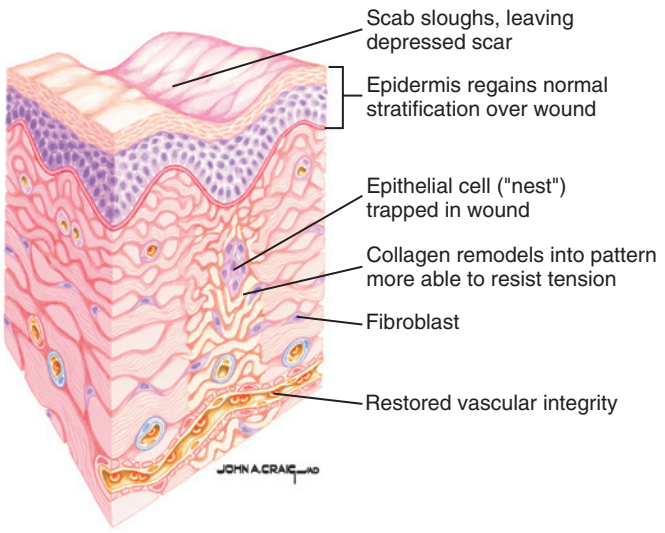
• **Fig. 4.2** Inflammatory (lag) stage of wound repair. Wound fills with clotted blood, inflammatory cells, and plasma. Adjacent epithelium begins to migrate into wound, and undifferentiated mesenchymal cells begin to transform into fibroblasts. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)



• **Fig. 4.3** Migratory phase of fibroplastic stage of wound repair. Continued epithelial migration occurs, leukocytes dispose of foreign and necrotic materials, capillary ingrowth begins, and fibroblasts migrate into wound along fibrin strands. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)



• **Fig. 4.4** Proliferative phase of fibroplastic stage of wound repair. Proliferation increases epithelial thickness, collagen fibers are haphazardly laid down by fibroblasts, and budding capillaries begin to establish contact with their counterparts from other sites in wound. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)



• **Fig. 4.5** Remodeling stage of wound repair. Epithelial stratification is restored, collagen is remodeled into more efficiently organized patterns, fibroblasts slowly disappear, and vascular integrity is reestablished. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)

maturation. During this stage, many of the previous randomly laid collagen fibers are removed as they are replaced by new collagen fibers, which are oriented to better resist tensile forces on the wound. In addition, wound strength increases slowly but not with the same magnitude of increase seen during the fibroplastic stage. Wound strength never reaches more than 80% to 85% of the strength of uninjured tissue. Because of the more efficient orientation of the collagen fibers, fewer of them are necessary; the excess is removed, which allows the scar to soften. As wound metabolism lessens, vascularity is decreased, which diminishes wound erythema. Elastin found in normal skin and ligaments is not replaced during wound healing, so injuries in those tissues cause a loss of flexibility along the scarred area (Fig. 4.5).

A final process, which begins near the end of fibroplasia and continues during the early portion of remodeling, is *wound contraction*. In most cases, wound contraction plays a beneficial role in wound repair, although the exact mechanism that contracts a wound is still unclear. During wound contraction, the edges of a wound migrate toward each other. In a wound in which the edges are not or will not be placed in apposition, wound contraction diminishes the size of the wound. However, contraction can cause problems such as those seen in victims of third-degree (full-thickness) burns of the skin, who develop deforming and debilitating contractures if wounds are not covered with skin grafts and aggressive physical therapy is not performed. Another example of detrimental contraction is seen in individuals suffering sharply curved lacerations, who frequently are left with a mound of tissue on the concave side of the scar because of wound contraction, even when the edges are well readapted. Contraction can be lessened by placement of a layer of epithelium between the free edges of a wound. Surgeons make use of this phenomenon when they place skin grafts on the bared periosteum during a vestibuloplasty or on full-thickness burn wounds.

Surgical Significance of Wound-Healing Concepts

The surgeon can create conditions that augment or impede the natural wound repair process. Adherence to surgical principles (see Chapter 3) facilitates optimal wound healing, with reestablishment of tissue continuity, minimization of scar size, and restoration of function. One should remember that no wound in skin, oral mucosa, or muscle heals without scar formation. The surgeon's goal with respect to scar formation is not to prevent a scar but rather to produce a scar that minimizes any compromise of function and looks as inconspicuous as possible.

Factors That Impair Wound Healing

Four factors can impair wound healing in an otherwise healthy individual: (1) foreign material, (2) necrotic tissue, (3) ischemia, and (4) wound tension.

Foreign Material

Foreign material is everything the host organism's immune system views as "non-self," including bacteria, dirt, and suture material. Foreign materials cause three basic problems. First, bacteria can proliferate and cause an infection in which released bacterial proteins destroy host tissue. Second, nonbacterial foreign material acts as a haven for bacteria by sheltering them from host defenses and thus promoting infection. Third, foreign material is often antigenic and can stimulate a chronic inflammatory reaction that decreases fibroplasia.

Necrotic Tissue

Necrotic tissue in a wound causes two problems. The first is that its presence serves as a barrier to the ingrowth of reparative cells. The inflammatory stage is then prolonged while white blood cells work to remove the necrotic debris through the processes of enzymatic lysis and phagocytosis. The second problem is that, similar to foreign material, necrotic tissue serves as a protected niche for bacteria. Necrotic tissue frequently includes blood that collects in

a wound (hematoma), where it can serve as an excellent nutrient source for bacteria.

Ischemia

Decreased blood supply to a wound interferes with wound repair in several ways. Decreased blood supply can lead to further tissue necrosis and can lessen the delivery to a wound of antibodies, white blood cells, and antibiotics, which thereby increases the chances of wound infection. Wound ischemia decreases the delivery of oxygen and the nutrients necessary for proper healing. Ischemia can be caused by several things, including tight or incorrectly located sutures, improperly designed flaps, excessive external pressure on a wound, internal pressure on a wound (seen, such as with hematomas), systemic hypotension, peripheral vascular disease, and anemia.

Tension

Tension on a wound is the final factor that can impede wound healing. Tension in this case is anything tending to hold wound edges apart. If sutures are used to pull tissues together forcefully, the fine blood vessels in the tissue encompassed by the sutures will be constricted, producing ischemia. If sutures are removed too early in the healing process, the wound under tension will probably reopen and then heal with excessive scar formation and wound contraction. If sutures are left in too long in an attempt to overcome wound tension, the wound will still tend to spread open during the remodeling stage of healing, and the tract into the epithelium through which the sutures ran will epithelialize, leaving permanent, disfiguring marks.

Healing by Primary, Secondary, and Tertiary Intention

Clinicians use the terms *primary intention* and *secondary intention* to describe the two basic methods of wound healing. In healing by primary intention, the edges of a wound in which there is no tissue loss are placed and stabilized in essentially the same anatomic position they held before injury and are allowed to heal. Wound repair then occurs with minimal scar tissue because the tissues would not "perceive" that an injury had occurred. Strictly speaking, healing by primary intention is only a theoretical ideal, impossible to attain clinically; however, the term is generally used to designate wounds in which the edges are closely reapproximated. This method of wound repair lessens the amount of reepithelialization, collagen deposition, contraction, and remodeling needed for healing. Therefore healing occurs more rapidly, with a lower risk of infection, and with less scar formation than in wounds allowed to heal by secondary intention. Examples of wounds that heal by primary intention include well-repaired lacerations or incisions and well-reduced bone fractures. In contrast, healing by secondary intention implies that a gap is left between the edges of an incision or laceration or between bone or nerve ends after repair, or it implies that tissue loss has occurred in a wound that prevents approximation of wound edges. These situations require a large amount of epithelial migration, collagen deposition, contraction, and remodeling during healing. Healing is slower and produces more scar tissue than is the case with healing by primary intention. Examples of wounds that heal by secondary intention include extraction sockets, poorly reduced fractures, deep ulcers, and large avulsive injuries of any soft tissue.

Some surgeons use the term *tertiary intention* to refer to the healing of wounds through the use of tissue grafts to cover large wounds and bridge the gap between wound edges.

Healing of Extraction Sockets

The removal of a tooth initiates the same sequence of inflammation, epithelialization, fibroplasia, and remodeling seen in prototypic skin or mucosal wounds. As previously mentioned, sockets heal by secondary intention, and many months must pass before a socket heals to the degree to which it becomes difficult to distinguish from the surrounding bone when viewed radiographically.

When a tooth is removed, the remaining empty socket consists of cortical bone (the radiographic lamina dura) covered by torn periodontal ligaments, with a rim of oral epithelium (gingiva) left at the coronal portion. The socket fills with blood, which coagulates and seals the socket from the oral environment.

The inflammatory stage occurs during the first week of healing. White blood cells enter the socket to remove contaminating bacteria from the area and begin to break down any debris such as bone fragments that are left in the socket. Fibroplasia also begins during the first week, with the ingrowth of fibroblasts and capillaries. The epithelium migrates down the socket wall until it reaches a level at which it contacts epithelium from the other side of the socket or it encounters the bed of granulation tissue (i.e., tissue filled with numerous immature capillaries and fibroblasts) under the blood clot over which the epithelium can migrate. Finally, during the first week of healing, osteoclasts accumulate along the crestal bone.

The second week is marked by the large amount of granulation tissue that fills the socket. Osteoid deposition has begun along the alveolar bone lining the socket. In smaller sockets, the epithelium may have become fully intact by this point.

The processes begun during the second week continue during the third and fourth weeks of healing, with epithelialization of most sockets complete at this time. The cortical bone continues to be resorbed from the crest and walls of the socket, and new trabecular bone is laid down across the socket. Not until 4 to 6 months after extraction is the cortical bone lining a socket usually fully resorbed; this is recognized radiographically by a loss of a distinct lamina dura. As bone fills the socket, the epithelium moves toward the crest and eventually becomes level with adjacent crestal gingiva. The only visible remnant of the socket after 1 year is the rim of fibrous (scar) tissue that remains on the edentulous alveolar ridge.

Bone Healing

The events that occur during normal wound healing of soft tissue injuries (e.g., inflammation, fibroplasia, and remodeling) also take place during the repair of an injured bone. However, in contrast to soft tissues, osteoblasts and osteoclasts are also involved to reconstitute and remodel the damaged ossified tissue.

Osteogenic cells (osteoblasts) important to bone healing are derived from the following three sources: (1) periosteum, (2) endosteum, and (3) circulating pluripotential mesenchymal cells. Osteoclasts, derived from monocyte precursor cells, function to resorb necrotic bone and bone that needs to be remodeled. Osteoblasts then lay down osteoid, which, if immobile during healing, usually goes on to calcify.

The terms *primary intention* and *secondary intention* are appropriate for descriptions of bone repair. If a bone is fractured* and the free ends of the bone are more than 1 mm or so apart, the bone

*The term *fracture* used with respect to bone repair includes not only traumatically injured bone, but also bone cuts purposely made by a surgeon during reconstructive surgery.

heals by secondary intention; that is, during the fibroplastic stage of healing, a large amount of collagen must be laid down to bridge the bony gap (Fig. 4.6). The fibroblasts and osteoblasts actually produce so much fibrous matrix that the healing tissue extends circumferentially beyond the free ends of the bone and forms what is called a *callus* (Fig. 4.7). Under normal conditions, the fibrous tissue, including the callus, ossifies. During the remodeling stage, bone that was haphazardly produced is resorbed by osteoclasts, and osteoblasts lay down new bone directed to resist low-grade tensions placed on the bone (Fig. 4.8).

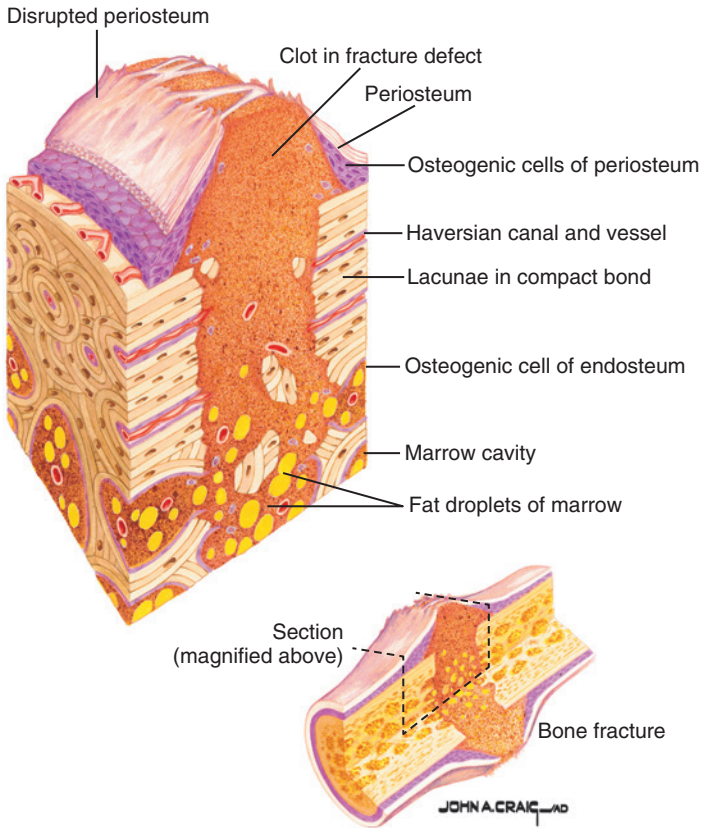
Healing of bone by primary intention occurs when the bone is incompletely fractured so that the fractured ends do not become separated from each other ("greenstick fracture") or when a surgeon closely reapproximates and rigidly stabilizes the fractured ends of a bone (anatomic reduction of the fracture). In both of these situations, little fibrous tissue is produced, and reossification of the tissue within the fracture area occurs quickly, with minimal callus formation. The surgical technique that comes closest to allowing bone to heal by primary intention is anatomic reduction of the application of bone plates that rigidly hold the ends of the bone together. This minimizes the distance between the ends of a fractured bone so that ossification across the fracture gap can occur with little intervening fibrous tissue formation.

Two factors are important to proper bone healing: (1) vascularity and (2) immobility. The fibrous connective tissue that forms in a bony fracture site requires a high degree of vascularity (which carries blood with a normal oxygen content) for eventual ossification. If vascularity or oxygen supplies are sufficiently compromised, cartilage, instead of bone, forms. Furthermore, if vascularity or oxygen supplies are poor, the fibrous tissue does not chondrify or ossify.

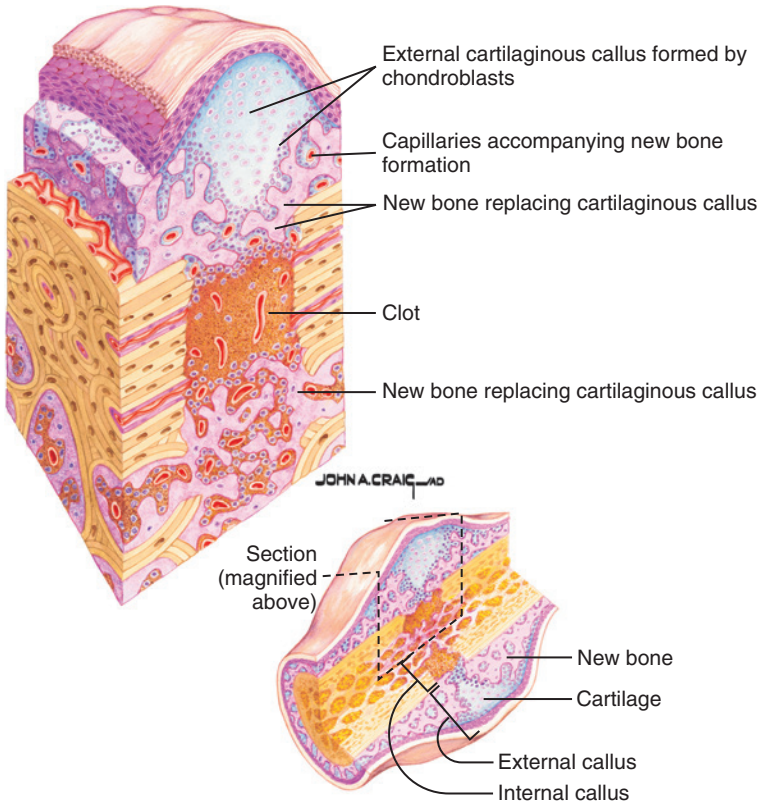
Placing bone under continuous or repeated cycles of some tension stimulates continued osteoblastic bone formation. Bone is formed perpendicular to lines of tension to help withstand the forces placed on it. This is the basis of the functional matrix concept of bone remodeling. However, excessive tension or torque placed on a healing fracture site produces mobility at the site. This mobility compromises vascularity of the wound and favors the formation of cartilage or fibrous tissue, rather than bone along the fracture line; in a contaminated fracture, it promotes wound infection (see Fig. 4.8).

Implant Osseointegration

The discovery of osseointegration in the 1960s forced a reexamination of traditional concepts of wound healing. Before acceptance of these findings it was thought that the body would eventually expel any foreign material placed through an epithelial surface. Expulsion would occur as the epithelium bordering the foreign material migrated down along the interface with the foreign material,



• **Fig. 4.6** Early phase of fibroplastic stage of bone repair. Osteogenic cells from periosteum and marrow proliferate and differentiate into osteoblasts, osteoclasts, and chondroblasts, and capillary budding begins. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)



• **Fig. 4.7** Late phase of fibroplastic stage of bone repair. Osteoclasts resorb necrotic bone. In areas of sufficient oxygen tension, osteoblasts lay down new bone; in areas of low oxygen tension, chondroblasts lay down cartilage. In addition, capillary ingrowth continues and internal and external calluses form. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)

finally fully surrounding the portion of the foreign body protruding into the body and causing the material to be completely external to the epithelial barrier. For a dental implant, this meant eventual loosening and loss of the implant.

The innate tendency of nonmalignant epithelium to surround and externalize foreign material was thought to be the result of the principle of contact inhibition (discussed previously) whereby any epithelial surface disrupted by any force or object triggers epithelial growth and migration. The epithelium continues to spread until it contacts other epithelial cells and is inhibited from further lateral growth. Investigators found that if an inert foreign material was placed through an epithelial barrier and allowed to develop a biologic bond with surrounding bone, epithelial migration down into the bone along the implant surface would be resisted. However, if, instead, the implant had an intervening layer of connective tissue between itself and the bone, epithelium would migrate down the implant, externalizing it. Thus, when an implant integrated with bone (osseointegration), lateral growth of epithelium stopped without contact inhibition, as it was classically conceived to function (Fig. 4.9).

The reasons why epithelium does not continue to migrate when it meets a bone and implant interface are still unclear. Nonetheless, dentistry has used this aberration in normal wound-healing principles to provide integrated metal posts (implants) that are useful to stabilize dental prostheses. Surgeons use similar techniques to place implants through skin in other body sites to stabilize prosthetic ears, eyes, and noses.

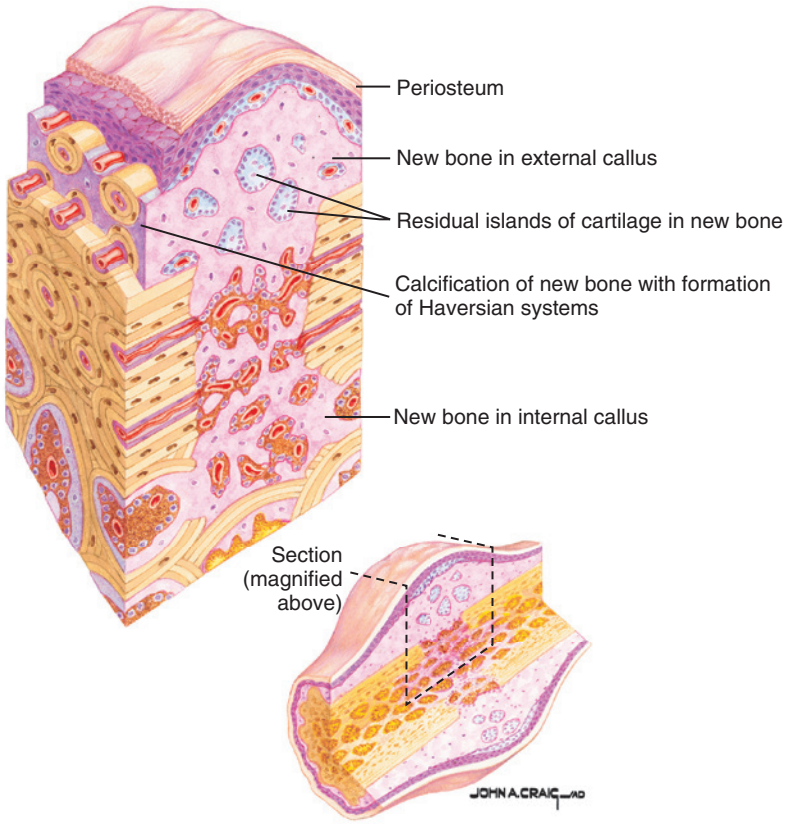
Wound healing around dental implants involves the two basic factors: (1) healing of bone to the implant and (2) healing of alveolar soft tissue to the implant. Dental implants made of pure titanium are used in the discussion of healing around dental implants; similar healing occurs around properly placed implants made of other inert materials.

Bone healing onto the surface of an implant must occur before any soft tissue forms between bone and implant surfaces. Maximizing the likelihood of bone winning this race with soft tissue to cover the implant requires the following four factors: (1) a short distance between bone and the implant, (2) viable bone at or near the surface of bone along the implant, (3) no movement of the implant while bone is attaching to its surface, and (4) an implant surface reasonably free of contamination by organic or inorganic materials.

A short distance between bone and the implant depends on preparing a bony site into which the implant fits precisely. Minimizing bone damage during site preparation preserves the viability of bone near the implant surface. Much of the damage caused by preparing an implant site is the result of heat from friction during the cutting process.

Limiting heat production and rapidly dissipating the heat created at the site help protect the viability of bone along the cut surface. This is accomplished by using sharp bone-cutting instruments, limiting cutting speeds to minimize frictional heat, and by keeping the bone cool with irrigation during site preparation. Additional damage to the cut surface of bone may occur if the site becomes infected. This is addressed to some degree by using aseptic surgical techniques, systemic topical antibiotics, or both.

Keeping forces off the implant prevents movement along the healing bone and implant interface during the critical portion of



• **Fig. 4.8** Remodeling stage of bone repair. Osteoclasts remove unnecessary bone, and osteoblasts lay new bone tissue in response to stresses placed on bone. New haversian systems develop as concentric layers of cortical bone are deposited along blood vessels. Calluses gradually decrease in size. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)

the healing period. Countersinking implants and using low-profile healing screws decrease the ability of any forces to be delivered to the implant. Covering the top of the implant with gingiva during healing further protects it, although some implant protocols do not require gingival coverage. Implants that are threaded or that otherwise fit tightly into the prepared site are better protected from movement than are nonthreaded or loose implants. Eventually, once initial integration has occurred, some limited daily pressure on the implant (1000 μm of strain) will actually hasten cortical bone deposition on the implant surface.

Finally, the surface to which bone is intended to attach must be reasonably free of surface contaminants. Such contaminants including bacteria, oil, glove powder, foreign metals, and foreign proteins should be minimized. The surface of an implant intended to osseointegrate should not be handled with bare or gloved fingers or forceps made of a metal different from the implant and must not have retained machine oil or detergent.

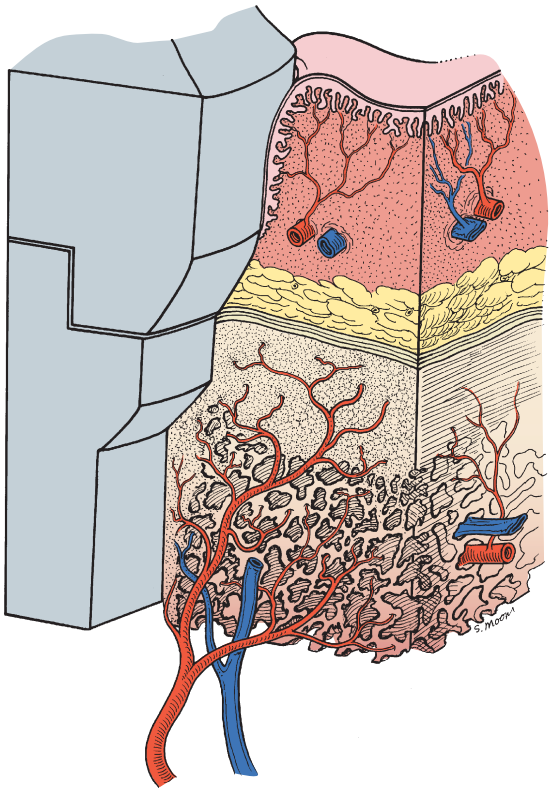
The surface of pure titanium implants is completely covered by a 2000-Å-thick layer of titanium oxide. This stabilizes the surface, and it is to this oxidized surface that bone must attach for osseointegration to occur.

Regardless of how much care is taken to minimize damage to bone during implant site preparation, a superficial layer of bone along the surface of a prepared implant site becomes nonviable as a result of thermal and vascular trauma. Although the living cells in bone die, the inorganic bone structure remains. Under the influence of local growth factors, bone cells directly underlying this bone structure and bloodborne undifferentiated mesenchymal cells repopulate and remodel the bony scaffold with osteoblasts, osteoclasts, and osteocytes. Nonviable bone is slowly replaced by new, viable cortical bone through the process of creeping substitution. Cutting cones move through the bone at a rate of 40 μm per day, removing dead bone and leaving new osteoid.

At the implant surface, glycosaminoglycans secreted by osteocytes coat the oxide layer. Soon, osteoblasts begin to secrete a layer of osteoid over the proteoglycan layer. Bone then forms if proper conditions (e.g., no implant movement and good oxygen supply) continue during the months required for healing. The greater the amount of available implant surface, the greater is the degree of implant osseointegration. Thus longer or wider-diameter implants and those with sandblasted rather than polished surfaces have more surface available for osseointegration.

The initial deposition of bone must occur before epithelium migrates onto or fibrous connective tissue forms on the implant surface. If soft tissue arrives first at any part of the implant surface, bone will never replace the soft tissue at that site. If too much of the implant surface becomes covered with soft tissue rather than bone, the implant will not become sufficiently osseointegrated to use for a dental prosthesis.

Clinicians have found that, in some circumstances, they can selectively aid the bone-forming process in its race to cover a surface before soft tissue fills the site. An example of this is the use of woven membranes that have a pore size adequate to allow oxygen and other nutrients to reach the bone grown beneath the



• **Fig. 4.9** Osseointegrated implant with direct bone and implant contact. Surface epithelium migration along the implant is halted by the direct bone-implant integration.

membrane while keeping fibroblasts and other tissue elements outside the membrane. By selectively excluding soft tissues, bone is "guided" into a desired position; thus *guided tissue regeneration* is the term used to describe this process.

The component of an implant that extends through the oral mucosa also has the ability to alter the contact inhibition process that normally controls closure of openings through epithelium. In this case, once oral epithelium reaches the surface of a titanium abutment, it seems to stop migrating and secretes a ground substance that attaches the soft tissue to the metal. A hemidesmosomal, basal lamina system forms, further strengthening soft tissue attaching to the implant abutment.

Facial Neuropathology of Traumatic Origin

Injuries to sensory nerves of the maxillofacial region occasionally occur as the result of facial fractures, during the treatment of impacted teeth or oral pathologic conditions, or when maxillofacial reconstructive surgery is performed. Fortunately, most injured nerves spontaneously recover. However, in the past, little was done to treat persistent sensory nerve disorders. Advances in the understanding of how nerves heal and in the surgical means of repairing peripheral nerves provide patients with the possibility of partially or fully regaining normal nerve function.

Nerve Healing

Nerve healing usually has two phases: (1) degeneration and (2) regeneration. Two types of degeneration can occur. The first is segmental demyelination, in which the myelin sheath is dissolved in isolated segments. This partial demyelination causes a slowing of conduction velocity and may prevent the transmission of some nerve impulses. Symptoms include *paresthesia* (a spontaneous and subjective altered sensation that a patient does not find painful), *dysesthesia* (a spontaneous and subjective altered sensation that a patient finds uncomfortable), *hyperesthesia* (excessive sensitivity of a nerve to stimulation), and *hypoesthesia* (decreased sensitivity of a nerve to stimulation). Segmental demyelination can occur after neurapraxic injuries or with vascular or connective tissue disorders (see Fig. 4.11) and may undergo spontaneous regeneration.

Wallerian degeneration is the second type of degeneration occurring after nerve trauma. In this process, the axons and myelin sheath of the nerve distal to the site of nerve trunk interruption* (away from the central nervous system [CNS]) undergo disintegration in their entirety. The axons proximal to the site of injury (toward the CNS) also undergo some degeneration, occasionally involving the cell body but generally only affecting a few nodes of Ranvier. Wallerian degeneration stops all nerve conduction distal to the proximal axonal stump. This type of degeneration follows nerve transsection and other destructive processes that affect peripheral nerves (see Fig. 4.10) and is likely to undergo spontaneous regeneration.

Regeneration of a peripheral nerve can begin almost immediately after nerve injury. Normally, the proximal nerve stump sends out a group of new fibers (axonal sprouts or the growth cone) that grow down the remnant Schwann cell tube. Growth progresses at a rate of 1 to 1.5 mm/day and continues until the site innervated by the nerve is reached or nerve regeneration is blocked by interposed fibrous connective tissue and nerve tissue (fibroma) or bone. During regeneration, new myelin sheaths may form as the axons increase in diameter. As functional contacts are made, the patient may experience altered sensations in the previously anesthetic area, which may take the form of paresthesias or dysesthesias.

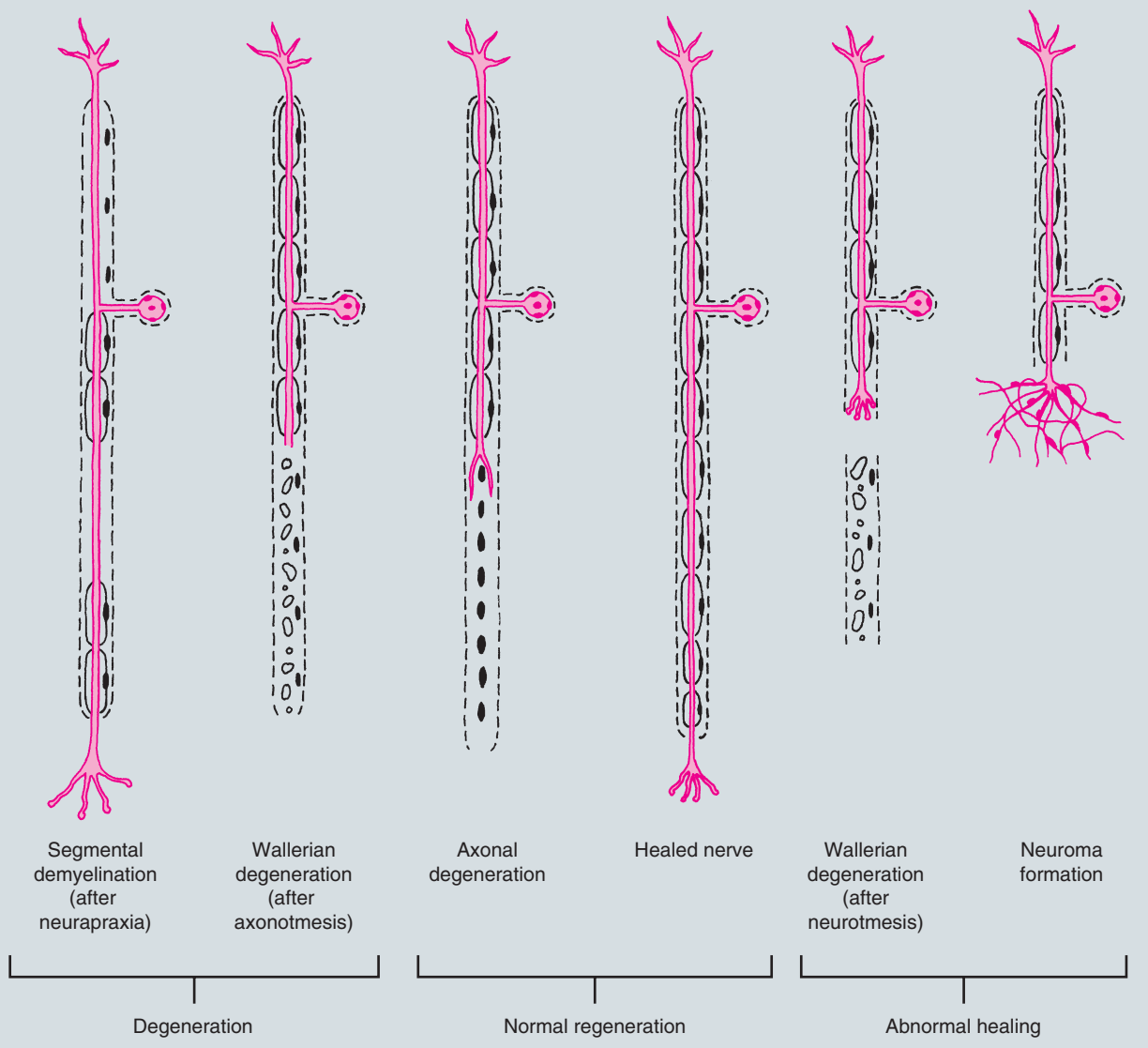
Problems can occur during regeneration that prevent normal nerve healing. If the continuity of the Schwann cell tube is disrupted, connective tissue may enter the tube while it is partially vacant. When the growth cone (axonal sprouts) reaches the connective tissue obstruction, it may find a way around it and continue on, or it may form a mass of aimless nerve fibers that constitutes a traumatic neuroma subject to pain production when disturbed (trigger point) (Fig. 4.10).

The two branches of the trigeminal nerve injured most commonly, for which the altered sensation is clinically significant, are (1) the inferior alveolar-mental nerve and (2) the lingual nerve. When the inferior alveolar-mental nerve is injured, the usual causes are the following:

1. Mandibular (body) and angle fractures
2. Preprosthetic surgical procedures including implant placement
3. Sagittal split osteotomy surgery
4. Mandibular resection for oral neoplasms
5. Removal of impacted lower third molars
6. Local anesthetic injection

Lingual nerve damage occurs in the course of surgery to remove oral malignancies or impacted third molars.

*The terms *distal* and *proximal* used in the description of nerves and bones refer to positions farthest away from (i.e., distal) or nearest to (i.e., proximal) the central nervous system. In this case, distal is not used in the same sense as is common when referring to teeth and the dental arch.



• **Fig. 4.10** Normal and abnormal peripheral nerve responses to injury.

Classification

Research and clinical experience have shown that surgical intervention to repair damaged nerves is more successful when performed soon after the injury has occurred. Thus an understanding of the various types of nerve damage, especially their prognoses, is important because it enables the clinician to decide when referral for peripheral nerve surgery is warranted.

The three types of nerve injuries are (1) neurapraxia, (2) axonotmesis, and (3) neurotmesis (Fig. 4.11). Although a determination as to which type of nerve damage has occurred is usually made retrospectively, knowledge of the pathophysiology of each type is important for gaining an appreciation of nerve healing.

Neurapraxia, the least severe form of peripheral nerve injury, is a contusion of a nerve in which continuity of the epineural sheath and the axons is maintained. Blunt trauma or traction (i.e., stretching) of a nerve, inflammation around a nerve, or local ischemia of a nerve can produce neurapraxia. Because there has been no loss in axonal continuity, spontaneous full recovery of nerve function usually occurs in a few days or weeks.

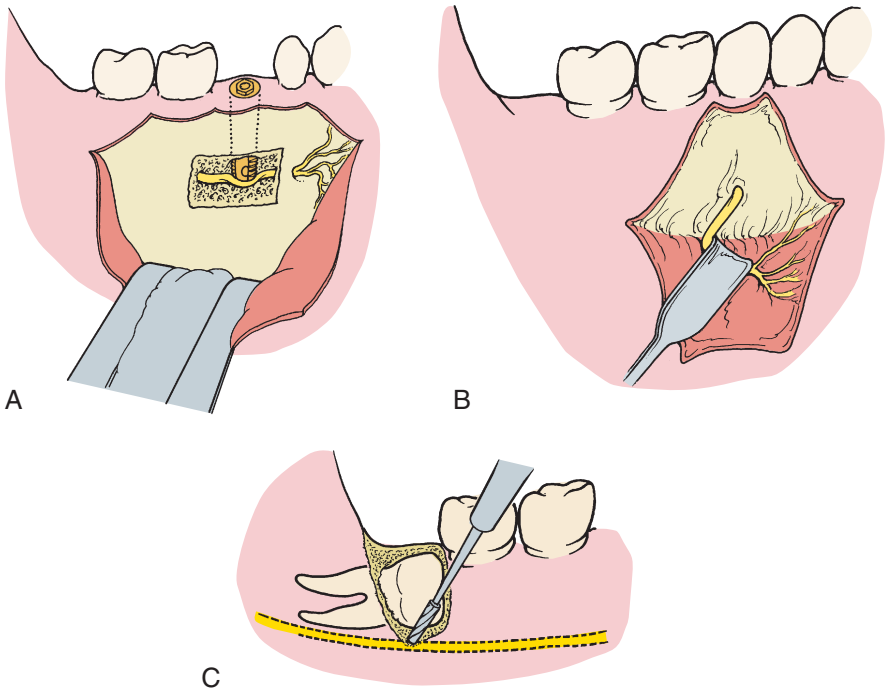
Axonotmesis has occurred when the continuity of the axons, but not the epineural sheath, is disrupted. Severe blunt trauma, nerve crushing, or extreme traction of a nerve can produce this type of injury. Because the epineural sheath is still intact, axonal regeneration can (but does not always) occur with a resolution of nerve dysfunction in 2 to 6 months.

Neurotmesis, the most severe type of nerve injury, involves a complete loss of nerve continuity. This form of damage can be produced by badly displaced fractures, severance by bullets or knives during an assault, or by iatrogenic transection. Prognosis for spontaneous recovery of nerves that have undergone neurotmesis is poor, except if the ends of the affected nerve have somehow been left in approximation and properly oriented.

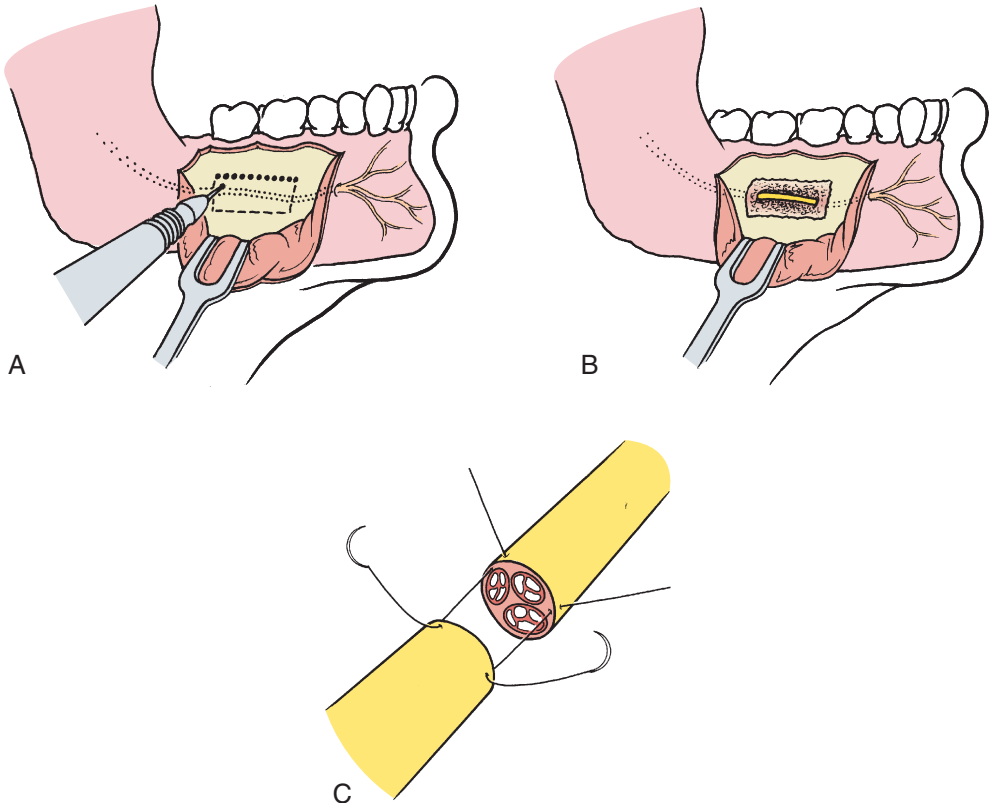
Other classification systems for nerve injuries exist, including Sunderland grading (I to V) and the Medical Research Council Scale; these allow ongoing assessment of nerve regeneration and serve as a way to facilitate communications between clinicians and researchers.

Nerve Repair

When there is a lack of spontaneous neurosensory regeneration due to neuroma formation, microneurosurgery may be required to achieve functional sensory recovery (Fig. 4.12). For an inferior



• **Fig. 4.11** Three types of peripheral nerve injury. (A) Neurapraxia. Injury to the nerve causes no loss of continuity of the axon or the endoneurium. The example shown is an implant placed in the inferior alveolar canal, compressing the nerve. (B) Axonotmesis. Injury to the nerve causes loss of axonal continuity but preserves the endoneurium. The example shown is overly aggressive retraction of mental nerve. (C) Neurotmesis. Injury to the nerve causes loss of axonal and endoneurium continuity. The example shows cutting of the inferior alveolar nerve during the removal of a deeply impacted third molar.



• **Fig. 4.12** (A) Example of intraoral approach to inferior alveolar nerve for microneurosurgery. The area over the portion of the nerve to be exposed is scored to allow the overlying bone to be removed. (B) Exposed nerve ready for surgical repair. (C) Epineural repair of sectioned nerve trunk. Epineurial sutures are being placed to reestablish the continuity of the epineurium. This type of repair is used for a recently severed nerve or after resection of a neuroma.

alveolar nerve injury, access must be obtained via a bony osteotomy (see Fig. 4.12A). This approach may provide a decompression of the nerve and allow inspection for a neuroma that may require resection (see Fig. 4.12B). If a neuroma is identified, microneurosurgery is performed to resect the neuroma. The nerve ends are then repaired with very fine epineurial sutures (see Fig. 4.12C). If repair is not possible without tension, then a nerve graft (autogenous or allogeneic) may be required in the gap between the nerve ends. Finally, in some cases in patients with dysesthesia, systemic medications (e.g., γ-aminobutyric acid agonists) may also be required to control unpleasant neuropathic symptoms.

5

Infection Control in Surgical Practice

JAMES R. HUPP

CHAPTER OUTLINE

It would be difficult for a person living in a modern society to have avoided learning the current concepts of personal and public hygiene. Personal cleanliness and public sanitation have been ingrained in the culture of civilized societies through parental and public education and are reinforced by government regulations and media advertising. This awareness contrasts starkly with earlier centuries, when the importance of hygienic measures for the control of infectious diseases was not widely appreciated. The monumental work of Semmelweis, Koch, and Lister led to enlightenment about asepsis so that today the need for the use of aseptic techniques seems instinctive.

Health care professionals must learn and practice protocols that limit the spread of contagions in the patient care setting. This is especially true for dentists performing surgery for two reasons: First, to perform surgery, the dentist typically violates an epithelial surface, the most important barrier against infection. Second, during most oral surgical procedures, the dentist, assistants, and equipment become contaminated with the patient's blood and saliva.

Communicable Pathogenic Organisms

Two of the most important pieces of knowledge in any conflict are the identity of your foe and their strengths and weaknesses. In the case of oral surgery, the opposition includes virulent bacteria, mycobacteria, fungi, and viruses. The strengths of the opposition are the various means that organisms use to prevent their elimination, whereas their weaknesses are their susceptibilities to chemical, biologic, and physical agents. By understanding the "enemy," the dentist can make rational decisions about infection control.

Bacteria

Upper Respiratory Tract Flora

Normal oral flora contains the microorganisms usually present in saliva and on the surfaces of oral tissues in healthy, immunocompetent individuals who have not been exposed to agents that alter the composition of oral organisms. A complete description of this flora can be found in Chapter 16. In brief, normal oral flora consists of aerobic, gram-positive cocci (primarily streptococci), actinomycetes, anaerobic bacteria, and candidal species (Table 5.1). The total number of oral organisms is held in check by the following four main processes: (1) rapid epithelial turnover with desquamation; (2) host immunologic factors such as salivary immunoglobulin A; (3) dilution by salivary flow; and (4) competition between oral organisms for available nutrients and attachment sites. Any agent—physical, biologic, or chemical—that alters any of the forces that keep oral microbes under control will permit potentially pathologic organisms to overgrow and set the stage for a wound infection.

The flora of the nose and paranasal sinuses consists primarily of gram-positive aerobic streptococci and anaerobes. In addition, many children harbor *Haemophilus influenzae* bacteria in these areas, and many adults have *Staphylococcus aureus* as a part of their transient or resident nasal and paranasal sinus flora. The normal flora in this region of the body is limited by the presence of ciliated respiratory epithelium, secretory immunoglobulins, and epithelial desquamation. The epithelial cilia move organisms trapped in blankets of mucus into the alimentary tract.

TABLE 5.1 Normal Microbiologic Flora

Region	Bacteria
Oral cavity	Aerobic gram-positive organisms, primarily *Streptococcus* spp., *Actinomyces* spp. Anaerobic bacteria, including *Prevotella melaninogenica* *Candida* spp.
Nasal cavity	Aerobic gram-positive organisms, primarily *Streptococcus* spp. In children, *Haemophilus influenzae* frequently present In adults, *Staphylococcus aureus* frequently present
Facial skin	*Staphylococcus* spp., primarily *S. epidermidis*, occasionally *S. aureus* *Corynebacterium diphtheriae* *Propionibacterium acnes*
All areas below clavicles, including hands	*S. epidermidis* *C. diphtheriae* Gram-negative aerobes such as *Escherichia coli*, *Klebsiella* spp., and *Proteus* spp. Anaerobic enteric organisms, including *Bacteroides fragilis*

Maxillofacial Skin Flora

The skin of the maxillofacial region has surprisingly few resident organisms in its normal flora. The bacteria *Staphylococcus epidermidis* and *Corynebacterium diphtheriae* are the predominant species present. *Propionibacterium acnes* is found in pores and hair follicles, and many individuals carry *S. aureus*, spread from the nose on the facial skin (see Table 5.1).

Skin has several means of preventing the entry of surface organisms. The most superficial layer of skin is composed of keratinized epithelial cells that are able to resist mild trauma. In addition, epithelial cells are joined by tight bonds that resist bacterial entrance.

Processes that alter skin flora are, for example, the application of occlusive dressings (which prevent skin desiccation and desquamation), dirt or dried blood (which provide increased nutrients and niches for organisms), and antimicrobial agents (which disturb the balance between various organisms).

Nonmaxillofacial Flora

The flora below the region of the clavicles make up a gradually increasing number of aerobic gram-negative and anaerobic enteric organisms, especially moving toward the pelvic region and unwashed fingertips. General knowledge of these bacteria is important for dental surgeons when preparing themselves for surgery and when treating patients requiring venipuncture or other procedures away from the orofacial region.

Viral Organisms

Viruses are ubiquitous in the environment, but, fortunately, only a few pose a serious threat to the patient and the surgical team. The viral organisms that cause the most difficulty are the hepatitis B and C viruses and human immunodeficiency virus (HIV). These viruses have differences in their susceptibility to inactivation that are important to understand when attempting to prevent their spread. Each virus is described with respect to hardiness and usual mode of transmission. In addition, the circumstances in which the clinician might suspect that an individual is carrying one of these viruses are briefly described, allowing the surgical team to take necessary precautions, although always taking universal precautions is the best practice strategy, as is discussed later in this chapter.

Hepatitis Viruses

Hepatitis A, B, C, and D viruses are responsible for most infectious hepatic diseases. Hepatitis A is spread primarily by contact with the feces of infected individuals. Hepatitis C virus may spread through contaminated feces or by contaminated blood. Hepatitis B and D viruses are spread by contact with any human secretion.

Hepatitis B virus has the most serious risk of transmission for unvaccinated dentists, their staff members, and their patients. This virus is usually transmitted by the introduction of infected blood into the bloodstream of a susceptible person; however, infected individuals may also secrete large numbers of the virus in their saliva, which can enter an individual through any moist mucosal surface or epithelial (skin or mucosal) wound. Minute quantities of the virus have been found capable of transmitting disease (only 105 to 107 virions/mL blood). Unlike most viruses, hepatitis B virus is exceptionally resistant to desiccation and chemical disinfectants, including alcohols, phenols, and quaternary ammonium compounds. Therefore hepatitis B virus is difficult to contain, particularly when oral surgery is being performed.

Fortunately, means of inactivating the hepatitis B virus include halogen-containing disinfectants (e.g., iodophor and hypochlorite), formaldehyde, ethylene oxide gas, all types of properly performed heat sterilization, and irradiation. These methods can be used to minimize the spread of hepatitis from one patient to another.

In addition to preventing patient-to-patient spread, the dentist and the staff also need to take precautions to protect themselves from contamination because in several instances, dentists have been the primary source of a hepatitis B epidemic. Dentists who perform oral surgical procedures are exposed to blood and saliva; therefore the dental surgery team should wear barriers to protect against contaminating any open wounds on the hands and any exposed mucosal surfaces. This includes wearing gloves, a facemask, hair coverage, and eyeglasses or goggles during surgery. During operative procedures the patient should also wear protective eyewear. The dental staff should continue to wear these protective devices when cleaning instruments and when handling impressions, casts, or specimens from patients. A common means of hepatitis inoculation is injury with a needle or blade that is contaminated with blood or saliva, so proper handling of sharp objects is important. In addition, members of the dental staff should receive hepatitis B vaccinations, which have been shown to effectively reduce an individual's susceptibility to hepatitis B infection, although the longevity of protection has not been definitively determined. Finally, office-cleaning personnel and commercial laboratory technicians can be protected by proper segregation and labeling of contaminated objects and by proper disposal of sharp objects (Box 5.1).

Recognition of all individuals known to be carriers of hepatitis B and C viruses would aid in knowing when special precautions are necessary. However, only about half of the persons infected with hepatitis ever have clinical signs and symptoms of the infection, and some individuals who have completely recovered from the disease still shed intact virus particles in their secretions. The concept of universal precautions was developed to address the inability of health care providers specifically to identify all patients with

• BOX 5.1 Methods Designed to Limit the Spread of Hepatitis Viruses

From Infected Patient to Other Patients

- Use disposable materials.
- Disinfect surfaces.
  - A. With halogen compounds:
    1. Iodophors
    2. Hypochlorite (bleach)
  - B. With aldehydes:
    1. Formaldehyde
    2. Glutaraldehyde
- Sterilize reusable instruments.
  - A. With heat
  - B. With ethylene oxide gas
- Use disposable materials.

From Infected Patient to Dental Staff

- Learn to recognize individuals likely to be carriers.
- Use barrier techniques (e.g., gloves, facemask, and eye protection) during surgery, when handling contaminated objects, and during cleanup.
- Promptly dispose of sharp objects into well-labeled protective containers.
- Dispose of needles immediately after use or resheathe in-use instruments.
- Use an instrument to place a scalpel blade on or take one off of a blade handle.
- Ensure hepatitis B vaccination of dental staff.

communicable diseases. The theory on which the universal precautions concept is based is that protection of self, staff, and patients from contamination by using barrier techniques when treating all patients as if they all had a communicable disease ensures that everyone is protected from those who do have an unrecognized contagious process.

Universal precautions typically include having all doctors and staff who come in contact with patient blood or secretions, whether directly or in aerosol form, wear barrier devices, including a facemask, hair coverage, eye protection, and gloves. Universal precaution procedures go on to include decontaminating or disposing of all surfaces that are exposed to patient blood, tissue, and secretions. Finally, universal precautions mandate avoidance of touching, and thereby contaminating, surfaces (e.g., the dental record, computer keyboard, uncovered light handles, and telephone) with contaminated gloves or instruments.

Human Immunodeficiency Virus

Because of its relative inability to survive outside the host organism, HIV (the causative agent of acquired immunodeficiency syndrome), acts in a fashion similar to other agents of sexually transmitted diseases. That is, transfer of the virions from one individual to another requires direct contact between virus-laden blood or secretions from the infected host organism and a mucosal surface or epithelial wound of the potential host. Evidence has shown that HIV loses its infectivity once desiccated. In addition, few persons carrying HIV secrete the virus in their saliva, and those who do, tend to secrete extremely small amounts. No epidemiologic evidence supports the possibility of HIV infection via saliva alone. Even the blood of patients who are HIV-positive has low concentrations of infectious particles (106 particles/mL compared with 1013 particles/mL in hepatitis patients). This probably explains why professionals who are not in any of the known high-risk groups for HIV positivity have an extremely low probability of contracting it, even when exposed to the blood and secretions of large numbers of patients who are HIV positive during the performance of surgery or if accidentally autoinoculated with contaminated blood or secretions. Nevertheless, until the transmission of HIV becomes fully understood, prudent surgeons will take steps to prevent the spread of infection from the HIV-carrying patient to themselves and their assistants through the use of universal precautions, including barrier techniques.

In general, the universal precautions used for bacterial, mycotic, and other viral processes protect the dentist, office staff, and other patients from the spread of the virus that causes acquired immunodeficiency syndrome (see Box 5.1). Also important is that patients with depressed immune function be afforded extra care to prevent the spread of contagions to them. Thus all patients infected with HIV who have $CD4^+$ T lymphocyte counts of less than 200/μL or category B or C HIV infection should be treated by doctors and staff free of clinically evident infectious diseases. These patients should not be put in a circumstance in which they are forced to be closely exposed to patients with clinically apparent symptoms of a communicable disease.

Mycobacterial Organisms

The only mycobacterial organism of significance to most dentists is *Mycobacterium tuberculosis*. Although tuberculosis (TB) is an uncommon disease in the United States and Canada, the frequent movement of persons between countries, including those where TB is common, continues to spread *M. tuberculosis* organisms worldwide, including to all parts of North America. In addition, some newer strains of *M. tuberculosis* have become resistant to the drugs historically used to treat TB. Therefore it is important that measures be followed to prevent the spread of TB from patients to the dental team. This should include TB skin testing of doctors and staff members.

TB is transmitted primarily through exhaled aerosols that carry *M. tuberculosis* bacilli from the infected lungs of one individual to the lungs of another individual. Droplets are produced by those with untreated TB during breathing, coughing, sneezing, and speaking. *M. tuberculosis* is not a highly contagious microorganism. However, transmission can also occur via inadequately sterilized instruments because, although *M. tuberculosis* organisms do not form spores, they are highly resistant to desiccation and to most chemical disinfectants. To prevent transmission of TB from an infected individual to the dental staff, the staff should wear facemasks (specifically, surgical N95 respirator masks) whenever treating or in close contact with these patients. The organisms are sensitive to heat, ethylene oxide, and irradiation; therefore to prevent their spread from patient to patient, all reusable instruments and supplies should be sterilized with heat or ethylene oxide gas. When safe to do so, patients with untreated TB should have their surgery postponed until they can begin treatment for TB.

Aseptic Techniques

Terminology

Different terms are used to describe various means of preventing infection. However, despite their differing definitions, terms such as *disinfection* and *sterilization* are often used interchangeably. This can lead to the misconception that a certain technique or chemical has sterilized an object, when it has merely reduced the level of contamination. Therefore the dental team must be aware of the

precise definition of words used for the various techniques of asepsis.

Sepsis is the breakdown of living tissue by the action of microorganisms and is usually accompanied by inflammation. Thus the mere presence of microorganisms, as in bacteremia, does not constitute a septic state. *Medical asepsis* is the attempt to keep patients, health care staff, and objects as free as possible of agents that cause infection. *Surgical asepsis* is the attempt to prevent microbes from gaining access to surgically created wounds.

Antiseptic and *disinfectant* are terms that are often misused. Both refer to substances that can prevent the multiplication of organisms capable of causing infection. The difference is that antiseptics are applied to living tissue, whereas disinfectants are designed only for use on inanimate objects.

Sterility is the freedom from viable forms of microorganisms. Sterility represents an absolute state; there are no degrees of sterility. *Sanitization* is the reduction of the number of viable microorganisms to levels judged safe by public health standards. Sanitization should not be confused with sterilization. *Decontamination* is similar to sanitization, except that it is not connected with public health standards.

Concepts

Chemical and physical agents are the two principal means of reducing the number of microbes on a surface. Antiseptics, disinfectants, and ethylene oxide gas are the major chemical means of killing microorganisms on surfaces. Heat, irradiation, and mechanical dislodgment are the primary physical means of eliminating viable organisms (Box 5.2).

The microbes that cause human disease include bacteria, viruses, mycobacteria, parasites, and fungi. The microbes within these groups have variable ability to resist chemical or physical agents. The microorganisms most resistant to elimination are bacterial endospores. Therefore, in general, any method of sterilization or disinfection that kills endospores is also capable of eliminating bacteria, viruses, mycobacteria, fungi, mold, and parasites. This concept is used in monitoring the success of disinfection and sterilization techniques.

Techniques of Instrument Sterilization

Any means of instrument sterilization to be used in office-based dental and surgical care must be reliable, practical, and safe for the instruments. The three methods generally available for instrument sterilization are dry heat, moist heat, and ethylene oxide gas.

• BOX 5.2 General Methods of Reducing the Number of Viable Organisms From a Surface

Physical
- Heat
- Mechanical dislodgment
- Radiation

Chemical
- Antiseptics
- Disinfectants
- Ethylene oxide gas

Sterilization With Heat

Heat is one of the oldest means of destroying microorganisms. Pasteur used heat to reduce the number of pathogens in liquids for preservation. Koch was the first to use heat for sterilization. He found that 1.5 hours of dry heat at 100°C would destroy all vegetative bacteria but that 3 hours of dry heat at 140°C was necessary to eliminate the spores of anthrax bacilli. Koch then tested moist heat and found it a more efficient means of heat sterilization because it reduces the temperature and time necessary to kill spores. Moist heat is probably more effective because dry heat oxidizes cell proteins, a process requiring extremely high temperatures, whereas moist heat causes destructive protein coagulation quickly at relatively low temperatures.

Because spores are the most resistant forms of microbial life, they are used to monitor sterilization techniques. The spore of the bacterium *Bacillus stearothermophilus* is extremely resistant to heat and is therefore used to test the reliability of heat sterilization. These bacilli can be purchased by hospitals, dental schools, and private offices and run through the sterilizer with the instruments being sterilized. A laboratory then places the heat-treated spores into culture. If no growth occurs, the sterilization procedure is considered successful.

It has been shown that 6 months after sterilization, the possibility of organisms entering sterilization bags increases, although some individuals think that an even longer period is acceptable as long as the bags are properly handled. Therefore all sterilized items should be labeled with an expiration date that is no longer than 6 to 12 months in the future (Fig. 5.1).

A useful alternative technique for sterilely storing surgical instruments is to place them into cassettes that are double wrapped in specifically designed paper and sterilized as a set for use on a single patient.

Dry Heat

Dry heat is a method of sterilization that can be provided in most dental offices because the necessary equipment is no more complicated than a thermostatically controlled oven and a timer. Dry heat is most commonly used to sterilize glassware and bulky items that can withstand heat but are susceptible to rust. The success of sterilization depends not only on attaining a certain temperature but also on maintaining the temperature for a sufficient time. Therefore the following three factors must be considered when using dry heat: (1) warmup time for the oven and the materials to be sterilized, (2) heat conductivity of the materials, and (3) air flow throughout the oven and through the objects being sterilized. In addition, time for the sterilized equipment to cool after heating must be taken into consideration. The time necessary for dry heat sterilization limits its practicality in the ambulatory setting because it lengthens the turnover time and forces the dentist to have many duplicate instruments.

The advantages of dry heat are the relative ease of use and the unlikelihood of damaging heat-resistant instruments. The disadvantages are the time required to achieve sterilization and the potential damage to heat-sensitive equipment. Guidelines for the use of dry heat sterilization are provided in Table 5.2.

Moist Heat

Moist heat sterilization is more efficient than dry heat sterilization because it is effective at much lower temperatures and requires less time. The reason for this is based on several physical principles. First, water boiling at 100°C takes less time to kill organisms than

• **Fig. 5.1** Tests of sterilization equipment. Color-coded packaging is made of paper and cellophane; test areas on package change color on exposure to sterilizing temperatures or to ethylene oxide gas (top and center). Vial contains spores of *Bacillus stearothermophilus*, which is used for testing efficiency of heat sterilization equipment (bottom).

TABLE 5.2 Guidelines for Dry Heat and Steam Sterilization

Temperature	Duration of Treatment or Exposure[a]
Dry Heat	
121°C (250°F)	6–12 h
140°C (285°F)	3 h
150°C (300°F)	2.5 h
160°C (320°F)	2 h
170°C (340°F)	1 h
Steam	
116°C (240°F)	60 min
118°C (245°F)	36 min
121°C (250°F)	24 min
125°C (257°F)	16 min
132°C (270°F)	4 min
138°C (280°F)	1.5 min

[a]Times for dry heat treatments do not begin until temperature of oven reaches goal. Use spore tests weekly to judge effectiveness of sterilization technique and equipment. Use temperature-sensitive monitors each time equipment is used to indicate that sterilization cycle was initiated.

does dry heat at the same temperature because water is better than air at transferring heat. Second, it takes approximately seven times as much heat to convert boiling water to steam as it takes to cause the same amount of room temperature water to boil. When steam comes into contact with an object, the steam condenses and almost instantly releases that stored heat energy, which quickly denatures vital cell proteins. Saturated steam placed under pressure (autoclaving) is even more efficient than nonpressurized steam. This is because increasing pressure in a container of steam increases the boiling point of water so that the new steam entering a closed container gradually becomes hotter. Temperatures attainable by steam under pressure include 109°C at 5 psi, 115°C at 10 psi, 121°C at 15 psi, and 126°C at 20 psi (see Table 5.2).

The container usually used for providing steam under pressure is known as an autoclave (Fig. 5.2). The autoclave works by creating steam and then, through a series of valves, increases the pressure so that the steam becomes super-heated. Instruments placed into an autoclave should be packaged to allow the free flow of steam around the instruments, such as by placing them in sterilization pouches or wrapping them in cotton cloth.

Simply placing instruments in boiling water or free-flowing steam results in disinfection rather than sterilization because at the temperature of 100°C, many spores and certain viruses survive.

The advantages of sterilization with moist heat are its effectiveness, speed, and the relative availability of office-proportioned autoclaving equipment. Disadvantages include the tendency of moist heat to dull and rust instruments and the cost of autoclaves (Table 5.3).

Sterilization With Gas

Certain gases exert a lethal action on bacteria by destroying enzymes and other vital biochemical structures. Of the several gases available for sterilization, ethylene oxide is the most commonly used. Ethylene oxide is a highly flammable gas, so it is mixed with carbon dioxide or nitrogen to make it safer to use. Ethylene oxide is a gas at room temperature and can readily diffuse through porous materials such as plastic and rubber. At 50°C ethylene oxide is effective for killing all organisms, including spores, within 3 hours. However, because it is highly toxic to animal tissue, equipment exposed to ethylene oxide must be aerated for 8 to 12 hours at 50°C to 60°C or at ambient temperatures for 4 to 7 days.

The advantages of ethylene oxide for sterilization are its effectiveness for sterilizing porous materials, large equipment, and materials sensitive to heat or moisture. The disadvantages are the need for special equipment and the length of sterilization and aeration time necessary to reduce tissue toxicity. This technique is rarely practical for dental use unless the dentist has easy access to a large facility willing to gas sterilize dental equipment (e.g., hospital or ambulatory surgery center).

• **Fig. 5.2** Office-proportioned autoclave (Lisa Sterilizer—a steam heat example) can be a steam or dry heat sterilizer. (Courtesy A-dec, Inc., Newberg, OR.)

TABLE 5.3 Comparison of Dry Heat Sterilization vs. Moist Heat Sterilization Techniques

	Dry Heat	Moist Heat
Principal antimicrobial effect	Oxidizes cell proteins	Denatures cell proteins
Time necessary to achieve sterilization	Long	Short
Equipment complexity and cost	Low	High
Tendency to dull or rust instruments	Low	High
Availability of equipment sized for office use	Good	Good

Techniques of Instrument Disinfection

Many dental instruments cannot withstand the temperatures required for heat sterilization. Therefore if sterilization with gas is not available and absolute sterility is not required, chemical disinfection can be performed. Chemical agents with potential disinfectant capabilities have been classified as being high, intermediate, or low in biocidal activity. The classification is based on the ability of the agent to inactivate vegetative bacteria, tubercle bacilli, bacterial spores, nonlipid viruses, and lipid viruses. Agents with low biocidal activity are effective only against vegetative bacteria and lipid viruses, intermediate disinfectants are effective against all microbes except bacterial spores, and agents with high activity are biocidal for all microbes. The classification depends not only on innate properties of the chemical but also, and just as importantly, on *how* the chemical is used (Table 5.4).

Substances acceptable for disinfecting dental instruments for surgery include glutaraldehyde, iodophors, chlorine compounds, and formaldehyde; glutaraldehyde-containing compounds are the most commonly used. Table 5.5 summarizes the biocidal activity of most of the acceptable disinfecting agents when used properly. Alcohols are not suitable for general dental disinfection because they evaporate too rapidly; however, they can be used to disinfect local anesthetic cartridges.

Quaternary ammonium compounds are not recommended for dentistry because they are not effective against the hepatitis B virus and become inactivated by soap and anionic agents.

Certain procedures must be followed to ensure maximal disinfection, regardless of which disinfectant solution is used. The agent must be properly reformulated and discarded periodically, as specified by the manufacturer. Instruments must remain in contact with the solution for the designated period, and no new contaminated instruments should be added to the solution during that time. All instruments must be washed free of blood or other visible material before being placed in the solution. Finally, after disinfection, the instruments must be rinsed free of chemicals and used within a short time.

An outline of the preferred method of sterilization for selected dental instruments is presented in Table 5.6.

TABLE 5.4 Classification System for the Biocidal Effects of Chemical Disinfectants

Level of Biocidal Activity[a]	Vegetative Bacteria	Lipid Viruses	Nonlipid Viruses	Tubercle Bacilli	Bacterial Spores
Low	+	+	–	–	–
Intermediate	+	+	+	+	
High	+	+	+	+	+

[a]In the absence of gross organic materials on surfaces being disinfected.

TABLE 5.5 Biocidal Activity of Various Chemical Disinfectants

Generic	Brand Names	Exposure Time	ACTIVITY LEVEL[a] Intermediate	High
Formaldehyde 3%				
8% or		≥30 min	+	
8% in 70% alcohol		10 h		
Glutaraldehyde 2% with nonionic ethoxylates of linear alcohol	Wavicide, Sterall			
Room temperature		≥10 min	+	
40°C–45°C		4 h		+
60°C		4 h		+
Glutaraldehyde 2% alkaline with phenolics buffer	Sporicidin			
Diluted 1:6		≥10 min	+	
Full strength		7 h		+
Glutaraldehyde 2% alkaline	Cidex, Procide, Glutarex, Omnicide	≥10 min	+	
		10 h		+
1% Chlorine compound, diluted 1:5	Clorox	≥30 min	+	
O-phenylphenol 9% plus O-benzyl-p-chlorophenol 1%, diluted 1:32	Omni II	≥10 min	+	
Iodophors 1% iodine	Betadine, Isodine	≥30 min	+	

[a]Grossly visible contamination such as blood must be removed before chemical disinfection to maximize biocidal activity.

TABLE 5.6 Methods of Sterilization or Disinfection of Selected Dental Instruments

Items	Steam Autoclave (15–30 Min Required per Cycle)	CHEMICAL DISINFECTION Dry Heat Oven (1–1.5 Hours Required per Cycle)	Sterilization[a]
Stainless instruments (loose) restorative burs	++	++	–
Instruments in packs	++	+ (Small packs)	–
Instrument tray setups, surgical or restorative	+ (Size limit)	++	–
Rust-prone instruments	(Only when coated with chemical protectant)	++	
Handpiece (autoclave)	++	–	–
Handpiece (nonautoclave)		–	± (Iodophor disinfectant)
Angle attachment[b]	+	+	–
Rubber items	++	–	–
Rag wheels	++	+	–
Removable prosthetics[c]	–	–	
Heat-resistant plastic evacuators	++	+	–

[a]Chemical disinfecting/sterilizing solutions are not the method of choice for sterilization of any items used in the mouth. In some circumstances, they may be used when other more suitable procedures have been precluded.
[b]Clinician should confirm with manufacturer that attachment is capable of withstanding heat sterilization.
[c]Rinse prosthetic well, immerse in 1:10 household bleach solution (5%–6% sodium hypochlorite) for 5 minutes. Rinse the prosthetic (repeat disinfection procedure before returning to patient).

• **Fig. 5.3** Method of sterilely transferring double-wrapped sterile supplies from clean individual (ungloved hands) to sterilely gowned individual (gloved hands). The package is designed to be peeled open from one end without touching the sterile interior of the package. Sterile contents are then promptly presented to the recipient.

Maintenance of Sterility

Disposable Materials

Materials and drugs used during oral and maxillofacial surgery—such as sutures, local anesthetics, scalpel blades, and syringes with needles—are sterilized by the manufacturer with a variety of techniques, including use of gases, autoclaving, filtration, and irradiation. To maintain sterility, only the dentist must properly remove the material or drug from its container. Most surgical supplies are double wrapped (the only common exception is scalpel blades). The outer wrapper is designed to be handled in a nonsterile fashion and usually is sealed in a manner that allows an ungowned and gloved individual to unwrap it and transfer the material still wrapped in a sterile inner wrapper. The ungloved individual may allow the surgical material in the sterile inner wrapper to drop onto a sterile part of the surgical field or allow an individual gloved in a sterile fashion to remove the wrapped material in a sterile manner (Fig. 5.3). Scalpel blades are handled in a similar fashion; the unwrapped blade may be dropped onto the field or grasped in a sterile manner by another individual.

Surgical Field Maintenance

An absolutely sterile surgical field is impossible to attain. For oral procedures, even a relatively clean field is difficult to maintain because of oral and upper respiratory tract contamination. Therefore, during oral-maxillofacial surgery, the goal is to prevent any organisms from the surgical staff or other patients from entering the patient's wound.

Once instruments are sterilized or disinfected, they should be set up for use during surgery in a manner that limits the likelihood of contamination by organisms foreign to the patient's maxillofacial flora. A flat platform such as a Mayo stand should be used, and two layers of sterile towels or waterproof paper should be placed on it. Then, the clinician or assistant should lay the instrument pack on the platform and open out the edges in a sterile fashion. Anything placed on the platform should be sterile or disinfected. Care should be taken not to allow excessive moisture to get on the towels or paper; if the towels become saturated, they can allow bacteria from the unsterile undersurface to wick up to the sterile instruments.

Operatory Disinfection

The various surfaces present in the dental operatory have different requirements concerning disinfection that depend on the potential for contamination and the degree of patient contact with the surface. Any surface that a patient or patient's secretions contact is a potential carrier of infectious organisms. In addition, when high-speed drilling equipment is used, patient blood and secretions are dispersed over much of the surfaces of the operatory. The operatory can be disinfected in two basic ways. The first is to wipe all surfaces with a hospital-grade disinfectant solution. The second is to cover surfaces with protective shields that are changed between each patient. Fortunately, many chemical disinfectants, including chlorine compounds and glutaraldehyde, can prevent transfer of the hepatitis viruses when used on surfaces in certain concentrations (0.2% for chlorine, 2% for glutaraldehyde). Headrests, tray tables, hosing and lines, controls for nitrous oxide, the chair, and light handles can be covered with commercially available, single-use, disposable covers; the rest of the dental chair can be quickly sprayed with a disinfectant. Countertops usually come into contact with patients only indirectly, so counters should be periodically disinfected, especially before surgical procedures. Limiting the number of objects left on operatory counters will make periodic cleaning easier and more effective.

Soap dispensers and sink faucets are another source of contamination. Unless they can be activated without using the hands, they should be disinfected frequently because many bacteria survive—even thrive—in a soapy environment (discussed later in this section). This is one reason common soap is not the ideal agent when preparing hands for surgery.

Anesthetic equipment used to deliver gases such as oxygen or nitrous oxide may also spread infection from patient to patient. Plastic nasal cannulas are designed to be discarded after one use. Nasal masks and the tubing leading to the mask from the source of the gases are available in disposable form or can be covered with disposable sleeves.

Surgical Staff Preparation

The preparation of the operating team for surgery differs according to the nature of the procedure being performed and the location of the surgery. The two basic types of personnel asepsis to be discussed are (1) the clean technique and (2) the sterile technique. Antiseptics are used during each of the techniques, so they are discussed first.

Hand and Arm Preparation

Antiseptics are used to prepare the surgical team's hands and arms before gloves are donned and are also used to disinfect the surgical site. Because antiseptics are used on living tissue, they are designed to have low tissue toxicity while maintaining disinfecting properties. The three antiseptics most commonly used in dentistry are (1) iodophors, (2) chlorhexidine, and (3) hexachlorophene.

Iodophors such as polyvinylpyrrolidone-iodine (povidone-iodine) solution have the broadest spectrum of antiseptic action, being effective for gram-positive as well as gram-negative bacteria, most viruses, *M. tuberculosis* organisms, spores, and fungi.

Iodophors are usually formulated in a 1% iodine solution. The scrub form has an added anionic detergent. Iodophors are preferred over noncompounded solutions of iodine because they are much less toxic to tissue than free iodine and more water soluble. However, iodophors are contraindicated for use on individuals sensitive to

iodinated materials, those with untreated hypothyroidism, and pregnant women. Iodophors exert their effect over a period of several minutes, so the solution should remain in contact with the surface for at least a few minutes for maximal effect.

Chlorhexidine and hexachlorophene are other useful antiseptics. Chlorhexidine is used extensively worldwide and is available in the United States as a skin preparation solution and for internal use. The potential for systemic toxicity with repeated use of hexachlorophene has limited its use. Both agents are more effective against gram-positive bacteria than against gram-negative bacteria, which makes them useful for preparation for maxillofacial procedures. Chlorhexidine and hexachlorophene are more effective when used repeatedly during the day because they accumulate on skin and leave a residual antibacterial effect after each wash. However, their ineffectiveness against tubercle bacilli, spores, and many viruses makes them less effective than iodophors.

Clean Technique

The clean technique is generally used for office-based surgery that does not specifically require a sterile technique. Office oral surgical procedures that call for a sterile technique include any surgery in which skin is incised. The clean technique is designed as much to protect the dental staff and other patients from a particular patient as it is to protect the patient from pathogens that the dental staff may harbor.

When using a clean technique, the dental staff may wear clean street clothing covered by long-sleeved laboratory coats (Fig. 5.4). Another option is a dental uniform (e.g., surgical scrubs) with no further covering or covered by a long-sleeved surgical gown.

Dentists should wear sterile gloves whenever they are providing invasive dental care. When the clean technique is used, hands may be washed with antiseptic soap and dried on a disposable towel before gloving. Gloves should be sterile and put on using an appropriate technique to maintain sterility of the external surfaces. The technique of sterile self-gloving is illustrated in Fig. 5.5.

In general, eye protection should be worn when blood or saliva are dispersed, such as when high-speed cutting equipment is used (see Fig. 5.4). A facemask and hair coverage should be used whenever aerosols are created or a surgical wound is to be made.

• **Fig. 5.4** Surgeon ready for office oral surgery, wearing clean gown over street clothes, mask over nose and mouth, cap covering scalp hair, sterile gloves, and shatter-resistant eye protection. Nondangling earrings are acceptable in clean technique.

In most cases, it is not absolutely necessary to prepare the operative site when using the clean technique. However, when surgery in the oral cavity is performed, perioral skin may be decontaminated with the same solutions used to scrub the hands, and the oral cavity may be prepared by brushing or rinsing with chlorhexidine gluconate (0.12%) or an alcohol-based mouthwash. These procedures reduce the amount of skin or oral mucosal contamination of the wound and decrease the microbial load of any aerosols made while using high-speed drills in the mouth. The dentist may desire to drape the patient to protect the patient's clothes, to keep objects from accidentally entering the patient's eyes, and to decrease suture contamination should it fall across an uncovered, unprepared part of the patient's body.

During an oral surgical procedure, only sterile water or sterile saline solution should be used to irrigate open wounds. A disposable injection syringe, a reusable bulb syringe, or an irrigation pump connected to a bag of intravenous solution can be used to deliver irrigation. Reservoirs feeding irrigation lines to handpieces are also available and can be filled with sterile irrigation fluids.

Sterile Technique

The sterile technique is used for office-based surgery when skin incisions are made or when surgery is performed in an operating room. (A clean wound is made through intact skin that has been treated with an antiseptic.) The purpose of sterile technique is to minimize the number of organisms that enter wounds created by the surgeon. The technique requires strict attention to detail and cooperation among the members of the surgical team.

The surgical hand and arm scrub is another means of lessening the chance of contaminating a patient's wound. Although sterile gloves are worn, gloves can be torn (especially when using high-speed drills or working around jaw fixation wires), thereby exposing the surgeon's skin. By proper scrubbing with antiseptic solutions, the surface bacterial level of the hands and arms is greatly reduced.

Most hospitals have a surgical scrub protocol that must be followed when performing surgery in those institutions. Although several acceptable methods can be used, standard to most techniques is the use of an antiseptic soap solution, a moderately stiff brush, and a fingernail cleaner. Hands and forearms are washed in a scrub sink, and hands are kept above the level of the elbows after washing until the hands and arms are dried. A copious amount of antiseptic soap is applied to the hands and arms from either wall dispensers or antiseptic-impregnated scrub brushes. The antiseptic soap is allowed to remain on the arms, while any dirt is removed from underneath each fingernail tip using a sharp-tipped fingernail cleaner.

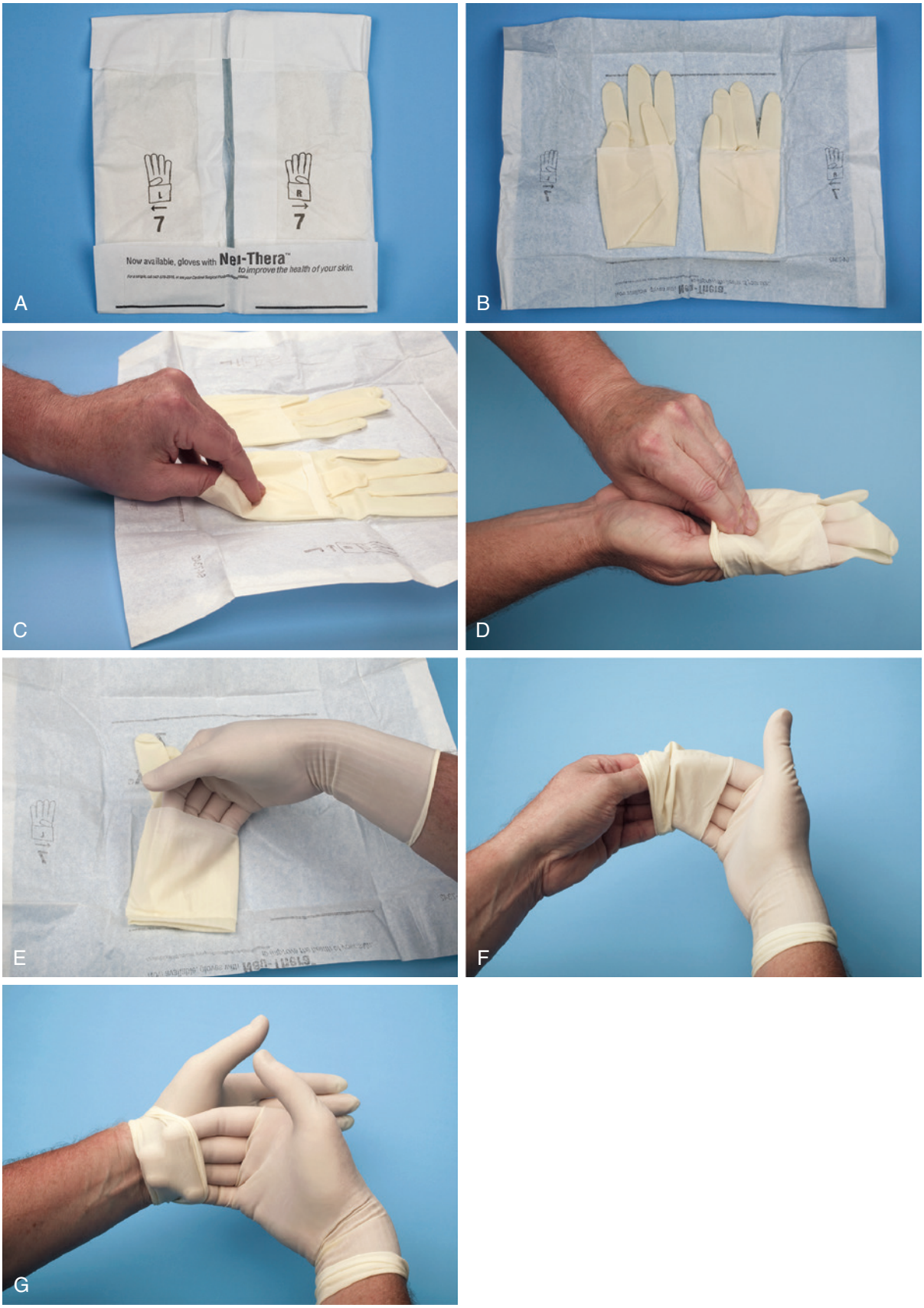
Postsurgical Asepsis

Wounds Management

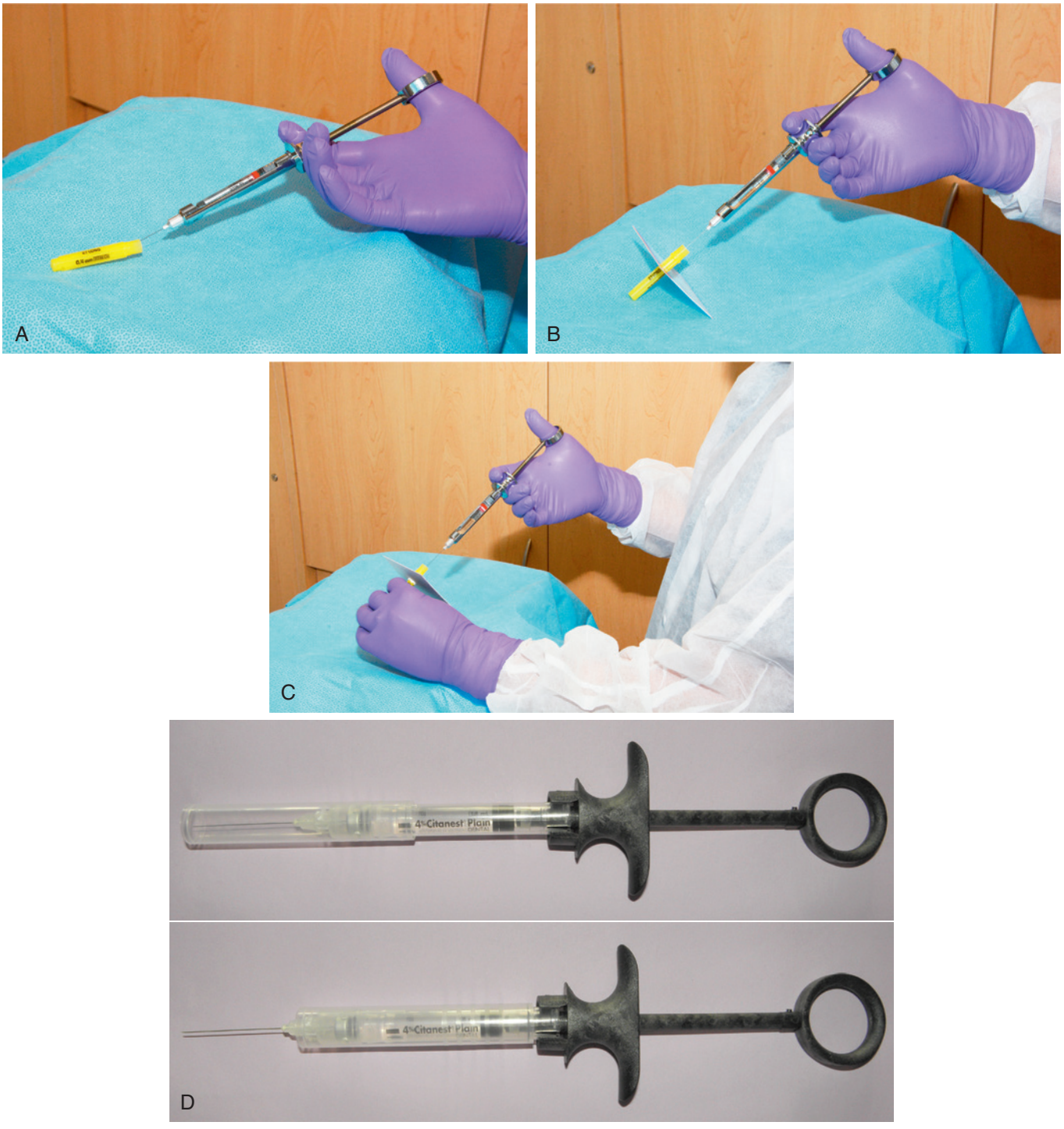
A few principles of postsurgical care are useful to prevent the spread of pathogens. Wounds should be inspected or dressed by hands that are covered with fresh, clean gloves. When several patients are waiting, those without infectious problems should be seen first, and those with problems such as a draining abscess should be seen afterward.

Sharps Management

During and after any surgery, contaminated materials should be disposed of in such a way that the staff and other patients will not be infected. The most common risk for transmission of disease



• **Fig. 5.5** (A) Inner wrapper laid open on surface with words facing the person gloving himself. Note that the outside surfaces of this wrapper are considered nonsterile, whereas the inner surface touching the gloves is sterile. (B) While touching the outside of wrapper, simultaneously pull the folds to each side, exposing the gloves. (C) Note that the open end of each glove is folded up to create a cuff; using the fingertip of the right hand, grasp the fold of the cuff of the left glove without touching anything else. Bring the glove to the outstretched fingers of the left hand and slide the finger into the glove while using the right hand to help pull the glove on. Release the glove's cuff without unfolding the cuff. (D) Place the fingers of the left hand into the cuff of the right glove. Bring the glove to the outstretched fingers of the right hand. (E) Slide the fingers of the right hand into the glove while continuing to hold the glove with the left fingers in the cuff to stabilize the glove. Once the glove is on, unfurl the cuff using the fingers still within the cuff. (F) Finally place the fingers of the right hand into the cuff of the left glove to unfurl the cuff. (G) The gloves can now be used to ensure that the fingertips of each glove are fully into the glove fingertips, while taking care to touch only the sterile glove surfaces.



• **Fig. 5.6** (A) Scoop technique for resheathing anesthetic needle. (B) Scoop needle resheathing technique using cardboard holder to stabilize needle cap. (C) Clinician holding needle cap with protective cardboard on the cap while resheathing needle. (D) Self-resheathing needle.

• **Fig. 5.6, cont'd** (E) Proper disposal of sharp, disposable supplies into well-marked, rigid container to prevent accidental inoculation of office or housekeeping workers with contaminants on sharp objects. (Pictured: Safety Plus XL syringe by Septodont Inc., New Castle, DE.)

from infected patients to the staff is by accidental needle sticks or scalpel lacerations. Sharps injuries can be prevented by using the local anesthetic needle to scoop up the sheath after use, using an instrument such as a hemostat to hold the cover while resheathing the needle, or using automatically resheathing needles (Fig. 5.6A–B); taking care never to apply or remove a blade from a scalpel handle without an instrument; and disposing of used blades, needles, and other sharp disposable items into rigid, well-marked receptacles specially designed for contaminated sharp objects (see Fig. 5.6C). For environmental protection, contaminated supplies should be discarded in properly labeled bags and removed by a reputable hazardous waste management company.

6

Pain and Anxiety Control in Surgical Practice

JAMES R. HUPP

CHAPTER OUTLINE

Virtually all oral surgery procedures produce pain, and for most patients the prospects of having surgery provoke some degree of anxiety. Therefore it is incumbent upon those performing oral surgery to master techniques that will control perioperative pain and anxiety. For most routine oral surgical procedures, local anesthesia is sufficient to manage pain produced during surgery and for the early postoperative period. Anxiety control, on the other hand, is a more complex topic. Patients may or may not require pharmacologic control. Most patients are adequately managed using nonpharmacologic behavioral techniques. However, some form of drug-mediated sedation is often useful or required for patients with higher levels of presurgical anxiety or for procedures known to cause intraoperative anxiety. This chapter focuses on the use of local anesthesia for routine oral surgery and limits it coverage of anxiety control to nitrous oxide sedation. The topics of local anesthesia and sedation for dental care are far more comprehensively covered in other textbooks.[1,2]

Local Anesthesia

The ability to locally anesthetize a specific part of the body is one of the marvels of pharmacology. It is hard to imagine the modern practice of dentistry without the availability of local anesthetics (LAs). The dental pulp and soft tissues adjacent to teeth are highly sensitive to stimulation of all forms, including pain-provoking stimuli. Thus profound local anesthesia is mandatory to properly perform oral surgery on an awake patient.

A large number of LAs are available for use by dental practitioners. However, like most medications, those administering drugs find it optimal to limit the number of different forms of a drug to produce a similar effect. This allows the clinician to truly master the use of the category of drug they select to administer, becoming completely familiar with the drug's chemistry, mechanism of action, and clinical pharmacodynamics. Practitioners choosing to limit the number of different versions of a category of drug are then able to focus on just those drugs. This gives them the opportunity to gain valuable clinical experience with the use of these drugs, enabling them to recognize usual and unusual patient reactions and more easily stay abreast of new knowledge related to these drugs. For this reason, this chapter limits its coverage to only six specific LAs. Other LAs are available throughout the world that are efficacious, and other references are available to provide detailed information about them.[1]

Mechanism of Action

LAs are, by definition, designed to block the function of sensory nerves, although they are also able to inhibit motor nerves and other nerve tissues. To understand the mechanism of action of LAs, one must recall how nerve fibers transmit electrical impulses. In the case of sensory nerves, when the peripheral nerve ending or nerve trunk is sufficiently stimulated, the resting potential of the nerve membrane is triggered to depolarize by a change in membrane permeability that allows the shift of sodium ions across the membrane into the axoplasm. Initially, a slow depolarization occurs; however, once the negative transmembrane potential decreases to the point of the firing threshold, rapid depolarization

occurs. Local currents within the axon help propagate the impulse down the axon, triggering rapid depolarization along the path to the cell body and central nervous system (CNS).

LAs primarily function by raising the membrane firing threshold necessary to trigger or propagate an electric impulse. LAs also produce local anesthesia by affecting sensory receptors and nerve membranes in other ways. The end result is that the nerve membrane remains in a polarized state unable to conduct impulses and not transmit otherwise painful sensations.

Pharmacology

The chemistry of various LAs directly affects the pharmacologic properties of each drug. The LAs discussed in this section are all tertiary amines and classified as amino amides, making them relatively resistant to hydrolysis. LAs tend to work best at a neutral pH. The pH of LAs without vasoconstrictors is about 6.5. Manufacturers lower the pH of LAs when vasoconstrictive agents such as epinephrine are added to inhibit the oxidation of the vasoconstrictor. The acidification of the LA produces the "burning" sensation patients can experience during injection. Another clinical effect related to local anesthetic pH is the tendency for LAs to be less effective when injected into an area of inflammation/infection. This happens because of the acidic nature of inflamed tissue that interferes with local anesthetic effectiveness.

LAs differ in their ability to bind to proteins and in their lipid solubility; they also come in varying concentrations. These factors affect their speed of onset and duration of action. When used for oral surgery the onset of action is also affected by the proximity of the injected deposition of the local anesthetic to the target nerve. The less the distance the drug needs to diffuse to reach the nerve, the faster the onset. The duration of action is affected by the amount of drug deposited and the vascularity of the tissue in the area of the injection. The more drug deposited and the less drug removed by local blood vessels, the longer the duration of action. Vasoconstrictors are added to LAs to dampen the effects of local vessels on drug removal, thereby prolonging the drug's duration.

The pharmacology of the various local anesthetic solutions that are used should be kept in mind so that they can be administered properly. Table 6.1 summarizes commonly used LAs and the expected duration of complete anesthesia. The surgeon must remember that pulpal anesthesia of maxillary teeth after local infiltration lasts a much shorter time compared with pulpal anesthesia of mandibular teeth after block anesthesia. In addition, pulpal anesthesia disappears 60 to 90 minutes before soft tissue anesthesia. Therefore it is common for the patient to have lip anesthesia but to have regained pulpal sensation and so may experience pain.

Toxic Reactions

Only a certain amount of local anesthetic can be safely used in a given patient. To provide anesthesia for multiple tooth extractions, it may be necessary to inject multiple cartridges of the local anesthetic. Thus it is important to know how many cartridges of a given local anesthetic solution can be administered safely. Table 6.2 summarizes (in two different ways) the maximum amounts of local anesthetic that can be used. First, each local anesthetic has a recommended maximum dose based on milligrams per kilogram (mg/kg). The second column in Table 6.2 indicates the number of cartridges that can safely be used on a healthy 154-lb (70-kg) adult. Rarely is it necessary to exceed this dose, even in patients heavier than 154 lb. Patients who are smaller, especially children, should be given proportionally less local anesthetic. A common risky situation involving local anesthetic overdose is the administration of 3% mepivacaine (Carbocaine) to a small child. For a child who weighs 44 lb (20 kg), the recommended maximum amount of mepivacaine is 100 mg. If the child is given two cartridges of 1.8 mL each, the dose totals 108 mg. Therefore a third cartridge of 3% mepivacaine should not be administered. As with any drug,

TABLE 6.1 Duration of Anesthesia

Local Anesthetic	Maxillary Teeth	Mandibular Teeth	Soft Tissue
Group 1[a]	10–20 min	40–60 min	2–3 h
Group 2[b]	50–60 min	90–100 min	3–4 h
Group 3[c]	60–90 min	3 h	4–9 h

[a]Group 1—local anesthetics without vasoconstrictors: mepivacaine 3%, prilocaine 4%.
[b]Group 2—local anesthetics with vasoconstrictors: lidocaine 2% with 1:50,000 or 1:100,000 epinephrine, mepivacaine 2% with 1:20,000 levonordefrin, prilocaine 4% with 1:400,000 epinephrine, articaine 4% with 1:100,000 epinephrine.
[c]Group 3—long-acting local anesthetics: bupivacaine 0.5% with 1:200,000 epinephrine, etidocaine 1.5% with 1:200,000 epinephrine.

TABLE 6.2 Recommended Maximum Local Anesthetic Doses

Drug/Solution	Maximum Amount (mg/kg)	Number of Cartridges for 70-kg (154-lb) Adult	Number of Cartridges for 20-kg (44-lb) Child
Lidocaine 2% with 1:100,000 epinephrine	5.0	10	3.0
Mepivacaine 2% with 1:20,000 levonordefrin	5.0	10	3.0
Mepivacaine 3% (no vasoconstrictor)	5.0	6	2.0
Prilocaine 4% with 1:200,000 epinephrine	5.0	6	2.0
Articaine 4% with 1:100,000 epinephrine	7.0	6	1.5
Bupivacaine 0.5% with 1:200,000 epinephrine	1.5	10	3.0
Etidocaine 1.5% with 1:200,000 epinephrine	8.0	15	5.0

the smallest amount of local anesthetic solution sufficient to provide profound anesthesia is the proper amount.

LAs can affect all types of nerves including those controlling the myocardium and peripheral blood vessels. In addition, because LAs can cross the blood-brain barrier, they can also affect CNS tissue. Excessive levels of LAs cause myocardial depression. This may reduce cardiac output and allow abnormal rhythms to occur. When at toxic levels LAs affect the peripheral blood vessels by relaxing smooth muscles responsible for maintaining normal vascular tone; this leads to hypotension. In the CNS, toxic levels of LAs have paradoxical effects. At the lower end of toxic levels LAs can produce CNS signs and symptoms of depression and have anticonvulsant properties. However, as the serum concentration rises to higher toxic levels, a preconvulsant state is produced that may lead to convulsions.

Vasoconstrictors

The two most common vasoconstrictors added to LAs used for dental surgery are epinephrine and levonordefrin. LAs used for oral surgery have varying concentrations of these two drugs. Epinephrine is added to all the LAs discussed in this chapter except mepivacaine. Mepivacaine is available in two forms; 3% mepivacaine used for dentistry contains no vasoconstrictor, whereas the 2% formulation of mepivacaine has levonordefrin in a 1/20,000 concentration.

Both epinephrine and levonordefrin prolong the duration of local anesthesia by producing local vasoconstriction. They also can promote local hemostasis through their vasoconstrictive effects on capillary beds. Epinephrine and levonordefrin have similar effects on other parts of the cardiovascular system, producing an increase in heart rate, myocardial contractility, and blood pressure. The cardiac effects increase myocardial oxygen consumption and may provoke dysrhythmias. Therefore techniques to limit the amount of these vasoconstrictors are part of the standard protocol of their administration; namely, aspirating before depositing the anesthetic in tissues with sizable blood vessels and limiting the total amount of local anesthetic used. This becomes even more important for patients with preexisting cardiovascular disorders such as coronary artery disease or dysrhythmic tendencies and in patients with poorly controlled hypertension. Yet it must be kept in mind that an inadequate degree or duration of local anesthesia exposes patients to intraoperative pain sensations that will then stimulate endogenous catecholamine release. Therefore guidelines exist about the use of vasoconstrictor-containing LAs to try to balance the need for profound anesthesia for the duration of a procedure with the requirement to avoid potentially dangerous side effects of vasoconstrictors.

Modulation of Injection Discomfort

In many clinical circumstances, patients are more fearful of the local anesthetic injection than of the surgical procedure. Although there are ongoing studies investigating the efficacy of buffered LAs to lessen the pain produced because of their acidity, there is little to counteract the burning or heavy pressure sensation patients feel while LAs are being deposited in the tissues when commonly available anesthetic syringes are in use. However, there are means of lessening the discomfort of the anesthetic needle piercing the mucosa. Local anesthetic needles are sharp and have a small diameter; therefore, when inserted properly, they cause relatively little discomfort. Many practitioners choose to use topical anesthesia before needle insertion to further minimize the discomfort of the injection. Benzocaine has pharmacologic properties that make it a useful topical anesthetic for oral mucosa. It has a very rapid onset of action (typically <1 minute) and an extremely low risk of causing unwanted side effects. When applied to dried mucosa it can eliminate the discomfort of needle insertion within 60 seconds. However, benzocaine does not penetrate deep enough to eliminate the discomfort of anesthetic deposition.

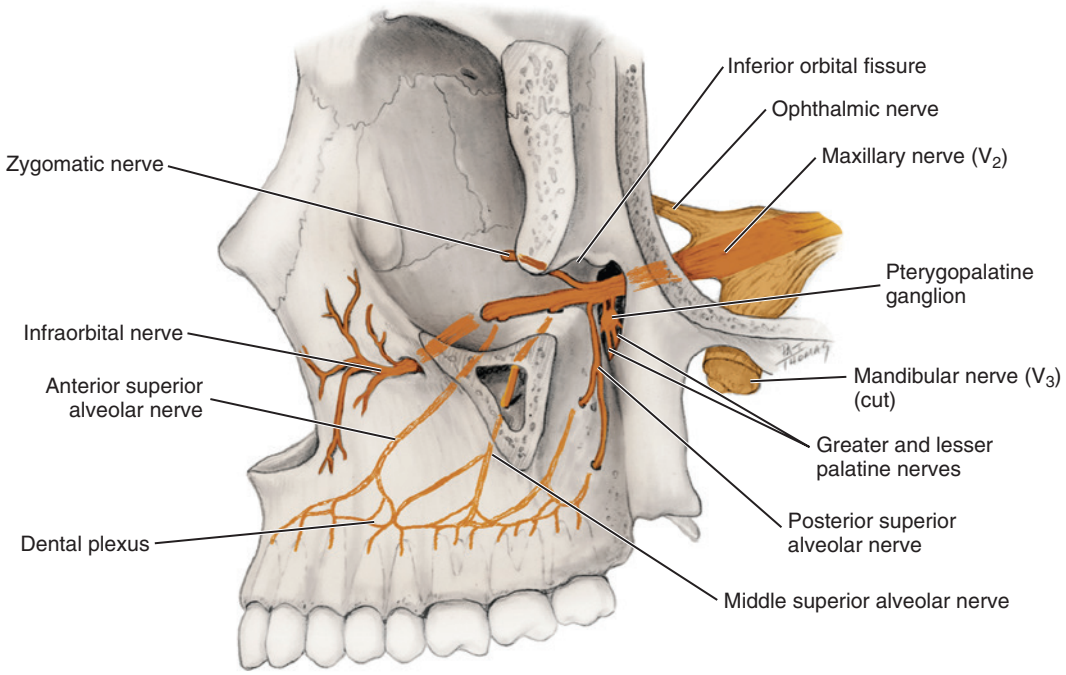
Other approaches to lessening the pain of a local anesthetic injection include lowering the rate of injection, prewarming anesthetic cartridges, and using distraction techniques such as wiggling adjacent tissue like the cheek or talking to the patient about topics unrelated to their surgery during the injection. For some patients, nitrous oxide sedation may be necessary prior to local anesthetic injection (discussed later in this chapter).

Relevant Anatomy

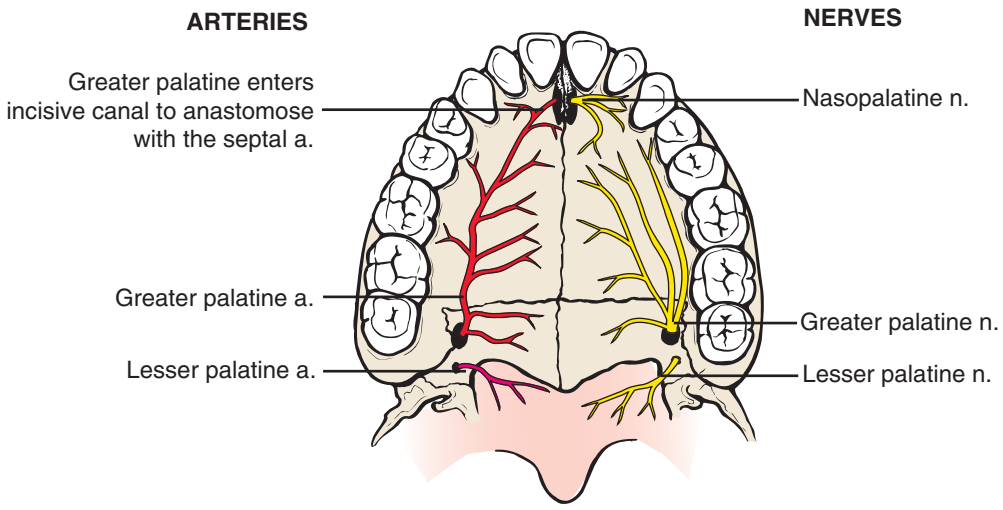
Profound local anesthesia is needed if the tooth is to be removed without causing sharp pain for the patient; therefore it is essential that the surgeon remember the precise innervations of all teeth and surrounding soft tissue, as well as the kinds of injection necessary to anesthetize those nerves completely. Table 6.3 summarizes the sensory innervation of teeth and the surrounding tissue. Figs. 6.1 to 6.4 show the primary nerves relevant to local anesthesia for dentoalveolar surgery.

TABLE 6.3 Sensory Innervation of Jaws

Nerve	Teeth	Soft Tissue
Inferior alveolar nerve	All mandibular teeth	Buccal soft tissue of premolars, canines, and incisors
Lingual nerve	None	Lingual soft tissue of all teeth
Long buccal nerve	None	Buccal soft tissue of molars and the second premolar
Anterior superior alveolar nerve	Maxillary incisors and canine teeth	Buccal soft tissue of incisors and canines
Middle superior alveolar nerve	Maxillary premolars and a portion of the first molar tooth	Buccal soft tissue of premolars
Posterior superior alveolar nerve	Maxillary molars except for a portion of the first molar tooth	Buccal soft tissue of molars
Greater palatine nerve	None	Lingual soft tissue of molars and premolars
Nasopalatine nerve	None	Lingual soft tissue of incisors and canines



• **Fig. 6.1** Superior alveolar nerve branches innervating maxillary teeth and adjacent labiobuccal soft tissues.



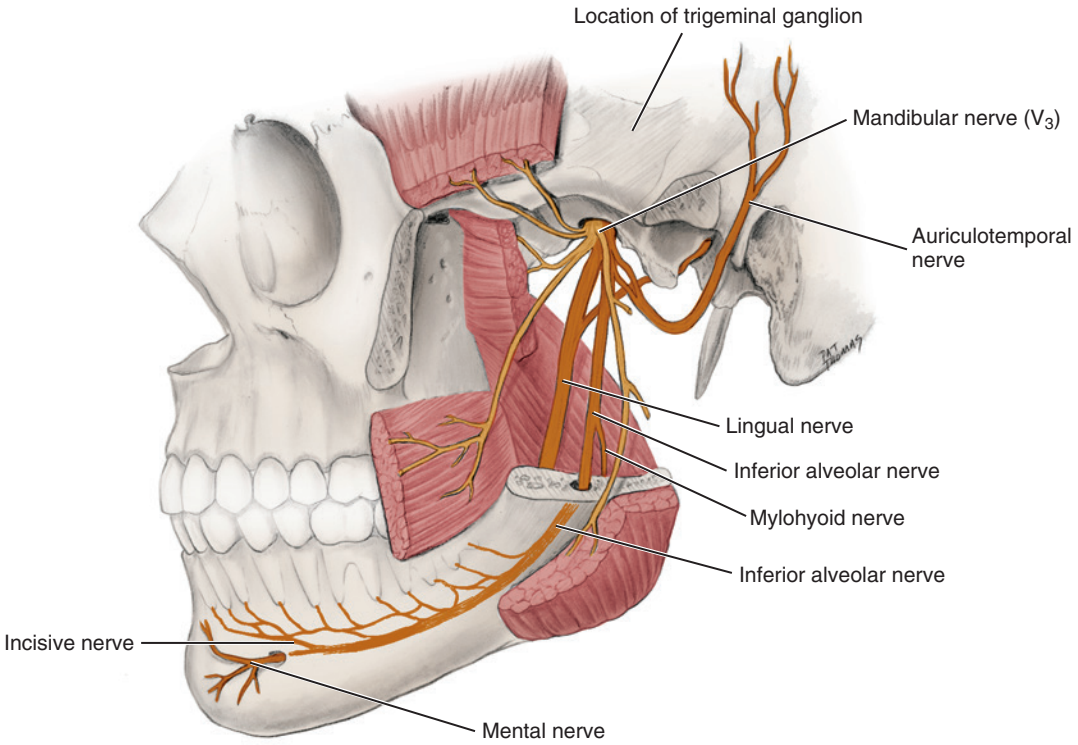
• **Fig. 6.2** Greater palatine and incisive nerves innervating soft tissue over the hard palate.

When anesthetizing a maxillary tooth for extraction, the surgeon should anesthetize adjacent teeth as well. During the extraction process, adjacent teeth are usually subjected to some pressure, which may be sufficient to cause pain. This is also true for mandibular extractions, but the mandibular block injection usually produces sufficient anesthesia to adjacent teeth.

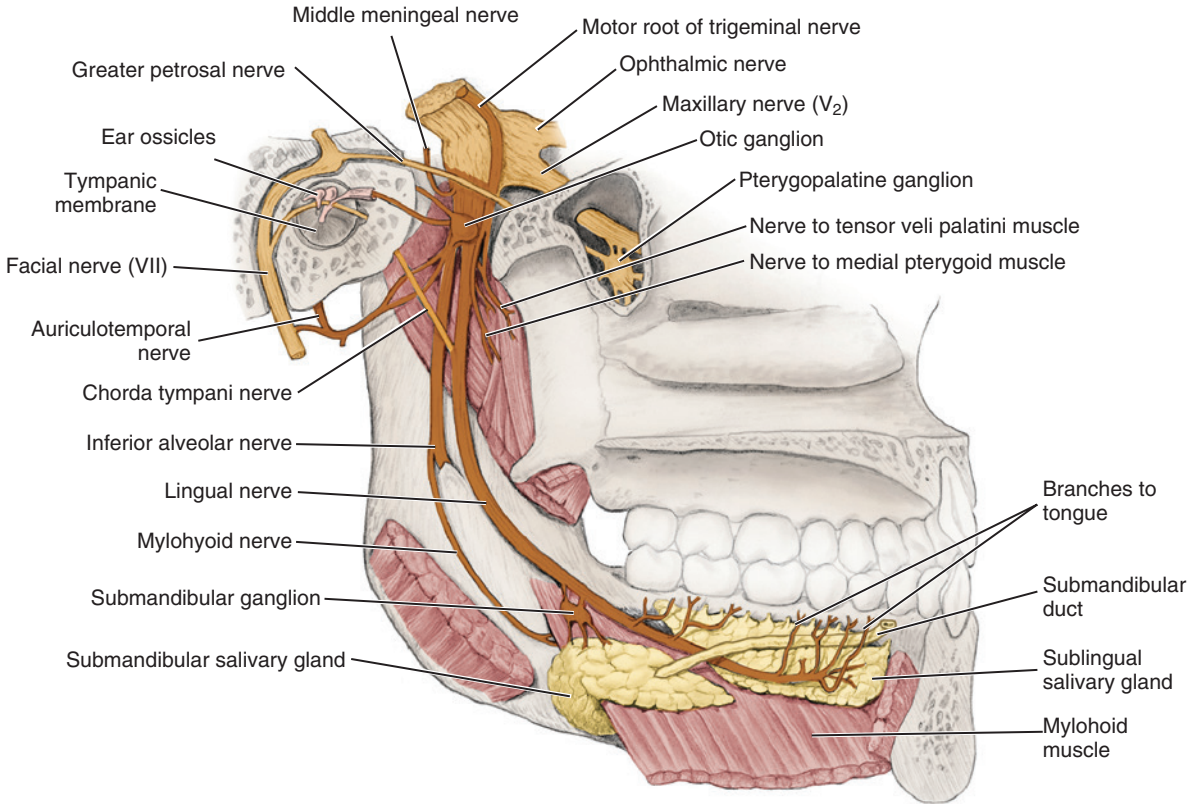
Dense local anesthesia results in the loss of all pain, temperature, and touch sensations, but it does not anesthetize the proprioceptive fibers of the involved nerves. Thus, during an extraction, the patient feels a sensation of pressure, especially when the force is substantial. The surgeon must therefore remember that the patient will need to distinguish between sharp pain and the dull, albeit intense, feeling of pressure when determining the adequacy of anesthesia. It is often difficult to make this distinction.

Technique for Administering Local Anesthesia for Oral Surgery

The administration of local anesthesia for routine oral surgery is best learned from highly experienced dentists. This section provides a review of the main approaches to providing local anesthesia for oral surgery. The figures are intended as a review of the basic techniques of the key injections used for basic oral surgery.



• **Fig. 6.3** Inferior alveolar nerve innervating mandibular teeth and soft tissues in distribution of the mental nerve.



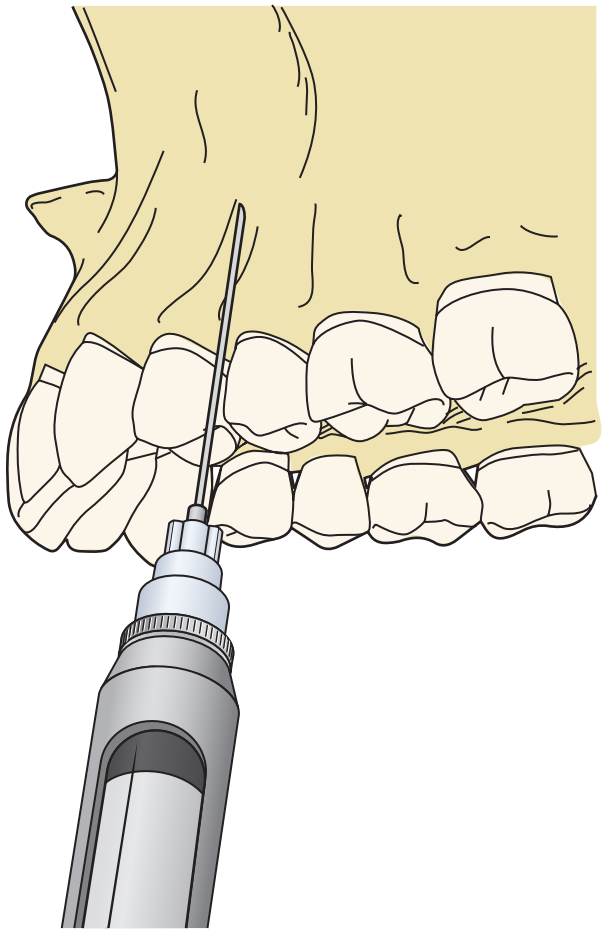
• **Fig. 6.4** Lingual and mylohyoid nerves innervating tongue and soft tissues of the floor of the mouth.

General Principles

The primary techniques used for dentoalveolar surgery are the inferior alveolar-lingual nerve block and long buccal nerve block in the mandible, whereas in the maxilla the teeth are anesthetized via buccal/labial infiltration along with palatal anesthesia of the incisive and/or greater palatine nerves. In addition, the lingual or palatal soft tissue of a tooth can be effectively anesthetized by infiltration in the soft tissue adjacent to the tooth or teeth to be operated upon. A few caveats apply to all of these types of injection. First, the slower the injection, the less pain produced. However, the slow speed of injection should be balanced against the anxiety most patients suffer as long as the injection is still being performed. Second, injections into palatal tissue tend to be more uncomfortable due to the limited amount of loose connective tissue present. Injections in such tissue require the clinician to apply more pressure to the plunger and cause pain due to the forceful delivery of anesthetic. Topical anesthetics may lessen the discomfort but do not eliminate it. Third, injections in areas with larger blood vessels should be preceded by aspiration to help lessen the possibility of intra-arterial injection. Of the techniques discussed, this applies to the inferior alveolar and posterior superior alveolar nerve blocks. Fourth, the onset of action of injected LA varies based on its pharmacology and the precision of drug deposition. Therefore adequate time should be allowed to elapse before commencing surgery. When attempting to anesthetize the inferior alveolar, lingual, and buccal nerves, the area of expected anesthesia should be tested for the patient's ability to detect a painful stimulus before the profound anesthesia is presumed to be present. Simply asking the patients if they feel anesthetized (numb) is not sufficient. Remember that a patient's proprioception is not eliminated by an LA, so both inadequately anesthetized and fully anesthetized patients retain that sensibility. Therefore asking a patient if they can feel you touching their lip is not the proper technique for testing the profoundness of local anesthesia. Fifth, for all planned procedures involving mandibular premolar or molar teeth, a long buccal nerve block should be given and be part of the approach to giving an inferior alveolar nerve block (give the long buccal injection using a small remaining part of the local anesthetic cartridge before removing the syringe from the mouth). Sixth, always resheathe the needle before putting the syringe down.

Maxillary Injections

In maxillary local anesthesia, the goal is to place the local anesthetic as close to the nerve to be anesthetized as possible so as to produce profound local anesthesia and to do so rapidly. Local anesthesia for maxillary dental surgery is relatively straightforward since the apices of most of the teeth are close to the surface of the typically thin alveolar bone. Thus placing the anesthetic close to the apex/apices of the teeth upon which one plans to operate is the objective. The apices of all maxillary teeth except the canine and palatal root of molars tend to rest at the depth of the mucobuccal fold. Positioning the tip of the anesthetic needle just through the mucosa in that area will provide pulpal anesthesia and will also anesthetize the buccal/labial soft tissue adjacent to the injection site. For the canines, the tip of the needle will need to penetrate a couple of millimeters deeper in the maxilla (Figs. 6.5 to 6.7). When operating on several posterior maxillary teeth, a posterior superior alveolar nerve block may be utilized (Fig. 6.8). Because the soft tissues on the palatal aspect of the tooth/teeth to be operated upon also need to be anesthetized, either a greater palatine nerve infiltration or incisive nerve infiltration is useful; however, the palatal soft tissue of any tooth may also be anesthetized by local infiltration adjacent to the tooth (Figs. 6.9 to 6.12).

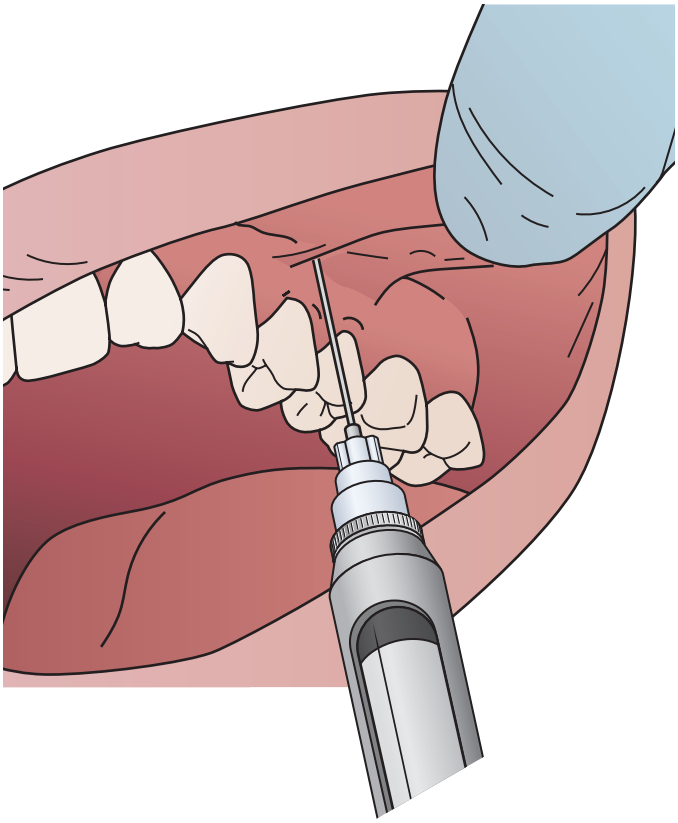


• **Fig. 6.5** Site of local anesthetic deposition for infiltration technique to anesthetize individual maxillary teeth. Needle tip should be positioned adjacent to the bone overlying the apex of the tooth to be anesthetized.

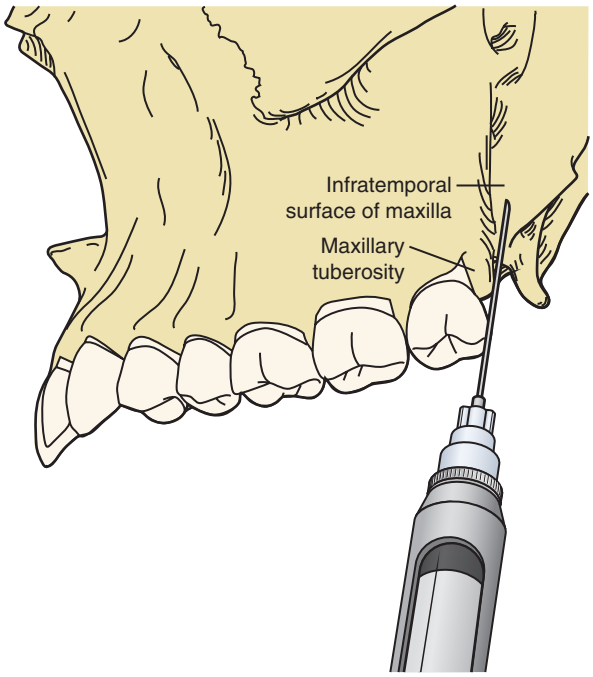
Mandibular Injections

Local anesthesia of mandibular teeth is more complex due to the thickness of the alveolar bone around the apices of those teeth. Therefore blocks of the inferior alveolar and lingual nerves are required (Figs. 6.13 to 6.17). Individuals desiring profound pulpal anesthesia of anterior mandibular teeth should avoid attempting to do so with a mental nerve block. Mental nerve blocks produce excellent anesthesia of the soft tissues in the distribution of that nerve but rarely provide reliable and adequate pulpal anesthesia. In addition, giving a mental nerve block makes it difficult to then determine the adequacy of a subsequently given inferior alveolar nerve block. Also, as discussed earlier, when performing procedures near the midline there is usually crossover innervation from the inferior alveolar nerve on the contralateral side, so bilateral inferior alveolar nerve blocks may be necessary. A bilateral inferior alveolar nerve block is not dangerous to the patient, so it should be given without hesitation when indicated.

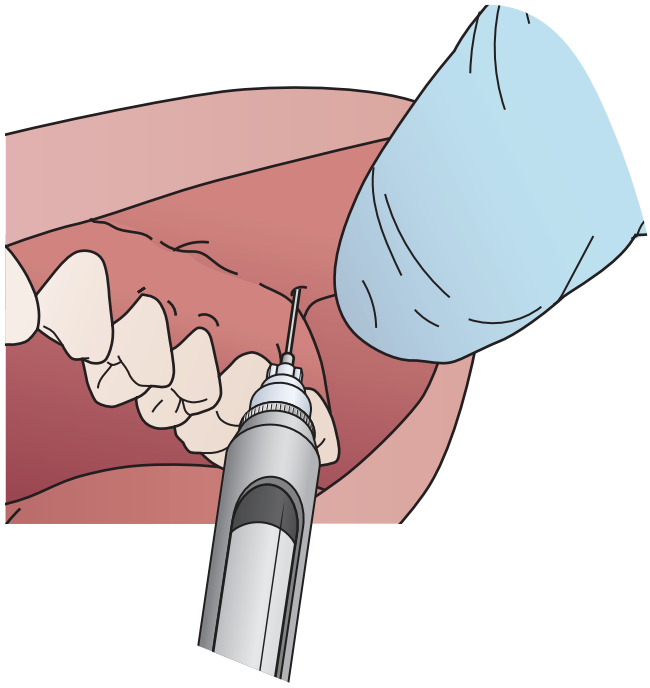
An important point to remember is that in areas of nerve transition, cross-innervation exists. For example, in the region of the mandibular second premolar, the buccal soft tissues are innervated primarily by the mental branch of the inferior alveolar



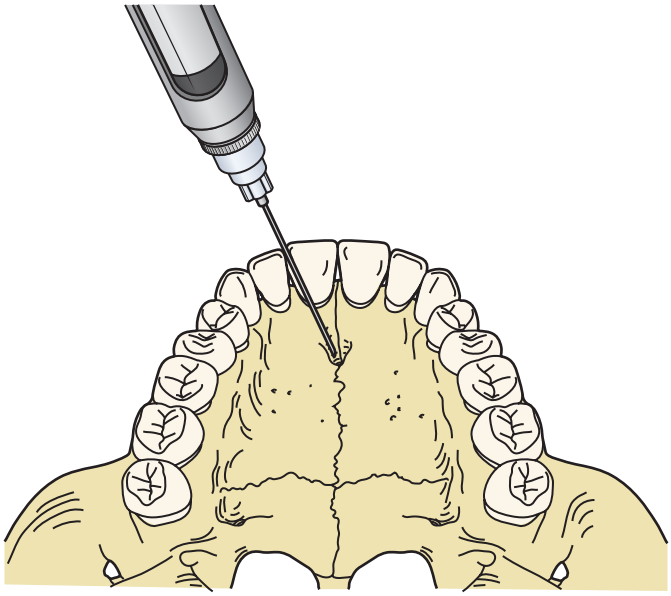
• **Fig. 6.6** Technique for infiltrating near apices of individual teeth. Note apices of maxillary teeth, other than the canine, tend to be at the depth of the mucobuccal fold. Needle tip penetration therefore only needs to be 2 to 3 mm.



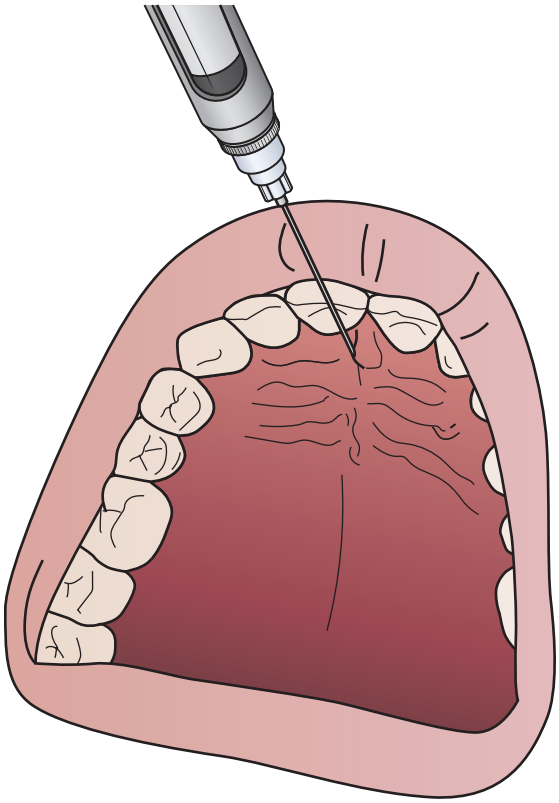
• **Fig. 6.8** Site of deposition of local anesthetic for anesthetizing the posterior superior alveolar nerve. Note how the surface of the maxillary bone runs medially as it begins to form the posterior maxillary wall. Thus the barrel of the syringe must be taken laterally while penetrating the tissue to help keep the needle tip close to the surface of the bone.



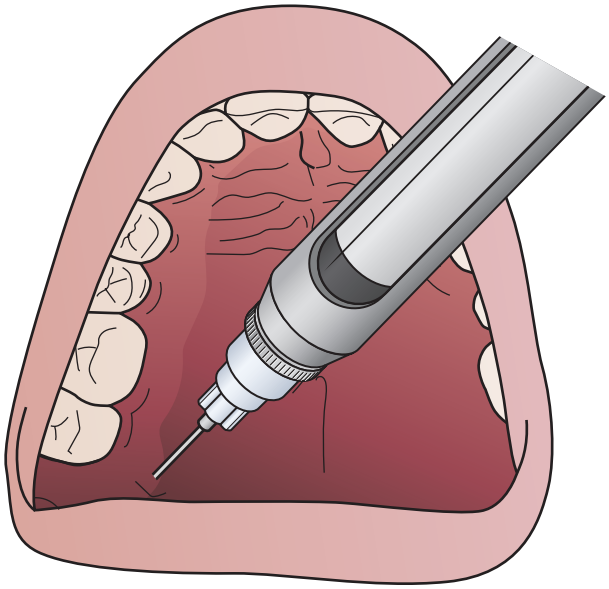
• **Fig. 6.7** Injection to anesthetize maxillary molars. Posterior superior nerve block may occur if depth of penetration is adequate and needle tip is close to the bony surface.



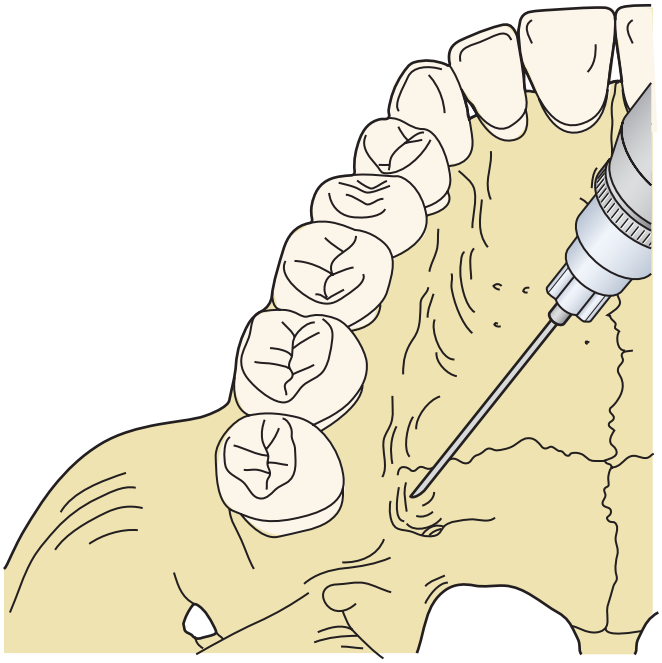
• **Fig. 6.9** Site of needle placement for infiltration to anesthetize the incisive nerve. Note that this is an infiltration so highly precise that needle tip placement is not required to achieve the desired result. No attempt is made to enter the incisive canal.



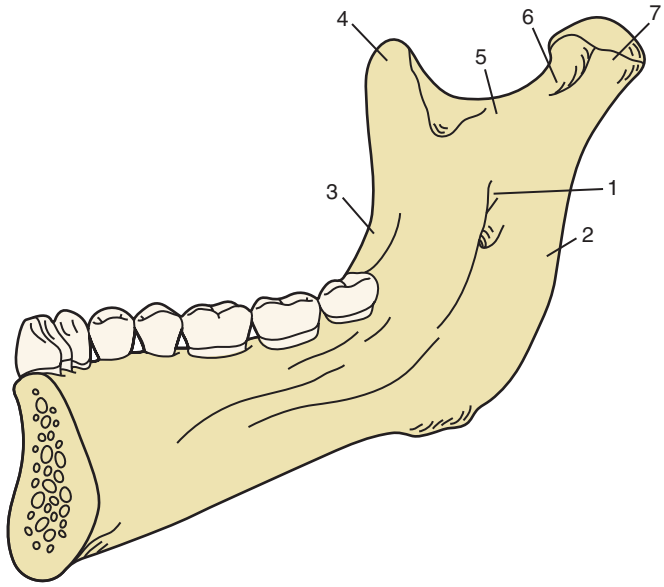
• **Fig. 6.10** Incisive nerve infiltration. Note needle enters just lateral to the incisive papilla. Depth of penetration is 2 to 3 mm. No attempt is made to enter the incisive canal. Injection tends to be uncomfortable due to the density of the tissue and its tight adherence to the underlying bone.



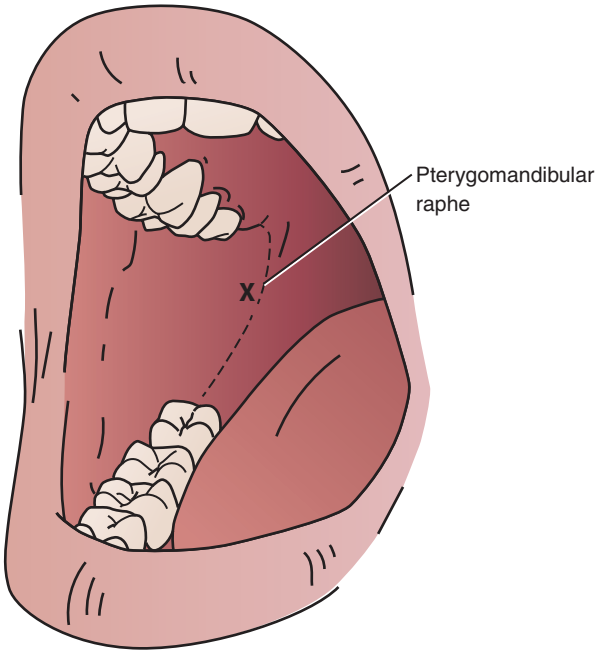
• **Fig. 6.12** Anesthetizing the greater palatine nerve. The greater palatine foramen is typically found at the junction of the vertical and horizontal elements of the hard palate in the second molar area. The needle only penetrates 2 to 3 mm. For this technique, no attempt is made to enter the foramen.



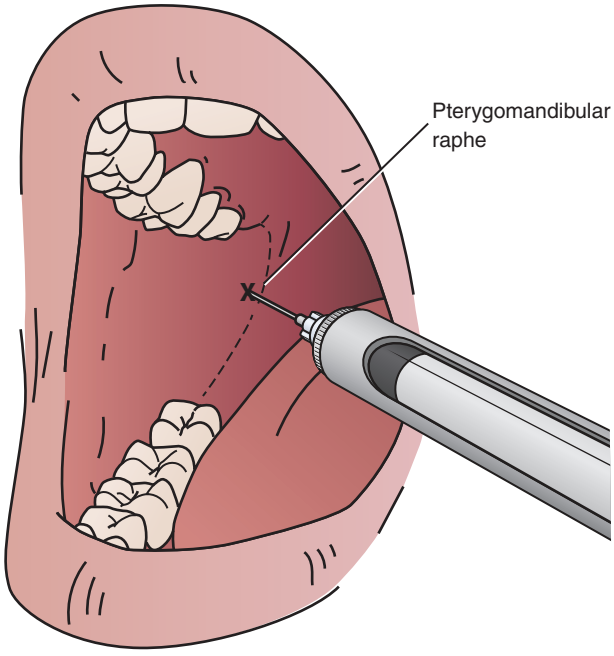
• **Fig. 6.11** Site of local anesthetic deposition for anesthetizing the greater palatine nerve. No attempt is made to enter the greater palatine canal.



• **Fig. 6.13** Lingual aspect of mandible showing *(1)* site of entrance of inferior alveolar nerve, *(2)* posterior border, *(3)* coronoid notch, *(4)* coronoid process, *(5)* sigmoid notch, *(6)* condylar neck, *(7)* and condylar head.

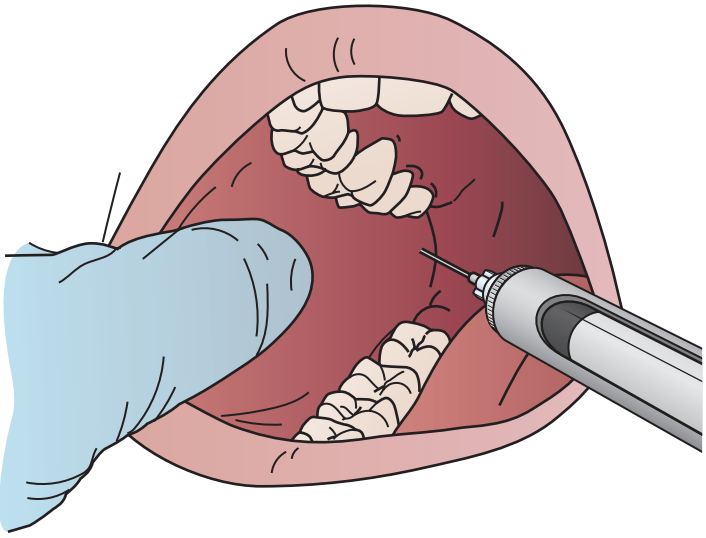


• **Fig. 6.14** Intraoral injection site point of mucosal penetration for an inferior alveolar nerve block. When a patient's mouth is held wide open, the pterygomandibular raphe tenses and usually becomes a visible reference line. The injection point should be just lateral to that line so the needle does not penetrate the raphe itself. At the time of first needle penetration the barrel of the syringe should be over the contralateral lower incisors.

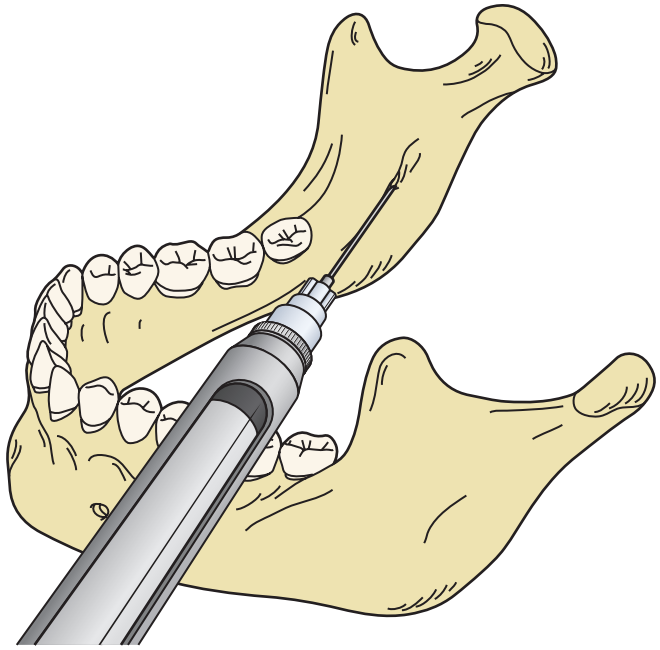


• **Fig. 6.15** Once the needle penetrates a few millimeters, the barrel of the syringe should be rotated to now be over the contralateral premolar area.

nerve but also by the terminal branches of the long buccal nerve. Therefore it is appropriate to supplement an inferior alveolar nerve block with a long buccal nerve block to achieve adequate anesthesia of buccal soft tissue when extracting a lower second premolar or placing an incision into that area (Fig. 6.18A–B).



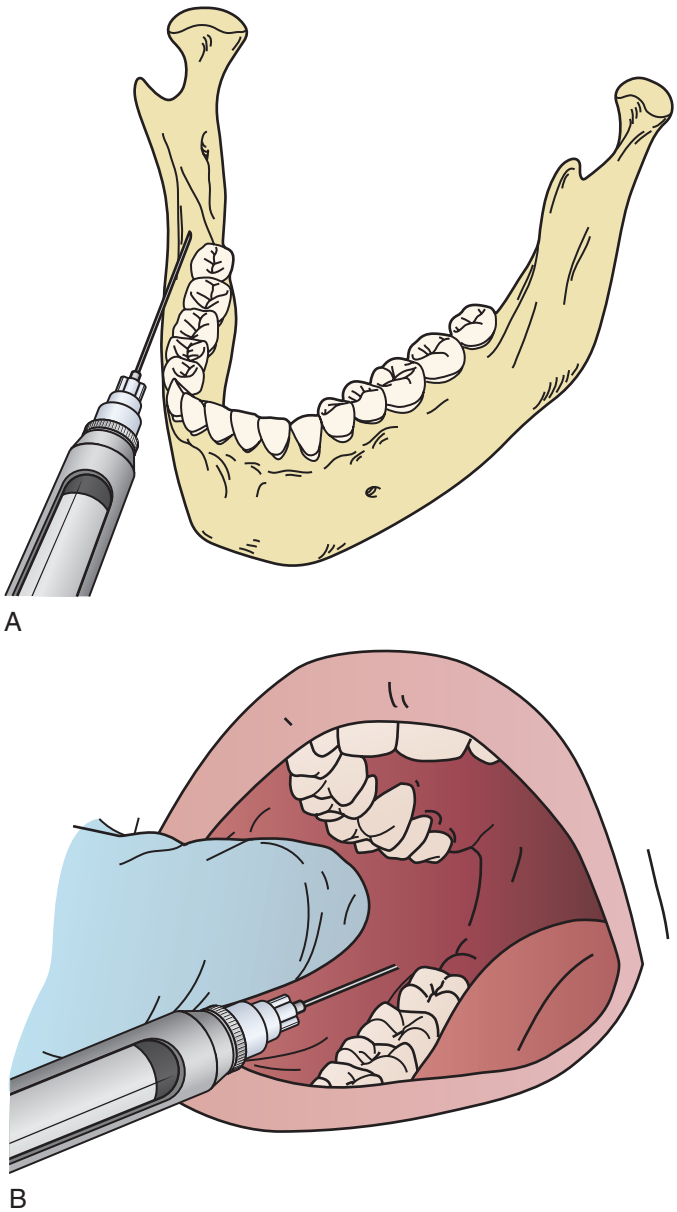
• **Fig. 6.16** During an inferior alveolar nerve block using a long needle, about two-thirds to three-fourths of the needle should be into the soft tissues. If all of the needle is buried within the tissues before bone is detected by the needle tip, the needle should be partially withdrawn and the barrel moved more posteriorly before again advancing the needle.



• **Fig. 6.17** Needle positioned at the site of local anesthetic deposition near the entrance of the inferior alveolar nerve. Note that the barrel of the syringe is over the contralateral premolars.

Periodontal Ligament Injection

Even with profound soft tissue anesthesia and apparent pulpal anesthesia, a patient may continue to have sharp pain as a tooth is luxated. This is especially likely when teeth have pulpitis or if the surrounding soft and hard tissues are inflamed or infected. A technique that should be used in these situations is the periodontal ligament injection. When this injection is delivered properly, with the local anesthetic solution injected under pressure, immediate profound local anesthesia occurs in almost all situations. The



• **Fig. 6.18** Needle placement for anesthetizing the long buccal nerve. The needle tip penetrates tissue just lateral and posterior to the site of the lower third molar. (A) Hard tissue anatomy. (B) Surface anatomy.

anesthesia is short-lived, so the surgical procedure should be one that can be accomplished within 15 to 20 minutes.

Finally, when performing an oral soft tissue biopsy, even when a block technique can provide adequate local anesthesia, infiltrating the tissues adjacent to the planned biopsy site with a vasoconstrictor containing local anesthetic can be useful to help limit bleeding. About 7 minutes should be allowed to elapse between the injection and incision to give the vasoconstrictor time to reach its optimal hemostatic effectiveness.

Managing Postextraction Pain

Although it is self-evident that local anesthesia is necessary for intraoperative pain control, the surgeon should also acknowledge its role in postoperative pain control. For routine extractions for which only mild to moderate analgesics will be needed, usually no additional local anesthetic is necessary. After procedures that have been more traumatic (e.g., the removal of impacted teeth) and where stronger analgesics are likely to be necessary, many surgeons use a long-lasting local anesthetic (e.g., bupivacaine) instead of or in addition to their usual local anesthetic. By doing this, the clinician provides the patient with 4 to 8 hours of local anesthesia. This method also allows adequate time for the patient to take the oral analgesics and for the analgesics to take effect before any serious discomfort begins. (See Chapter 12 for further information on this topic.)

Anxiety Control

Management of patient anxiety must be a major consideration in oral surgical procedures. Anxiety is a more important factor in oral surgical procedures than in most other areas of dentistry. Patients are frequently already in pain and may be agitated and fatigued, both of which lower the patient's ability to endure pain or pain-producing situations. Patients who are to have extractions may have preconceived notions or prior experiences of how painful such a procedure will be; they may have seen other patients, including family members, who have reported how painful it is to have a tooth extraction. Many are convinced that the procedure they are about to undergo will be very unpleasant. In addition, patients may experience certain psychological complications when oral surgical procedures are being performed. The removal of teeth causes a variety of reactions; a patient may grieve over lost body parts or perceive the extraction as a confirmation that youth has passed. This adds to the presurgical anxiety caused by fear of pain.

Finally, anxiety is normal even in patients with positive past experiences with extractions because the procedure truly has unpleasant aspects. As noted previously, although the sharp pain is eliminated by local anesthesia, a considerable amount of proprioceptive (pressure) sensation still exists. Other noxious stimuli such as the cracking of teeth and the clinking of instruments are present during an extraction procedure. For these reasons, prudent dentists use a planned method of anxiety control to prepare their patients to deal with the anxiety associated with tooth extraction.

Nonpharmacologic Anxiety Control

Anxiety control begins, in most cases, with a proper explanation of the planned procedure, including assurance that the doctor will take all measures to minimize the patient experiencing unexpected sharp pain; an expression of empathy from the dentist of what the patient may be fearing is also appropriate. For the mildly anxious patient with a caring dentist, no pharmacologic assistance, other than LA, is typically necessary for routine extractions.

Oral Sedation

As patient anxiety increases, it often becomes necessary to use pharmacologic assistance. Preoperatively, oral medication such as diazepam may help a patient rest well the night before the surgery and provide some relief of anxiety in the morning. A drug such as lorazepam may be useful when administered on the morning of surgery (someone other than the patient should drive him or her to the appointment in such circumstances). Other sources provide more detailed coverage of the use of oral sedatives.[2]

Pharmacologic Sedation

Sedation by the inhalation of nitrous oxide is frequently the technique of choice for anxious patients and may be the only technique required for many patients who have mild to moderate anxiety. Nitrous oxide has a remarkably good margin of safety when properly used. An extremely anxious patient who is to have several uncomplicated extractions may require deeper sedation, usually by the intravenous route. Sedation with anxiolytic drugs such as using diazepam or midazolam, with or without a narcotic, allows patients with moderate to severe anxiety to undergo surgical procedures with minimal psychological stress. If the dentist is not skilled at using this modality, patients requiring intravenous sedation should be referred to a dentist who is trained to provide it.[2]

Nitrous Oxide Sedation

Nitrous oxide is an odorless and colorless gas that is not irritating to airways. It is toxic to humans if given in very high concentrations, but, when properly mixed with pure oxygen and given appropriately, it can be an extremely potent analgesic and anxiolytic. This makes it useful when providing oral surgery as well as for patients who primarily fear local anesthetic injections.

Nitrous Oxide Storage and Delivery

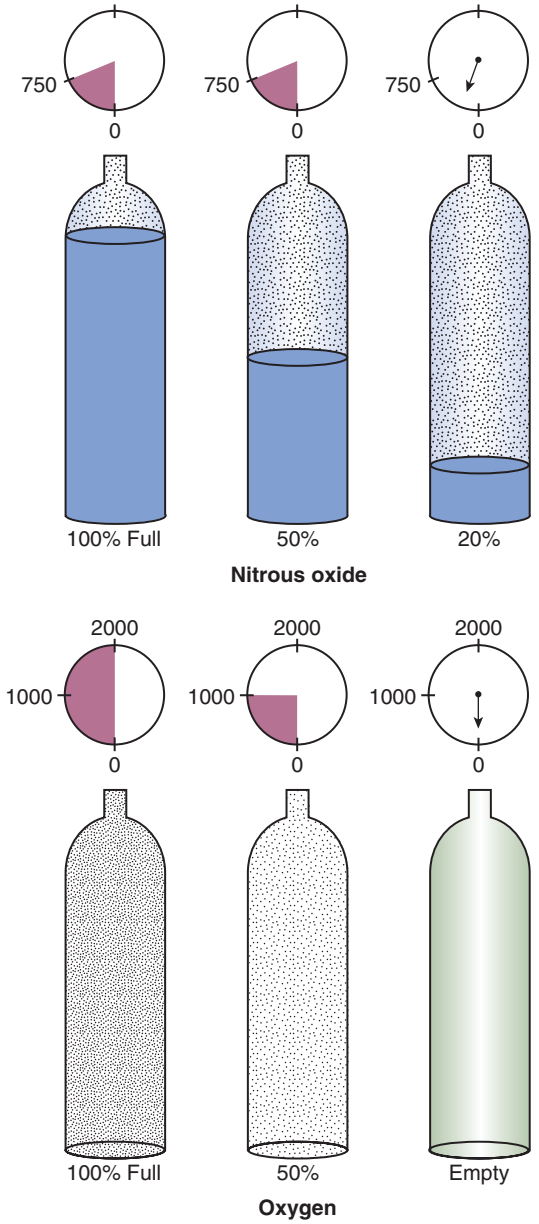
In clinical facilities equipped to deliver nitrous oxide, both the nitrous oxide and oxygen come in pressurized tanks. The primary difference is that nitrous oxide is in the liquid form when under pressure, while oxygen is in the gaseous state under cylinder tank pressure (Fig. 6.19). This results in the differences in readings and behavior of pressure gauges on nitrous oxide and oxygen tanks; while oxygen tank gauges will directly show the actual pressure in the tank at all pressures, nitrous oxide tank guages will read 750 psi as long as the pressure is above that amount. However, it is only once the pressure falls below 750 psi that the gauge represents the actual tank pressure proportional to the amount of gas remaining (Fig. 6.20).

The tanks used to deliver nitrous oxide sedation may be centrally located and plumbed to the operatory or in smaller tanks located in the operatory itself. In both cases the equipment used for gas delivery utilizes a pin index system to prevent attaching the wrong gas to the wrong delivery line (Fig. 6.21).

The nitrous oxide and oxygen lines are connected to a delivery system known as a continuous-flow inhalation unit. A large variety of types of these units are available. Some use a single dial to control the nitrous oxide/oxygen mix, while other units have separate control knobs to use to set the liters-per-minute flow of each gas (Figs. 6.22 and 6.23). Tubes attach to the flow unit and to the nasal hood to deliver the gas mixture and remove the expired air. Variously sized nasal hoods are used to deliver the gas mixture to the patient; all should allow for a good fit of the patient's face and for scavenging the expired air from the patient to minimize nitrous oxide in the operatory air. In addition to using the proper nasal hood, the clinician must also ensure that the exhaled gas is connected to and drawn into a waste gas scavenging system at the proper rate (Fig. 6.24).

Presedation Evaluation

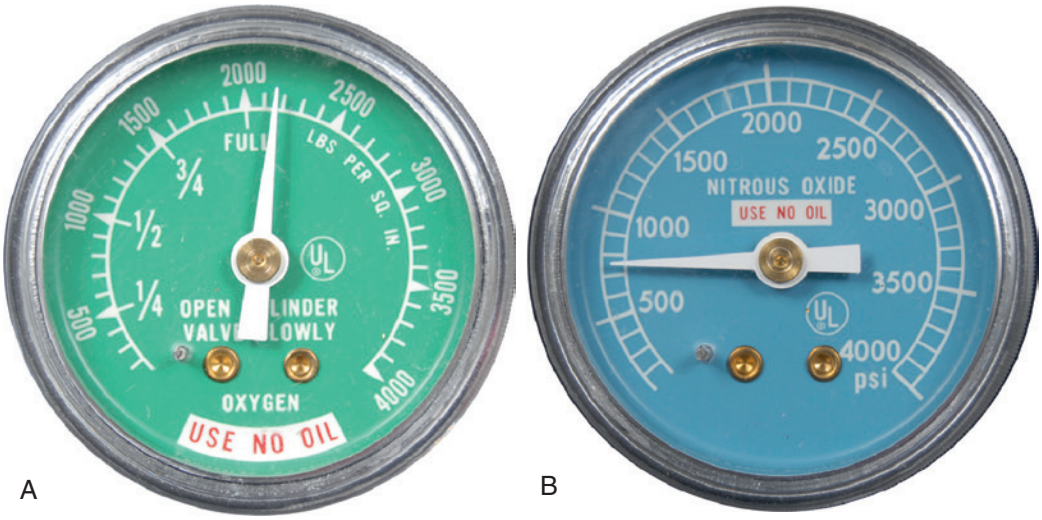
Before deciding if nitrous oxide should be used with a patient, the doctor must learn about the patient's past medical and anesthetic history. Prior bad experience with nitrous oxide may make it the wrong choice for dental sedation. Claustrophobic patients may not be able to tolerate a nasal hood. Patients who cannot handle mind-altering drugs are poor candidates for nitrous oxide; this includes patients with disorders who cannot tolerate the relative loss of control they may feel under the influence of nitrous oxide. This can also be a problem in older patients but may not manifest until after the effects of the nitrous oxide begin to occur. Medical problems such as poorly controlled chronic obstructive pulmonary disease or a respiratory infection interfering with nasal breathing are relative contraindications to the use of nitrous oxide sedation. It is prudent to avoid the use of nitrous oxide during the first trimester in pregnant patients. The use in later trimesters should be guided by the patient's obstetrician.



• **Fig. 6.19** Comparison of the behaviors of stored nitrous oxide and oxygen. Nitrous oxide is primarily in the liquid state when stored under pressure at 70°F, whereas oxygen is in the gaseous state.

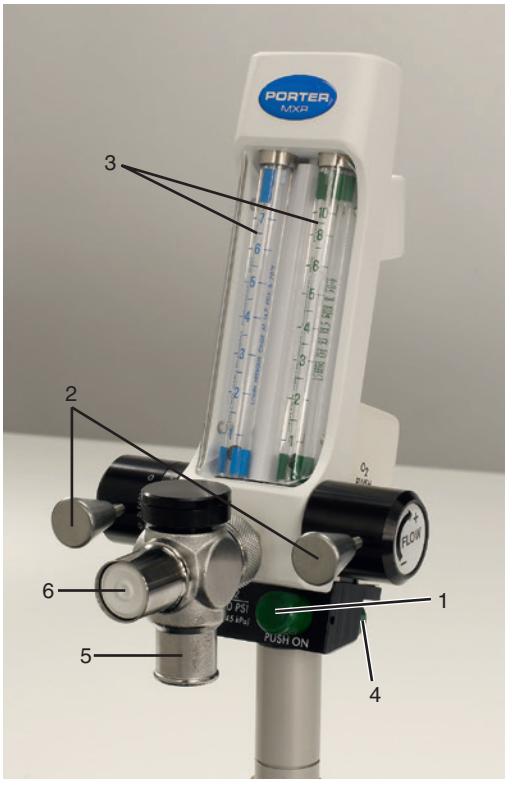
General Protocol for Using Nitrous Oxide

The general protocol for administering nitrous oxide in the dental setting begins with giving the patient 100% oxygen. While this is



• **Fig. 6.20** Pressure gauges on tanks containing (A) oxygen and (B) nitrous oxide require different interpretations of how much remains in the tank. When an oxygen tank is full, the gauge shows the actual psi of the oxygen remaining in the tank. However, for nitrous oxide, the psi represented on the gauge only represents the pressure of the N_2O vapor floating above the liquid N_2O. It is only when the amount of liquid begins to run out that the psi on the N_2O gauge begins to fall below 750 psi. Until that time, the gauge will read 750 psi.

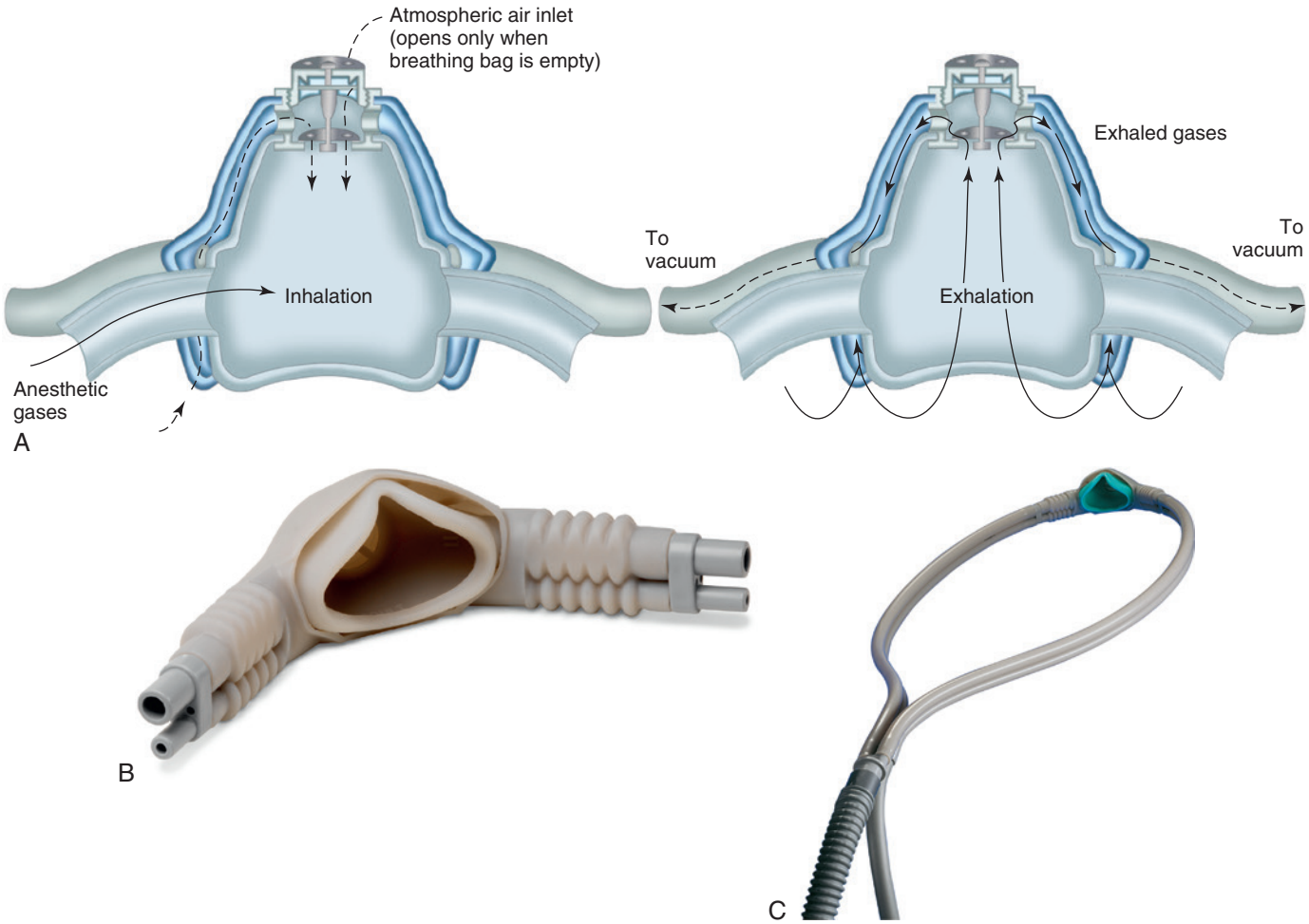
• **Fig. 6.21** Pin index system is used to prevent attaching the wrong gas to the wrong port of the continuous-flow sedation unit/controller. Note the differing patterns of depression below the gas exit port for (A) oxygen and (B) nitrous oxide.



• **Fig. 6.22** Example of a continuous-flow sedation unit/controller used to create the desired N_2O:O_2 blend. *(1)* Master control (on-off), *(2)* controls for O_2 and N_2O, *(3)* flowmeters, *(4)* O_2 flushing button, *(5)* attachment site for reservoir bag, *(6)* one-way valve to patient.

• **Fig. 6.23** Examples of inhalation sedation control units.

being done, the clinician should check for proper mask adaptation to the patient's face as well as allow the patient a few minutes to become accustomed to the mask and thus able to tolerate the mask. After a few minutes of preoxygenation, the amount of nitrous oxide (N_2O)/oxygen (O_2) flows should be adjusted to deliver a 20%/80% N_2O:O_2 mix. For the vast majority of patients this will not produce any effect; nonetheless, after 2 minutes at this level the patient should be queried as to whether they are beginning to sense any changes in mood or other sensations. If they are not, the gas mix should be changed to 30%:70% N_2O:O_2. Again, after 2 minutes at this level the patient should be queried as to whether they are beginning to sense any changes in mood or other sensations. If they are, they should be asked if the feelings are good or bad. If bad, the percentage of N_2O should be lowered to 25%, and after 2 minutes the patient should be asked if they still feel any effect and whether it is positive or negative. If negative, it may be that the patient cannot tolerate even low levels of N_2O and the attempt at inhalation sedation is then ended. However, if the patient feels no effect at 30% N_2O or some positive effects, the clinician should raise the N_2O percentage to 35%. Again, after 2 minutes the patients should be asked whether they can now feel some effects or if they previously felt some positive effects, whether or not the effects became more positive. If they became more positive and the patient is feeling relaxed, the practitioner can proceed with local anesthesia and the surgery. If the patient feels that the previously positive effects are not as positive as at 30%, the doctor can lower the N_2O concentration to 32% or 33% to try to fine-tune the sedative effects. Titration of the gas mixture should continue until the patient feels relaxed and is enjoying the experience. Once a good level is reached, clinical care can move forward. Note that some patients who have regular experience being in mind-altering states may desire higher doses of N_2O, but it is important to make sure their mask fits properly and that they are breathing in and out of their nose. The clinician must use their judgment as to how high a concentration of N_2O to provide in such circumstances. Generally, levels of N_2O above 50% should



• **Fig. 6.24** (A) Nasal hood that patient wears when receiving nitrous oxide sedation. Note that during exhalation the expired air is vacuumed through a one-way valve into the scavenging system. (B) Nasal hood designed to deliver oxygen and nitrous oxide and scavenge expired air. (C) Nasal hood connected to tubing that then connects to the O_2-N_2O feeder tubing and the scavenging tubing.

be avoided, and when levels above 40% are in use, monitor the patient's mood since in some circumstances patients may suddenly become disoriented or even combative. In addition, for longer procedures the dentist should regularly check that the patient is still relaxed and feeling good. Patients can begin to find the nitrous oxide effects less comfortable and need a break from the sedation. Fortunately, once the patient begins to breathe 100% oxygen or room air, the effects of the N_2O rapidly dissipate. This also occurs once the need for sedation ends and the patient is placed on 100% oxygen for about 5 minutes to recover.

Important Caveats to Use of Nitrous Oxide

There are a few important caveats to the use of nitrous oxide sedation. First, like other procedures in dental care, even though it is very safe to use, patients must give informed consent to nitrous oxide sedation. Second, like all drugs administered to patients, the dental records must document the patient's vital signs and dose of drug used while undergoing nitrous oxide sedation. This is also useful since once the optimal mixture of nitrous oxide and oxygen is determined, the same optimal dose is likely to be effective thus gradual titration becomes unnecessary. Third, there are rare instances in which patients under the influence of nitrous oxide experience erotic delusions. Therefore a member of the gender opposite that of the operating surgeon should always be present during the use of nitrous oxide. Fourth, someone on the clinical staff should always be present with the patient while nitrous oxide is in use and during the recovery period.

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PART II

Principles of Exodontia

For most laypersons the term *oral surgery* usually brings to mind the removal of a tooth. The atraumatic extraction of a tooth is a procedure that requires finesse, knowledge, and skill on the part of the surgeon. The purpose of this section is to present the principles of exodontia as well as the instrumentation, techniques, and management of patients who are undergoing extraction surgery.

Chapter 7 presents the armamentarium commonly used for exodontia. The basic instrumentation and the fundamental applications of instruments to their surgical purposes are illustrated and discussed.

Chapter 8 presents the basic aspects of how to remove an erupted tooth atraumatically. The preoperative assessment and preparation of the patient are briefly discussed. The position of the patient in the chair and the position of the surgeon and the surgeon's hands for the removal of teeth in various parts of the mouth are detailed. The armamentarium and movements necessary to extract each type of tooth are presented in illustrations and descriptions.

Chapter 9 presents the basic aspects of managing complicated extractions (commonly termed *surgical extractions*). Surgical extractions primarily involve retrieving tooth roots and teeth that are likely to fracture, have fractured, or, for some other reason, pose an obstacle to extraction. In these situations, surgical removal of bone or surgical sectioning of the tooth is commonly required.

Chapter 10 presents the fundamental aspects of the management of impacted teeth. The rationale for timely removal of impacted teeth is presented in the initial portion of the chapter. Classification and determination of the degree of difficulty of the impaction follows. Finally, a brief description of the basic surgical techniques required to remove impacted third molars is provided.

Chapter 11 presents the techniques for managing the patient during the postoperative period. This chapter discusses postoperative instructions that should be given to the patient as well as typical postoperative medications. The chapter goes on to cover common surgical sequelae and complications that are encountered in the removal of teeth. Emphasis is placed on anticipating sequelae and complications and taking measures to prevent or minimize them.

Chapter 12 discusses the medical and legal considerations involved in basic exodontia. An important portion of this chapter discusses the concept of informed consent for the patient as it relates to exodontia. Patient privacy rights are also covered.

7

Instrumentation for Basic Oral Surgery

JAMES R. HUPP

CHAPTER OUTLINE

This chapter is designed to introduce the instrumentation commonly used to perform routine dental extractions and other basic oral surgical operations. The instruments illustrated and described are used for a wide variety of purposes, including soft and hard tissue procedures. This chapter primarily provides a description of instruments; their use is discussed in subsequent chapters.

Incising Tissue

Many surgical procedures begin with an incision. The primary instrument for making incisions is the scalpel, which is composed of a handle and a sterile, very sharp blade (Fig. 7.1). Scalpels are available as single-use instruments with plastic handles and fixed blades; scalpel handles to which disposable blades can be attached are also available. The most commonly used handle for oral surgery is the No. 3 handle. The tip of a scalpel handle is configured to receive a variety of differently shaped scalpel blades that are inserted onto the slotted portion of the handle.

The most frequently used scalpel blade for intraoral surgery is the No. 15 blade (Fig. 7.2). The blade is small and is used to make incisions around teeth and through soft tissue. The blade is similar in shape to the larger No. 10 blade, which is used for large skin incisions in other parts of the body. Other commonly used blades for intraoral surgery include the No. 11 and No. 12 blades. The No. 11 blade is a sharp-pointed blade that is used primarily for making small stab incisions as for incising an abscess to establish drainage. The hooked No. 12 blade is useful for mucogingival procedures in which incisions are made on the posterior aspects of teeth or in the maxillary tuberosity area.

The scalpel blade must be carefully loaded onto the handle, ideally holding the blade with a needle holder. This lessens the chance of injuring one's fingers. The blade is held along the unsharpened edge, where it is reinforced with a small rib, and the handle is held so that the male portion of the fitting is pointing upward (Fig. 7.3A). The scalpel blade is then slowly slid onto the handle along the grooves in the male portion until it clicks into position (see Fig. 7.3B).

The scalpel is unloaded in a similar manner. The needle holder grasps the end away from the blade (see Fig. 7.3C) and lifts it to disengage it from the male fitting. The scalpel is then slid off the handle, always away from the body and anyone nearby (see Fig. 7.3D). The used blade is immediately discarded into a specifically designed rigid-sided sharps container (see Fig. 5.6C).

When using the scalpel to make an incision, the surgeon typically holds the handle in the pen grasp (Fig. 7.4) to allow maximal control of the blade as the incision is made. For maximum cutting efficiency, mobile tissue should be held firmly in place under some tension so that as the incision is made, the blade will incise and not just push away the mucosa. When incising depressible soft tissue, an instrument such as a retractor should be used to hold the tissue taut while incising. When a full-thickness mucoperiosteal incision is desired, the blade should be pressed down firmly so that the incision penetrates the mucosa and periosteum with the same stroke.

Fig. 7.1 A scalpel is composed of a handle and a sharp blade. *Top,* Reusable scalpel No. 3 handle with single-use blade (a No. 15 blade is most commonly used for oral surgery). *Bottom,* Single-use handle-blade unit with No. 15 blade.

Fig. 7.2 Scalpel blades used in oral surgery include No. 10, No. 11, No. 12, and No. 15 (left to right).

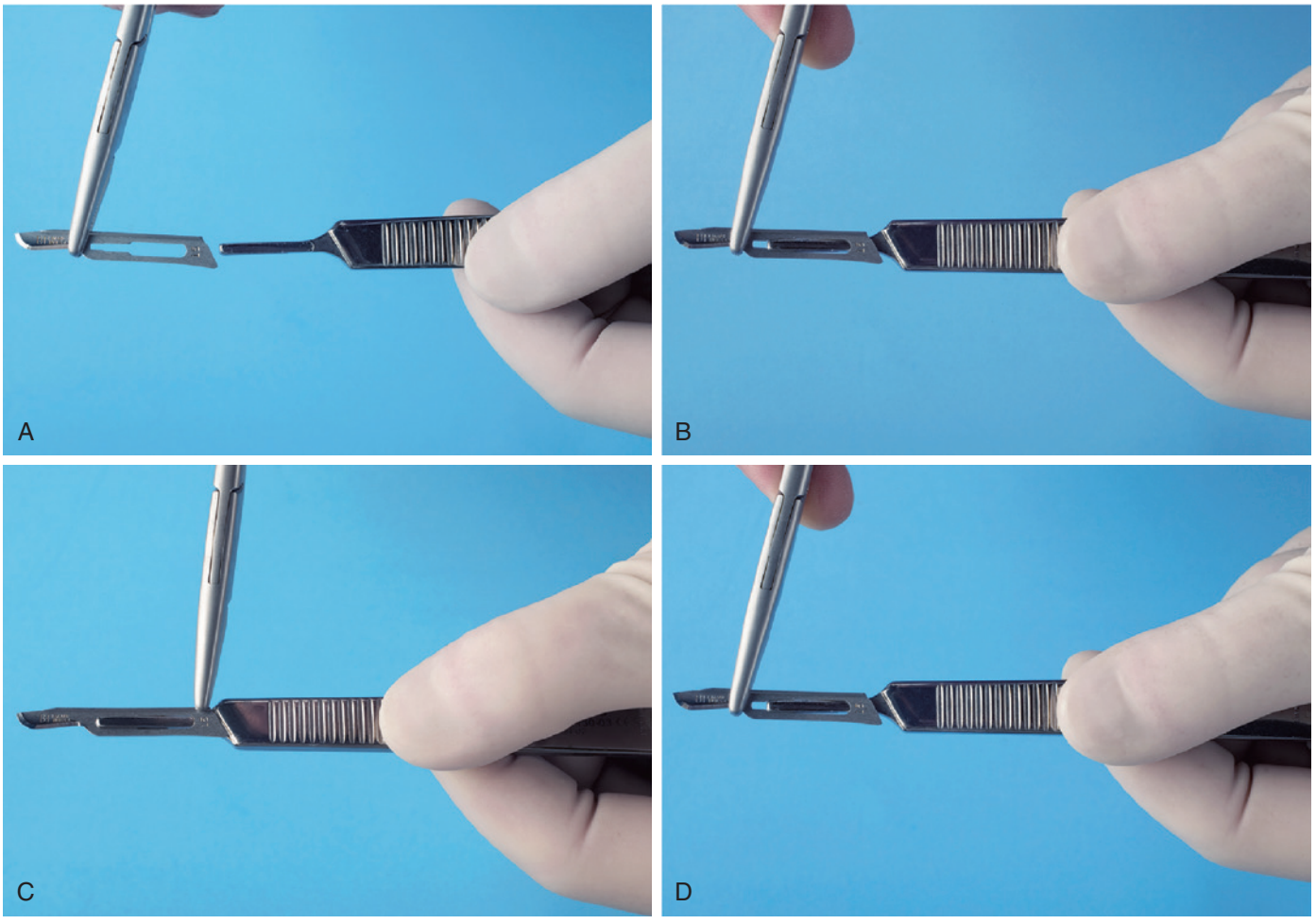


Fig. 7.3 (A) When loading a scalpel blade, the surgeon holds the noncutting portion of the blade in the needle holder and handle, with the male portion of the fitting pointing upward. (B) The surgeon then slides the blade into the handle until it clicks into place. (C) To remove the blade, the surgeon uses the needle holder to grasp the end of the blade next to the handle and lifts it to disengage it from the fitting. (D) The surgeon then gently slides the blade off the handle away from the body and anyone nearby.

Scalpel blades are designed for single-patient use. Blades dull easily when they come into contact with hard tissue such as bone or teeth and even after repeated strokes through keratinized tissue. If several incisions through the mucoperiosteum to bone are required, it may be necessary to use additional blades during a single operation. Dull blades do not make clean, sharp incisions in soft tissue and therefore should be replaced before they become overly dull.

Elevating the Mucoperiosteum

The tissue plane between periosteum and bone is relatively bloodless and well defined. When an incision is made through the periosteum, ideally the periosteum should be reflected from the underlying cortical bone in a single subperiosteal layer with a periosteal elevator. The instrument that is most commonly used in oral surgery is the No. 9 Molt periosteal elevator (Fig. 7.5). This instrument has a sharp, pointed end and a broader, rounded end. The pointed end is used to begin the periosteal reflection and to reflect dental papillae from between teeth, whereas the broad, rounded end is used to continue the elevation of the periosteum from bone.

The No. 9 Molt periosteal elevator is typically used to reflect tissue by two methods. In the first method, the pointed end is used in a twisting, prying motion to elevate soft tissue, most commonly when elevating a dental papilla from between teeth or the attached gingiva around a tooth to be extracted or when beginning to elevate a full thickness mucoperiosteal flap. The second method involves the push stroke in which the side of the pointed end or the broad end of the instrument is slid underneath the periosteum, separating it from the underlying bone. This is the most efficient stroke that results in the cleanest reflection of periosteum.

There are other types of periosteal elevators for use by periodontists, orthopedic surgeons, and other surgeons involved in work on bones.

Retracting Soft Tissue

Good access and vision are critical to performing excellent surgery. A variety of retractors have been specifically designed to retract the cheek, tongue, and mucoperiosteal flaps to provide access and visibility during surgery. Retractors are also used to help protect soft tissue from sharp cutting instruments.

The two most popular cheek retractors are (1) the right-angle Austin retractor (Fig. 7.6) and (2) the broad offset Minnesota retractor (Fig. 7.7). These retractors can also be used to retract the cheek and a mucoperiosteal flap simultaneously. Before the flap is created, the retractor is held loosely in the cheek. Once the flap is reflected, the retractor edge is placed on bone and is then used to retract the flap.

The Henahan and Seldin retractors are other types of instruments used to retract oral soft tissue (Fig. 7.8). Although these retractors may look similar to a periosteal elevator, the leading edge is not sharp but, instead, smooth; these instruments are not typically used to elevate the mucoperiosteum. The No. 9 Molt periosteal elevator can also be used as a retractor for small flaps. Once the periosteum has been elevated, the broad blade of the periosteal elevator is held firmly against bone, with the mucoperiosteal flap elevated into a reflected position.

The instrument most commonly used to retract the tongue during routine exodontia is the mouth mirror. This is usually part of every basic setup because it is useful for examining the mouth and for indirect visualization during dental procedures. The Weider tongue retractor is a broad, heart-shaped retractor that is serrated on one side so that it can more firmly engage the tongue and retract it medially and anteriorly (Fig. 7.9A). When this retractor is used, care must be taken not to position it so far posteriorly as to cause gagging or to push the tongue into the oropharynx (see Fig. 7.9B).

A towel clip (see Fig. 7.28) can also be used to hold the tongue in certain circumstances. When a biopsy procedure is to be

Fig. 7.4 The scalpel handle is held in the pen grasp to allow maximal control.

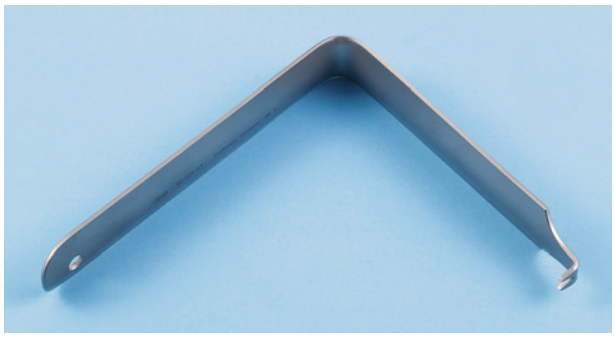


Fig. 7.6 The Austin retractor is a right-angle retractor that can be used to retract the cheek, tongue, or flaps.

Fig. 7.5 The No. 9 Molt periosteal elevator is most commonly used in oral surgery.

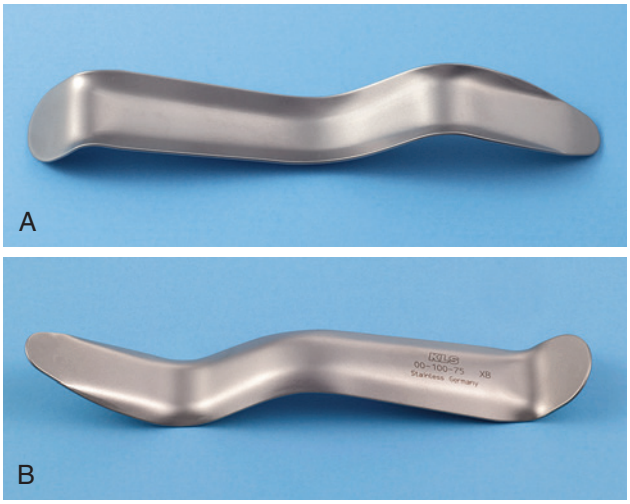


Fig. 7.7 The Minnesota retractor is an offset retractor used to retract the cheek and flaps. (A) Front. (B) Back.

Fig. 7.8 The Henahan (top) and Seldin (bottom) retractors are broader instruments that provide broader retraction and increased visualization.

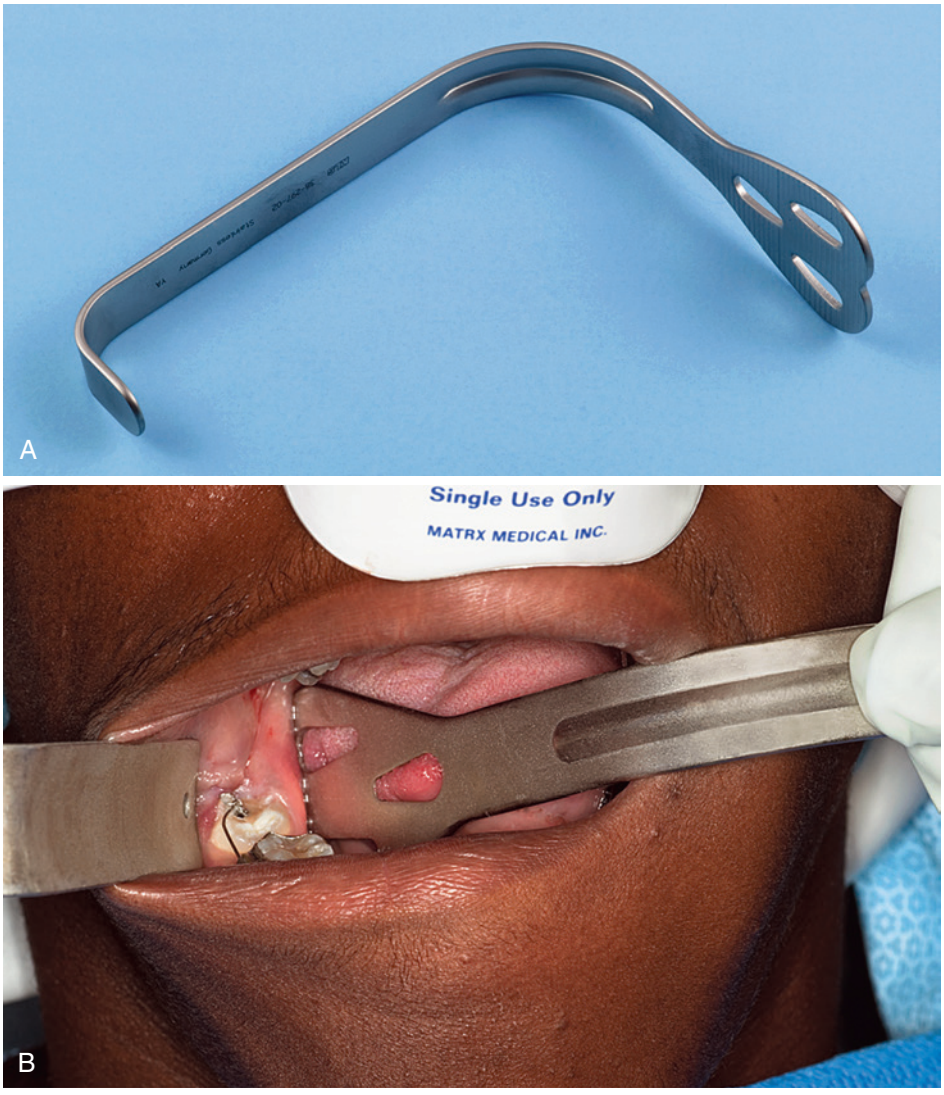


Fig. 7.9 (A) The Weider retractor is a large retractor designed to retract the tongue. The serrated surface helps engage the tongue so that it can be held securely. (B) The Weider retractor is used to hold the tongue away from the surgical field. The Austin retractor is used to retract the cheek.

performed on the posterior aspect of the tongue, the most positive way to control the tongue is by holding the anterior tongue with a towel clip. Local anesthesia must be profound where the clip is placed, and, if anticipated, it is wise to mention to the patient that this method of retraction may be used.

Grasping Soft Tissue

Various oral surgical procedures require the surgeon to grasp soft tissue to incise it, to stop bleeding, or to pass a suture needle. The instrument most commonly used for this purpose is the Adson forceps (or pickup; Fig. 7.10A). These are delicate forceps, with or without small teeth at the tips, that can be used to hold tissue gently while stabilizing it. When this instrument is used, care should be taken not to grasp the tissue too tightly to avoid crushing it. Toothed forceps allow tissue to be securely held with a more delicate grip than untoothed forceps.

When working in the posterior part of the mouth, the Adson forceps may be too short. Longer forceps that have a similar shape are the Stillies forceps. These forceps are usually 7 to 9 inches long and can easily grasp tissue in the posterior part of the mouth, still leaving enough of the instrument protruding beyond the lips for the surgeon to hold and control it (see Fig. 7.10B).

Occasionally it is more convenient to have an angled forceps. These include the college, or cotton, forceps (they are also called *cotton pliers*) (see Fig. 7.10B). Although these forceps are not especially useful for handling tissue, they are an excellent instrument for picking up loose fragments of tooth, amalgam, or other foreign material and for placing or removing gauze packs.

In some types of surgery, especially when removing larger amounts of tissue or doing biopsies, such as in an epulis fissurata, forceps with locking handles and teeth that will firmly grip the tissue are necessary. In this situation, the Allis tissue forceps are used (Fig. 7.11A–B). The locking handle allows the forceps to be placed in the proper position and then to be held by an assistant to provide the necessary tension for proper dissection of the tissue. The Allis forceps should never be used on tissue that is to be left in the mouth because they cause a relatively large amount of tissue crushing (see Fig. 7.11C). However, the forceps can be used to grasp the tongue in a manner similar to a towel clamp.

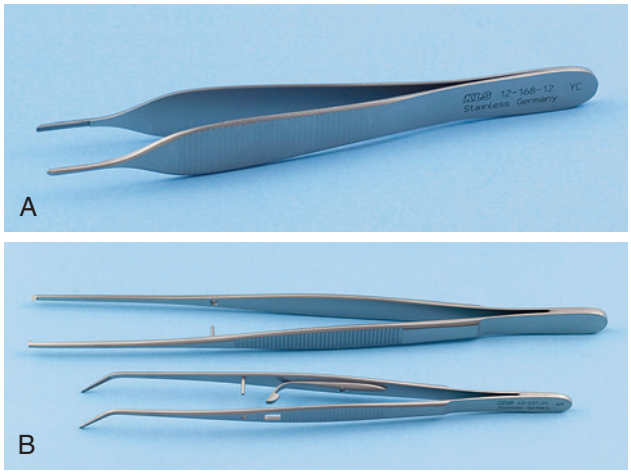


Fig. 7.10 (A) Small, delicate Adson tissue forceps are used to gently stabilize soft tissue for suturing or dissection. (B) The Stillies pickup (top) is longer than the Adson pickup and is used to handle tissue in the more posterior aspect of the mouth. The college pliers (bottom) are angled forceps that are used for picking up small objects in the mouth or from the tray stand. The college pliers shown here represent the locking version.

Controlling Hemorrhage

When incisions are made through tissue, small arteries and veins are incised, causing bleeding. For most dentoalveolar surgery, pressure on the wound is usually sufficient to control bleeding. Occasionally pressure does not stop the bleeding from a larger artery or vein. When this occurs, an instrument called a *hemostat* is useful (Fig. 7.12A). Hemostats come in a variety of shapes; they may be small and delicate or larger and are either straight or curved. The hemostat most commonly used in surgery is the curved hemostat (see Fig. 7.12B).

A hemostat has long, delicate beaks that are used to grasp tissue and a locking handle. The locking mechanism allows the surgeon to clamp the hemostat onto a vessel and then let go of the instrument or let an assistant hold it. The tip of the hemostat will remain clamped onto the tissue. This is useful when the surgeon plans to

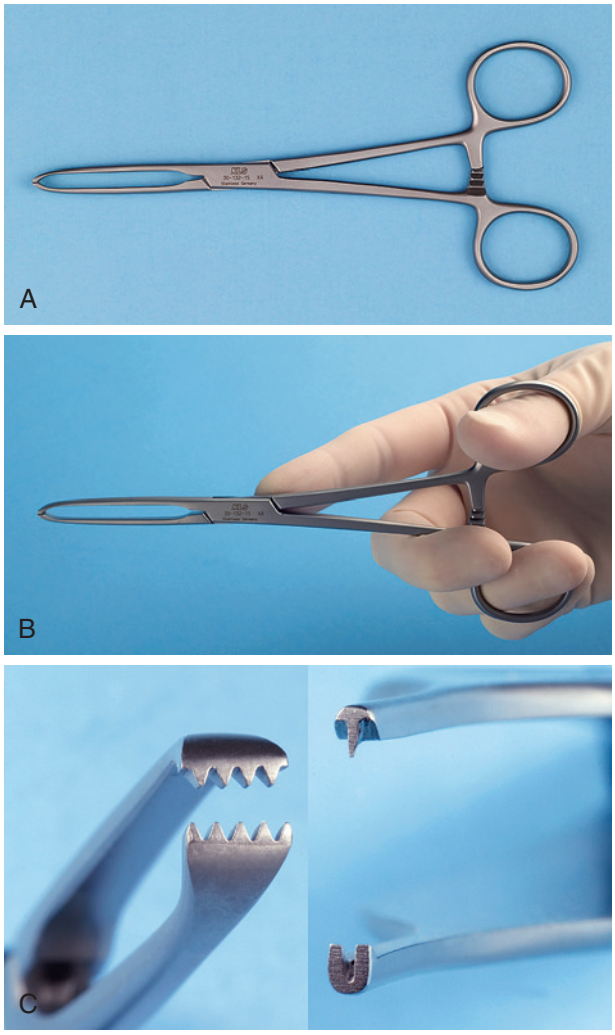


Fig. 7.11 (A) Allis tissue forceps are useful for grasping and holding tissue that will be excised. (B) Allis forceps are held in the same fashion as the needle holder. (C) Comparison of Adson beaks (right) with Allis beaks (left) shows the differences in their designs and uses.

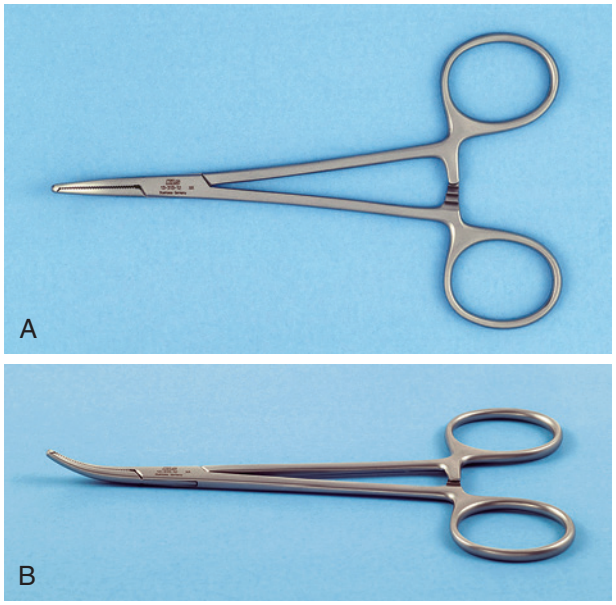


Fig. 7.12 (A) Superior view of the hemostat used for oral surgery. (B) Oblique view of the curved hemostat. Straight hemostats are also available.

place a suture around the vessel or to cauterize it (i.e., use heat to sear the vessel closed).

In addition to its use as an instrument for controlling bleeding, the hemostat is especially useful in oral surgery to remove granulation tissue from tooth sockets and to pick up small root tips, pieces of calculus, amalgam, fragments, and any other small particles that have dropped into the wound or adjacent areas. However, it should never be used to suture.

Removing Bone

Rongeurs

The instrument most commonly used for removing bone in dentoalveolar surgery is the rongeur forceps. This instrument has sharp blades that are squeezed together by the handles, cutting or pinching through bone. Rongeur forceps have a rebound mechanism incorporated so that when hand pressure is released, the instrument reopens. This allows the surgeon to make repeated bone-trimming actions without manually reopening the instrument (Fig. 7.13A). The two major designs for rongeur forceps are (1) a side-cutting forceps and (2) the side- and end-cutting forceps (see Fig. 7.13B).

The side-cutting and end-cutting rongeurs are more practical for most dentoalveolar surgical procedures that require bone removal. The end-cutting forceps can be inserted into sockets for the removal of interradicular bone and can also be used to remove sharp edges of bone. Rongeurs can be used to remove large amounts of bone efficiently and quickly. Because a rongeur is a delicate instrument, the surgeon should not use it to remove large amounts of bone in single bites. Rather, smaller amounts of bone should be removed in multiple bites. Likewise, the rongeur should never be used to remove teeth because this practice will quickly dull and destroy the instrument and risks losing a tooth in the patient's throat because a rongeur is not designed to hold an extracted tooth firmly. Rongeurs are expensive, so care should be taken to keep them sharp and in working order.

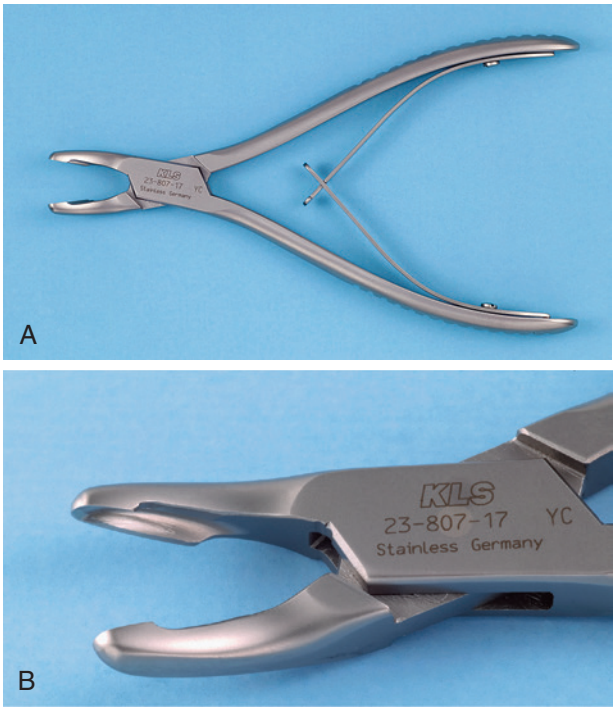


Fig. 7.13 (A) Rongeurs are bone-cutting forceps that have spring-loaded handles. (B) Blumenthal rongeurs comprise both end- and side-cutting blades. They are preferred for oral surgery procedures.

Fig. 7.14 Typical moderate-speed high-torque sterilizable handpiece with No. 703 burr.

Burr and Handpiece

Another method for removing bone is with a burr in a handpiece. This is the technique that most surgeons use when removing bone for the surgical removal of teeth. Moderate-speed, high-torque handpieces with sharp carbide burrs remove cortical bone efficiently (Fig. 7.14). Burrs such as No. 557 or No. 703 fissure burr and No. 8 round burr are used. When large amounts of bone must be removed, as in torus reduction, a large-bone burr that resembles an acrylic burr is typically used.

Any handpiece that is used for oral surgery must be completely sterilizable. When a handpiece is purchased, the manufacturer's specifications must be checked carefully to ensure that they can be met. The handpiece should have high speed and torque. This allows rapid bone removal and efficient sectioning of teeth. The handpiece must not exhaust air into the operative field, which would make it improper to use the typical high-speed air-turbine drills employed in routine restorative dentistry. The reason is that the air exhausted into the wound may be forced into deeper tissue planes and produce tissue emphysema, a dangerous occurrence.

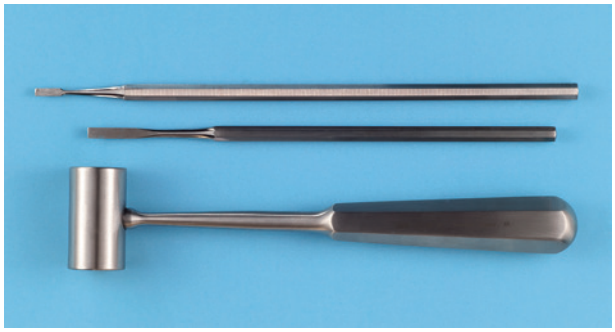


Fig. 7.15 The surgical mallet and chisel can be used for removing bone.

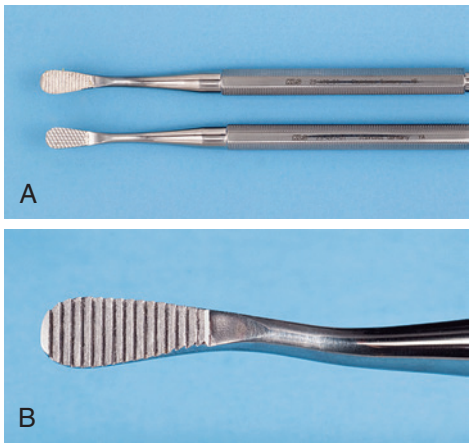


Fig. 7.16 (A) The double-ended bone file is used for smoothing small, sharp edges or spicules of bone. (B) The teeth of this bone file are effective only in the pull stroke.

Mallet and Chisel

Occasionally bone removal is performed using a mallet and chisel (Fig. 7.15), although the availability of high-speed handpieces for removing bone and sectioning teeth has greatly limited the need for mallets and chisels. The mallet and chisel are sometimes used in removing lingual tori. The edge of the chisel must be kept sharp if it is to function effectively (see Chapter 13).

Bone File

Final smoothing of bone before the completion of surgery is usually performed with a small bone file (Fig. 7.16A). The bone file is usually a double-ended instrument with small and larger ends. The bone file cannot be used efficiently for removal of large amounts of bone; therefore it is used only for final smoothing. The teeth of most bone files are arranged in such a fashion that they properly remove bone only on a pull stroke (see Fig. 7.16B). Pushing this type of bone file against bone results only in burnishing and crushing the bone and should be avoided.

Removing Soft Tissue From Bony Cavities

The curette commonly used for oral surgery is an angled, double-ended instrument used to remove soft tissue from bony defects (Fig. 7.17). Its principal use is to remove granulomas or small cysts from periapical lesions, but the curette may also be used to remove small amounts of granulation tissue debris from a tooth socket. Larger currettes are available for removing soft tissue from larger bony cavities such as cysts. Note that the periapical curette is distinctly different in design and function from the periodontal curette.

Fig. 7.17 The periapical curette is a double-ended, spoon-shaped instrument used to remove soft tissue from bony cavities.

Fig. 7.18 A needle holder has a locking handle and a short, blunt beak.

Suturing Soft Tissue

Once a surgical procedure has been completed, the mucoperiosteal flap is returned to its original position and held in place by sutures. The needle holder is the instrument used to place the sutures.

Needle Holder

The needle holder is an instrument with a locking handle and a short, blunt beak. For intraoral placement of sutures, a 7-inch (15-cm) needle holder is usually recommended (Fig. 7.18). The beaks of a needle holder are shorter and stronger than the beaks of a hemostat (Fig. 7.19). The face of the shorter beak of the needle holder is cross-hatched to permit a positive grasp of the suture needle. The hemostat has parallel grooves on the face of the beaks, thereby decreasing the control over needle and suture. Therefore the hemostat is not an instrument used for suturing.

To control the locking handles properly and to direct the long needle holder, the surgeon must hold the instrument in the proper fashion (Fig. 7.20). The thumb and ring finger are inserted through the rings. The index finger is held along the length of the needle holder to steady and direct it. The second finger aids in controlling the locking mechanism. The index finger should not be put through the finger ring because this will result in a dramatic decrease in control.

Suture Needle

The needle used in closing oral mucosal incisions is usually a small half-circle or three-eighths–circle suture needle. The needle is curved to allow it to pass through a limited space where a straight needle cannot reach, and passage can be done with a twist of the wrist.

Suture needles come in a large variety of shapes, from very small to very large (Fig. 7.21A). The tips of suture needles either

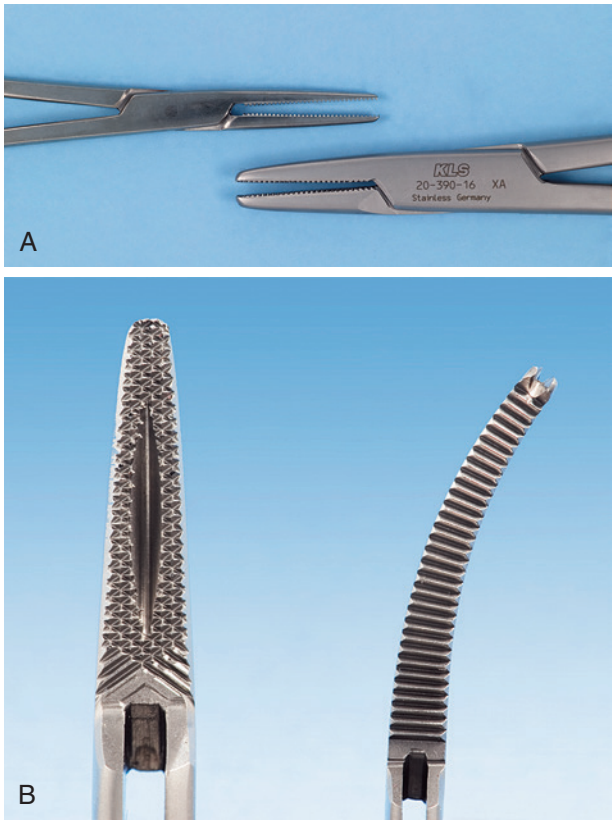


Fig. 7.19 (A) The hemostat (top) has a longer, thinner beak compared with the needle holder (bottom) and therefore should not be used for suturing. (B) The face of the shorter beak of the needle holder is cross-hatched to ensure a positive grip on the needle (left). The face of the hemostat has parallel grooves that do not allow a firm grip on the needle (right).

are tapered like sewing needles or have triangular tips that allow them to be cutting needles. A cutting needle will pass through the mucoperiosteum more readily than a tapered needle (see Fig. 7.21B). The cutting portion of the needle extends about one-third the length of the needle, and the remaining portion of the needle is rounded. Tapered needles are used for more delicate tissues, as in ocular or vascular surgery. Care must be taken with cutting needles because, if not used correctly, they can cut through tissue lateral to the track of the needle. The suture material used for oral surgery is usually purchased already swaged on (by fusing the end of a suture onto a needle) by the manufacturer.

The curved needle is held approximately two-thirds of the distance between the tip and the base of the needle (Fig. 7.22). This allows enough of the needle to be exposed to pass through the tissue while allowing the needle holder to grasp the needle in its strong portion to prevent bending of the needle or dulling of the tip. Techniques for placing sutures are further discussed in Chapter 8.

Suture Material

Many types of suture materials are available. The materials are classified by diameter, resorbability, and whether they are monofilament or polyfilament.

The size of suture relates to its diameter and is designated by a series of zeros. The diameter most commonly used in the suturing of oral mucosa is 3-0 (000). A larger-sized suture is 2-0, or 0. Smaller sizes are designated with more zeros, for example 4-0, 5-0, and 7-0. Sutures of very fine size, such as 7-0, are usually used in conspicuous places on the skin—for example, the face—because properly placed smaller sutures usually cause less scarring. Sutures of size 3-0 are large enough to withstand the tension placed on them intraorally and strong enough for easier knot tying with a needle holder compared with smaller-diameter sutures.

Sutures may be resorbable or nonresorbable. Nonresorbable suture materials include such types as silk, nylon, vinyl, and stainless steel. The most commonly used nonresorbable suture in the oral cavity is silk. Nylon, vinyl, and stainless steel are rarely used in the mouth. Resorbable sutures are primarily made of gut. Although the term *catgut* is often used to designate this type of suture, gut actually is derived from the serosal surface of sheep intestines. Plain catgut resorbs quickly in the oral cavity, rarely lasting longer than 3 to 5 days. Gut that has been treated with a tanning solution (chromic acid) is called *chromic gut* and lasts longer than plain gut by up to 7 to 10 days. Several synthetic resorbable sutures are also available. These materials consist of long chains of polymers braided into suture material. Examples are polyglycolic acid and polylactic acid. These materials are slowly resorbed, taking up to 4 weeks to do so. Such long-lasting resorbable sutures are rarely indicated for basic oral surgery.

Finally, sutures are classified on the basis of their being monofilament or polyfilament. Monofilament sutures are sutures such as plain and chromic gut, nylon, and stainless steel. Polyfilament sutures are braided sutures such as silk, polyglycolic acid, and polylactic acid. Sutures that are made of braided material are easier to handle and tie than monofilament sutures and rarely come untied. The cut ends are usually soft and nonirritating to the tongue and surrounding soft tissues. However, because of the multiple filaments, they tend to "wick" oral fluids along the suture to the underlying tissues. This wicking action may carry bacteria along with saliva. Monofilament sutures do not cause this wicking action but may be more difficult to tie and tend to come untied. Also the cut ends are stiffer, being more irritating to the tongue and soft tissue.

One of the most commonly used sutures for the oral cavity is 3-0 black silk. The size 3-0 has the appropriate amount of strength; the polyfilament nature of the silk makes it straightforward to tie and well tolerated by the patient's soft tissues. The color makes the suture easy to see when the patient returns for suture removal. Sutures that are holding mucosa together usually stay no longer than 5 to 7 days, so the wicking action is of little clinical importance. Many surgeons prefer 3-0 chromic suture to avoid the need to later remove it. (Techniques for suturing and knot tying are presented in Chapter 8.)

Scissors

The final instruments necessary for placing sutures are suture scissors (Fig. 7.23). Suture scissors usually have short cutting edges because their sole purpose is to cut sutures. The most commonly used suture scissors for oral surgery are Dean scissors. These have slightly curved handles and serrated blades that make cutting sutures easier. Suture scissors usually have long handles and thumb and finger rings. Scissors are held in the same manner as needle holders.

Other types of scissors are designed for cutting soft tissue. The two major types of tissue scissors are iris scissors and Metzenbaum scissors (Fig. 7.24). These scissors can have straight or curved blades. Iris scissors are small, sharp-pointed, delicate tools used for fine work. Metzenbaum scissors are used for undermining soft tissue and for cutting. They can have either sharp or blunt (rounded) tips. Tissue scissors such as iris or Metzenbaum scissors should not be used to cut sutures because the suture material will dull

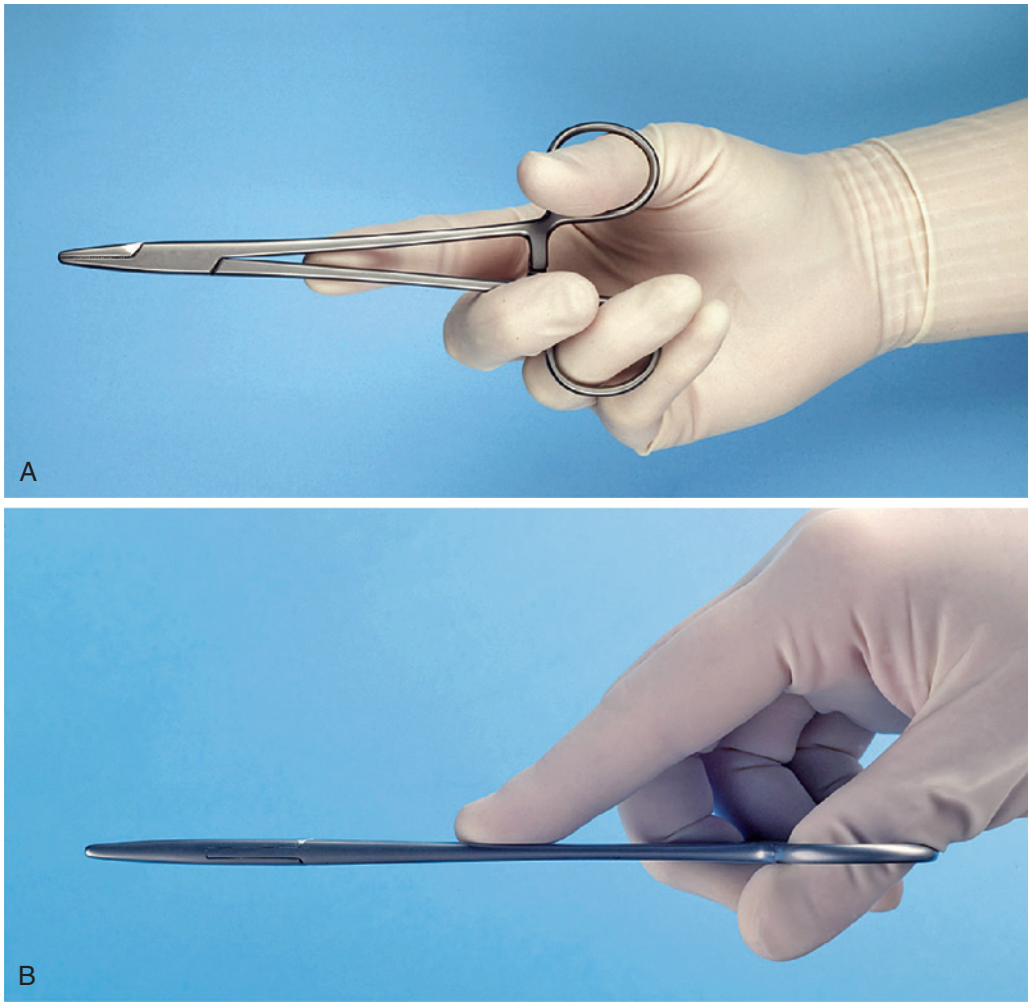


Fig. 7.20 The needle holder is held by using the thumb and ring finger in rings (A) and the first and second fingers to control the instrument (B).

the edges of the blades and make them less effective and more traumatic when cutting tissue.

Holding the Mouth Open

In performing extractions of mandibular teeth, it is necessary to support the mandible to prevent stress on the temporomandibular joint (TMJ). Supporting the patient's jaw on a bite block will help protect the joint. The bite block is just what the name implies (Fig. 7.25). It is a soft, rubber-like block on which the patient can rest his or her teeth. The patient opens the mouth to a comfortably wide position, the rubber bite block is inserted, and the block holds the mouth in the desired position without effort on the patient's part. Bite blocks come in several sizes to fit variously sized patients and produce varying degrees of opening. Should the surgeon need the mouth to be opened wider using any size of bite block, the patient must open his or her mouth more widely and the bite block must be positioned more to the posterior of the mouth. For most adult patients, a pediatric-sized bite block is adequate when placed over the molar teeth.

The side-action mouth prop or Molt mouth prop (Fig. 7.26) can be used by the operator to open the mouth wider if necessary. This mouth prop has a ratchet-type action, opening the mouth wider as the handle is closed. This type of mouth prop should be used with caution because great pressure can be applied to the teeth and the TMJ and injury may occur with injudicious use. This type of mouth prop is useful in patients who are deeply sedated or have mild forms of trismus.

Whenever a bite block or side-action mouth prop is used, the surgeon should take care to avoid opening the patient's mouth too much because it may cause stress on the TMJ. Occasionally this may result in stretch injury to the joint, necessitating additional treatment. When long procedures are being performed, it is a good idea to remove the prop periodically and allow the patient to move the jaw and rest the muscles for a short time.

Removing Fluids

To provide adequate visualization, blood, saliva, and irrigating solutions must be removed from the operative site. Surgical suction has a smaller orifice than the type used in general dentistry to more rapidly evacuate fluids from the surgical site to maintain adequate visualization. Many of these suction tips are designed with several orifices so that the soft tissue will not become aspirated into the suction hole and cause tissue injury (Fig. 7.27A).

The Fraser suction has a hole in the handle portion that can be covered with a fingertip as needed. When hard tissue is being cut under copious irrigation, the hole is covered so that the solution is removed rapidly. When soft tissue is being suctioned, the hole

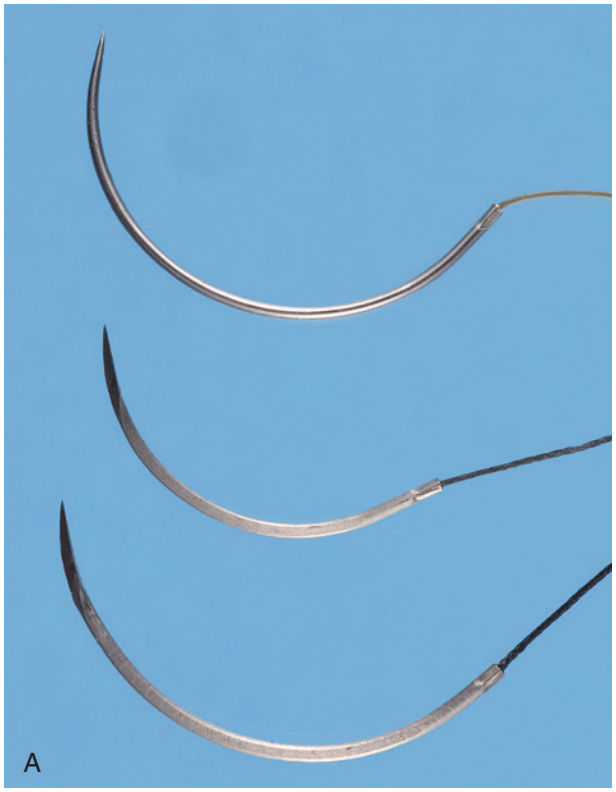


Fig. 7.21 (A) Comparison of needles used in oral surgery. *Top*, C-17 needle, which usually holds a size 4-0 suture. *Middle*, PS-2 needle. *Bottom*, SH. All are cutting needles, and the suture material is swaged onto the needle. (B) The tip of the needle used to suture mucoperiosteum is triangular in cross section to make it a cutting needle.

Fig. 7.22 The needle holder grasps the curved needle two-thirds of the distance from the tip of the needle.

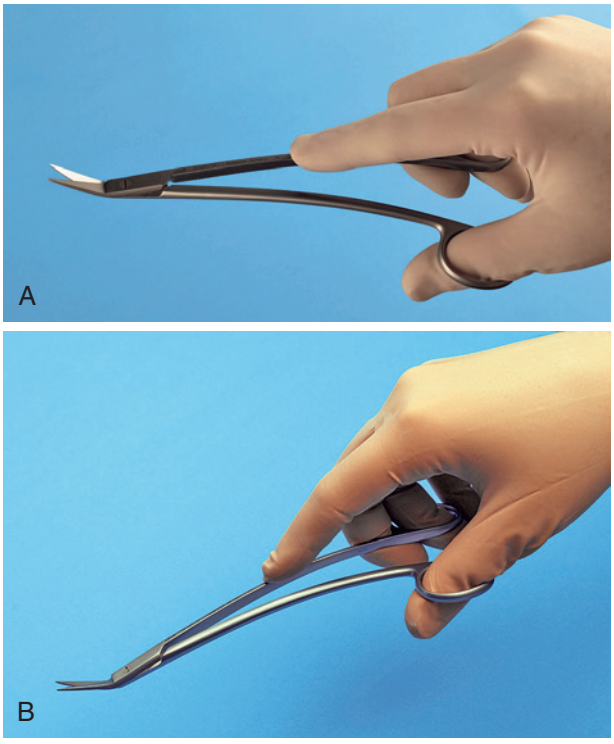


Fig. 7.23 Suture scissors should be held in the same fashion as the needle holder.

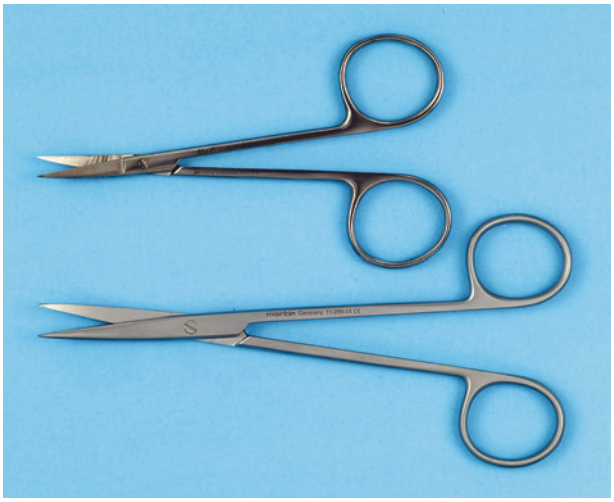


Fig. 7.24 Soft tissue scissors are of two designs: Iris scissors (top) are small, sharp-pointed scissors. Metzenbaum scissors (bottom) are longer, more delicate scissors. Metzenbaum scissors are available as either sharp tipped (shown here) or blunt tipped.

can be left uncovered to prevent tissue injury or soft tissue obstruction of the suction tip (see Fig. 7.27B).

Holding Towels and Drapes in Position

When drapes are placed around a patient, they can be held together with a towel clip (Fig. 7.28). This instrument has a locking handle and finger and thumb rings. The action ends of the towel clip can be sharp or blunt. Those with curved points penetrate the towels and drapes. When this instrument is used, the operator must exercise extreme caution so as not to pinch the patient's underlying skin.

Fig. 7.25 (A) The bite block is used to hold the patient's mouth open in the position chosen by the patient. (B) The sides of the bite block are corrugated to provide a surface for teeth to engage. (C) The blocks come in a variety of sizes.

Fig. 7.26 The side-action, or Molt, mouth prop can be used to open the patient's mouth when the patient is unable to cooperate, such as during sedation or in the presence of some degree of trismus.

Irrigating

When a handpiece and burr are used to remove bone, it is essential that the area be irrigated with a steady stream of irrigation solution, usually sterile saline or sterile water. The irrigation cools the burr and prevents bone-damaging heat buildup. The irrigation also increases the efficiency of the burr by washing away bone chips from the flutes of the burr and providing a certain amount of lubrication. In addition, once a surgical procedure is completed and before the mucoperiosteal flap is sutured back into position, the surgical field should be thoroughly irrigated. A large plastic syringe with a blunt 18-gauge needle is commonly used for irrigation. Although the syringe is disposable, it can be sterilized multiple times before it is discarded. The needle should be blunt and smooth so that it does not damage soft tissue, and it should be angled for more efficient direction of the irrigating stream (Fig. 7.29).

Extracting Teeth

One of the most important instruments used in the extraction procedure is the dental elevator. These instruments are used to luxate (loosen) teeth from surrounding bone. Loosening teeth before the application of the dental forceps makes extractions more straightforward. By elevating teeth before the application of the forceps, the clinician can minimize the incidence of broken crowns, roots, and bone. Finally, luxation of teeth before forceps application facilitates the removal of a broken root, should it occur, because prior elevator use is likely to have loosened the root in the dental

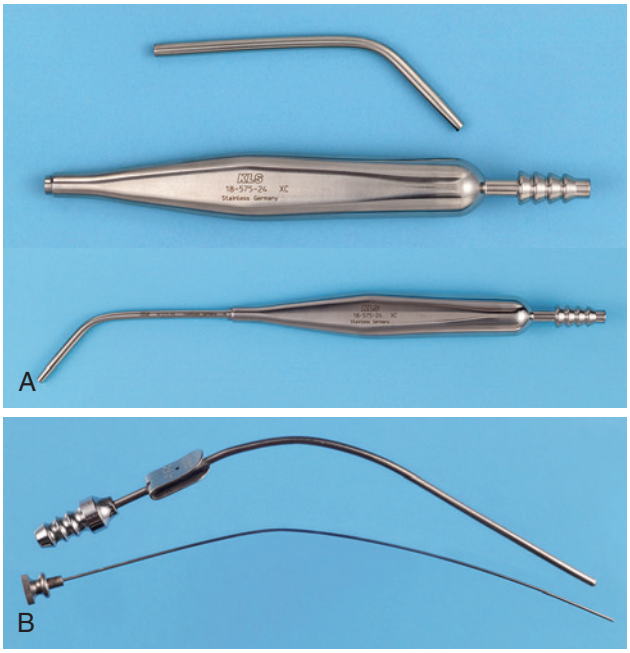


Fig. 7.27 (A) The typical surgical suction has a small-diameter tip. Suction tips usually have a hole to prevent tissue injury caused by excessive suction pressure. *Top*, Unassembled for cleaning. *Bottom*, Assembled for use. (B) The Fraser suction tip has a blade in the handle to allow the operator more control over the amount of suction power. Holding the thumb over the hole increases suction at the tip. A wire stylet is used to clean the tip when bone or tooth particles plug the suction.

Fig. 7.28 The towel clip is used to hold the drape in position. The tips clasp the towels, and the locking handles maintain the drape in position. The clip shown has nonpenetrating blunt tips. Towel clamps with sharp penetrating tips are also available.

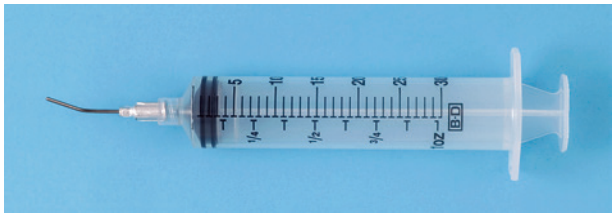


Fig. 7.29 Large plastic syringes with an angled blunt tip may be used to deliver the irrigation solution to the operative site.

socket. In addition to their role in loosening teeth from surrounding bone, dental elevators are also used to expand alveolar bone. By expanding the buccocervical plate of bone, the surgeon facilitates the removal of a tooth that has a limited and obstructed path for removal. Finally, elevators are used to remove broken or surgically sectioned roots from their sockets.

Dental Elevators

The three major components of the elevator are the handle, shank, and blade (Fig. 7.30). The handle of the elevator is usually of generous size, so it can be held comfortably in the hand to apply substantial but controlled force. The application of specifically applied force is critical in the proper use of dental elevators. In some situations, crossbar or T-bar handles are used. These instruments must be used with great caution because they can generate an excessive amount of force that can fracture both teeth and bones (Fig. 7.31).

The shank of the elevator simply connects the handle to the working end, or blade, of the elevator. The shank is generally of substantial size and is strong enough to transmit the force from the handle to the blade. The blade of the elevator is the working tip of the elevator and is used to transmit the force to the tooth, bone, or both.

Types of Elevators

The biggest variation in the type of elevator is in the shape and size of the blade. The three basic types of elevators are (1) the straight type, (2) the triangle or pennant-shaped type, and (3) the pick type. The straight elevator is the most commonly used elevator to luxate teeth (Fig. 7.32A). The blade of the straight elevator has

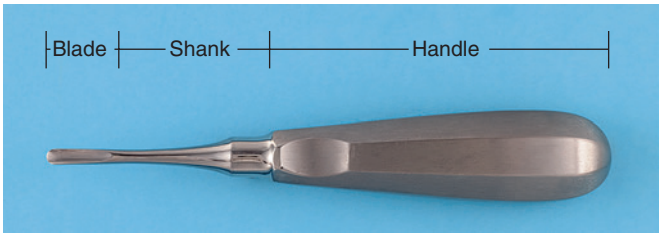


Fig. 7.30 The major components of an elevator are the handle, shank, and blade.

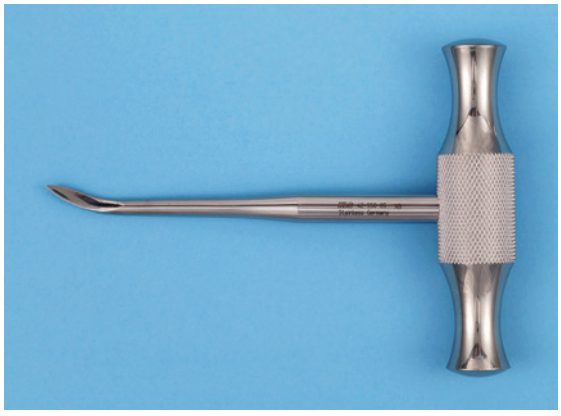


Fig. 7.31 A crossbar handle is used on certain elevators. This type of handle can generate large amounts of force and therefore must be used with great caution.

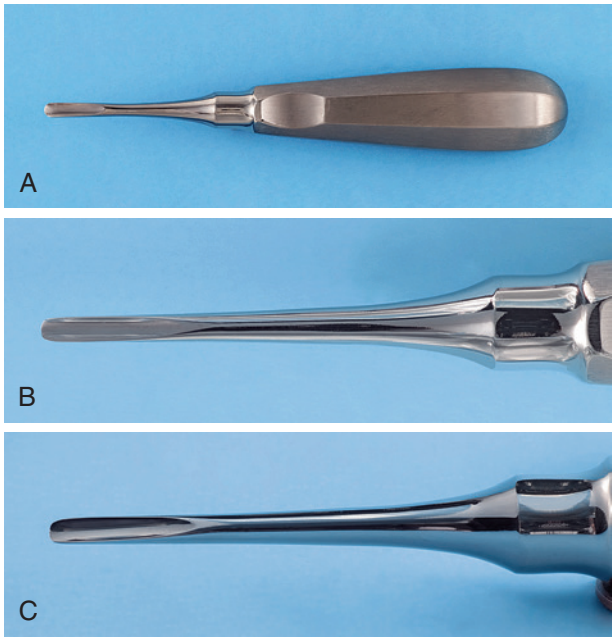


Fig. 7.32 (A) Straight elevators are the most commonly used type. (B–C) The blade of the straight elevator is concave on its working side.

Fig. 7.33 Straight elevators vary in size depending on the width of the blade.

a concave surface on one side that is placed toward the tooth to be elevated (see Fig. 7.32B). The small straight elevator, No. 301, is frequently used for beginning the luxation of an erupted tooth before application of the forceps (Fig. 7.33). Larger straight elevators are used to displace roots from their sockets and to luxate teeth that are more widely spaced, or they are used once a smaller-sized straight elevator becomes less effective. The most commonly used large straight elevator is the No. 34S, but the No. 46 and the No. 77R elevators are also used occasionally.

The shape of the blade of the straight elevator can be angled from the shank, allowing this instrument to be used in the more posterior aspects of the mouth. Two examples of the angled-shank elevator with a blade similar to that of the straight elevator are the Miller elevator and the Potts elevator.

The second most commonly used type of elevator is the triangular elevator (Fig. 7.34). These elevators are provided in pairs: a left and a right. The triangular elevator is most useful when a broken root remains in the tooth socket and the adjacent socket is empty. A typical example would be when a mandibular first molar is fractured, leaving the distal root in the socket but the mesial root

Fig. 7.34 Triangular elevators (Cryer) are pairs of instruments and are therefore used for mesial or distal roots.

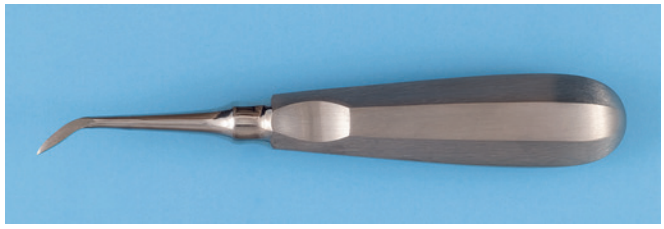


Fig. 7.35 The Crane pick is a heavy instrument used to elevate whole roots or even teeth after the purchase point has been prepared with a burr.

removed with the crown. The tip of the triangular elevator is placed into the socket with the shank of the elevator resting on the buccal plate of bone. The elevator is then turned in a wheel-and-axle rotation, with the sharp tip of the elevator engaging the cementum of the remaining distal root; the elevator is then turned and the root is delivered. Triangular elevators come in a variety of types and angulations, but the Cryer elevator is the most common type. (Pairs of these elevators are also commonly referred to as *east-west elevators*.)

The third type of elevator used with some frequency is the pick-type elevator. This type of elevator is used to remove roots. The heavy version of the pick is the Crane pick (Fig. 7.35). This instrument is used as a lever to elevate a broken root from the tooth socket. Usually it is necessary to drill a hole with a burr (purchase point) approximately 3 mm deep into the root just at the bony crest. The tip of the pick is then inserted into the hole, and, with the buccal plate of bone as a fulcrum, the root is elevated from the tooth socket. Occasionally the sharp point can be used without preparing a purchase point by engaging the cementum or the furcation of the tooth.

The second type of pick is the root-tip pick or the apex elevator (Fig. 7.36). The root-tip pick is a delicate instrument that is used to tease small root tips from their sockets. It must be emphasized that this is a thin instrument and should not be used as a wheel-and-axle or lever type of elevator such as the Cryer elevator or the Crane pick. The root-tip pick is used to tease the very small root end of a tooth by inserting the tip into the periodontal ligament space between the root tip and the socket wall. This instrument works best on roots left after a tooth has been well elevated.

Periotomes

Periotomes are instruments used to extract teeth while preserving the anatomy of the tooth's socket. The general principle behind their use is to sever some of the periodontal ligaments of the tooth

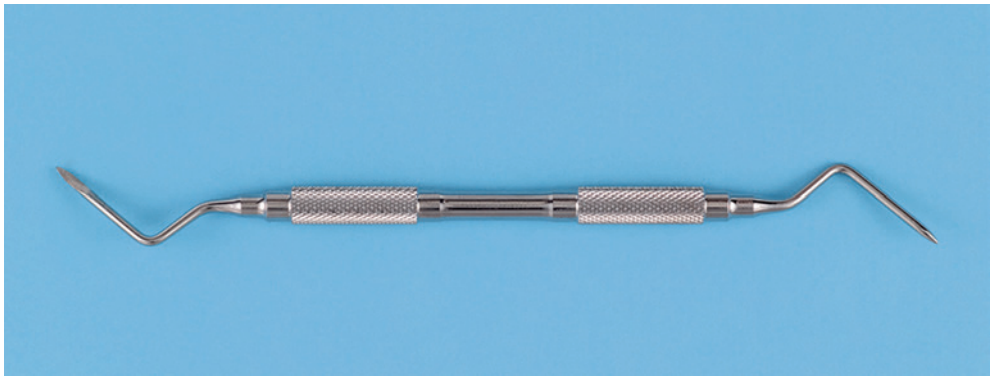


Fig. 7.36 The delicate root-tip pick is used to tease root tip fragments from the socket. The fine tip can be broken off or bent if the instrument is used improperly.

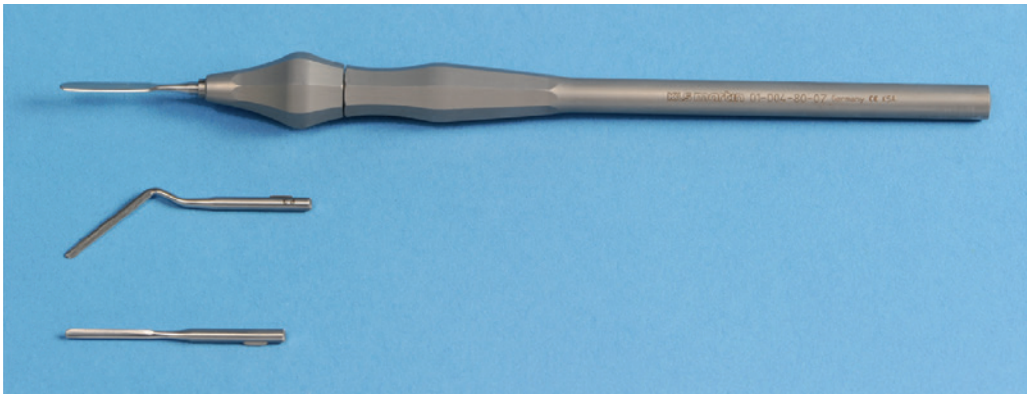


Fig. 7.37 A periotome with a handle and exchangeable blades. Other types of periotomes have fixed blades or are connected to a motor.

to facilitate its removal. There are varying types of periotomes with different blade shapes (Fig. 7.37).

The tip of the periotome blade is inserted into the periodontal ligament space and advanced using pressure in the apical direction along the long axis of the tooth. It is advanced about 2 to 3 mm and then removed and reinserted into an adjacent accessible site. The process is continued around the tooth, gradually advancing the depth of the periotome tip while progressing apically. Once sufficient severance of periodontal ligaments has been accomplished, the tooth is removed by using a dental elevator, extraction forceps, or both, taking care to avoid excessive expansion or fracture of bone.

Extraction Forceps

The extraction forceps are instruments used for removing the tooth from alveolar bone. Ideally, forceps are used to lift elevator-luxated teeth from their sockets rather than to pull teeth from their sockets. When properly used, they can also help to expand bone during extractions.

Forceps are designed in many styles and configurations to adapt to the variety of teeth for which they are used. Each basic design offers a multiplicity of variations to coincide with individual operator preferences. This section deals with the basic fundamental designs and briefly discusses several of the variations.

Forceps Components

The basic components of dental extraction forceps are the handles, hinge, and beak (Fig. 7.38). The handles are usually of adequate size to be used comfortably and to deliver sufficient pressure and leverage to remove the required tooth. The handles have a serrated surface to allow a positive grip and to prevent slippage.

The handles of the forceps are held differently depending on the position of the tooth to be removed. Maxillary forceps are held with the palm to the side or underneath the forceps so that the beak is directed in a superior direction (Fig. 7.39). The forceps used for removal of mandibular teeth are held with the palm on top of the forceps so that the beak is pointed down toward teeth (Fig. 7.40). The handles of the forceps are usually straight, but some may be curved to provide the operator with a better fit (Fig. 7.41).

The hinge of the forceps, like the shank of the elevator, is merely a mechanism for connecting the handles to the beak. The hinge transfers and concentrates the force applied to the handles to the beak. One distinct difference in styles does exist: The usual American type of forceps has a hinge in a horizontal direction and is used as has been described (see Fig. 7.38). The English preference is for a vertical hinge and a corresponding vertically positioned handle (Fig. 7.42A). Thus the English-style handle and hinge are used with the hand held in a vertical direction as opposed to a horizontal direction (see Fig. 7.42B).

The beaks of the extraction forceps are the source of the greatest variation among forceps. The beaks are designed to adapt to the tooth root near the junction of the crown and root. It must be remembered that the beaks of the forceps are designed to be adapted to the root structure of the tooth and not to the crown of the tooth. In a sense, then, different beaks are designed for

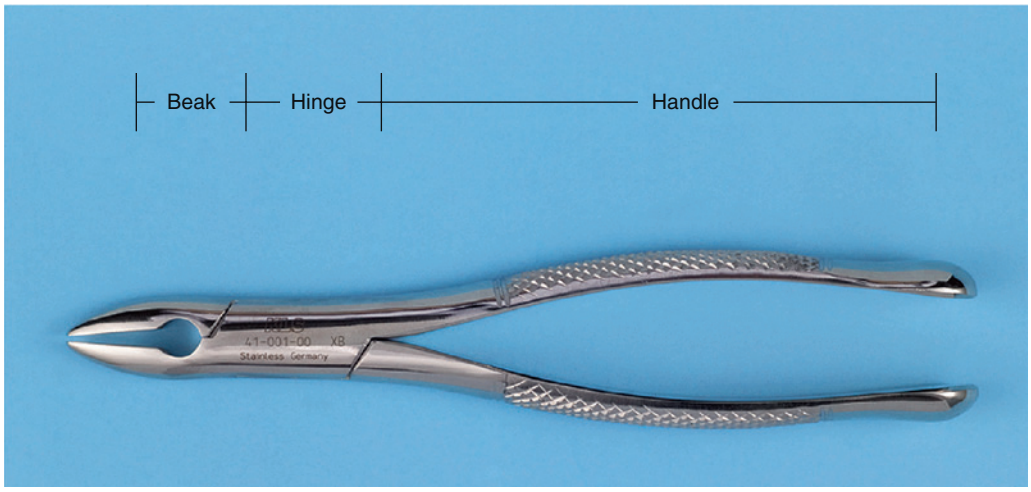


Fig. 7.38 Basic components of extraction forceps.

Fig. 7.39 Forceps used to remove maxillary teeth are held with the palm under the handle.

Fig. 7.41 Straight handles are usually preferred, but curved handles are favored by some surgeons.

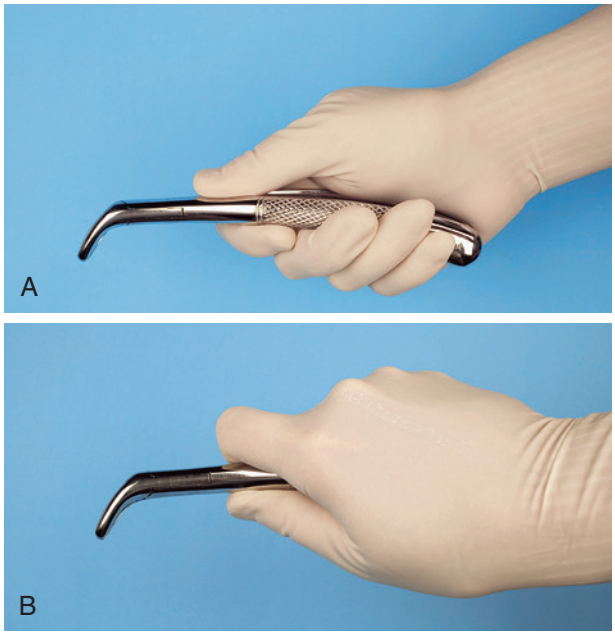


Fig. 7.40 (A) Forceps used to remove mandibular teeth are held with the palm on top of forceps. (B) A firmer grip for delivering greater amounts of rotational force can be achieved by moving the thumb around and under the handle.

Fig. 7.42 (A) English style of forceps have the hinge in the vertical direction. (B) English style of forceps are held in the vertical direction.

single-rooted teeth, two-rooted teeth, and three-rooted teeth. The design variation is such that the tips of the beaks will adapt closely to the various root formations, improving the surgeon's control of forces on the root and decreasing the chances of a root fracture. The more closely the beaks of the forceps adapt to the tooth roots, the more efficient is the extraction and the lower is the chance for undesired outcomes.

A final design variation is in the width of the beak. Some forceps beaks are narrow because their primary use is to remove narrow teeth such as incisor teeth. Other forceps beaks are broader because the teeth they are designed to remove are substantially wider, for example, lower molar teeth. Forceps designed to remove a lower incisor can theoretically be used to remove a lower molar, but the beaks are so narrow that they will be inefficient for that application. Similarly, the broader molar forceps will not adapt to the narrow space occupied by the lower incisor; therefore it cannot be used in that situation without damage to adjacent teeth.

The beaks of forceps are angled such that they can be placed parallel to the long axis of the tooth, with the handle in a comfortable position. Therefore the beaks of maxillary forceps are usually parallel to the handles. Maxillary molar forceps are offset in a bayonet fashion to allow the operator to reach the posterior aspect of the mouth comfortably and yet keep the beak parallel to the long axis of the tooth. The beaks of mandibular forceps are usually set perpendicular to the handles, which allows the surgeon to reach lower teeth and maintain a comfortable controlled position.

Maxillary Forceps

The removal of maxillary teeth requires the use of instruments designed for single-rooted teeth and for teeth with three roots. Maxillary incisors, canine teeth, and premolar teeth are considered single-rooted teeth. The maxillary first premolar frequently has a bifurcated root, but because this occurs in the apical third, it has no influence on the design of the forceps. The maxillary molars have trifurcated roots, so there are extraction forceps that will adapt to that configuration.

After proper elevation, single-rooted maxillary teeth are usually removed with maxillary universal forceps, usually No. 150 (Fig. 7.43). The No. 150 forceps are slightly S-shaped when viewed from the side and are essentially straight when viewed from above. The beaks of the forceps curve to meet only at the tip. The slight curve of the No. 150 forceps allows the operator to comfortably reach not only incisors but also premolars. The beak of the No. 150 forceps comes in a style that has been modified slightly to form the No. 150A forceps (Fig. 7.44). No. 150A forceps are useful for extracting maxillary premolar teeth and should not be used for extracting incisors because of its poor adaptation to the roots of incisors.

In addition to the No. 150 forceps, straight forceps are also available. No. 1 forceps (Fig. 7.45), which can be used for maxillary incisors and canines, are easier to use compared with the No. 150 forceps for upper incisors.

Maxillary molar teeth are three-rooted teeth, with a single palatal root and a buccal bifurcation. Therefore forceps that are specifically adapted to fit maxillary molars must have a smooth, concave surface for the palatal root and a beak with a pointed design that will fit into the buccal bifurcation. This requires that the molar forceps come in pairs: a left and a right. In addition, the maxillary molar forceps should be offset so that the surgeon can reach the posterior aspect of the mouth and remain in the correct position. The most commonly used molar forceps are the No. 53 right and left forceps (Fig. 7.46). These forceps are designed to fit anatomically around the palatal beak, and the pointed buccal beak fits into the buccal bifurcation. The beak is offset to allow for good surgeon positioning.

A design variation is shown in the No. 88 right and left forceps, which have a longer, more accentuated pointed beak formation (Fig. 7.47). They are particularly useful for maxillary molars with crowns that are severely carious. The sharply pointed beaks may reach deeper into the trifurcation to sound dentin. The major disadvantage is that they crush crestal alveolar bone, and when used on intact teeth without due caution and proper elevation, they can fracture large amounts of buccal alveolar bone.

On occasion maxillary second molars and erupted third molars have a single conical root. In this situation, forceps with broad, smooth beaks that are offset from the handle can be useful. The No. 210S forceps exemplifies this design (Fig. 7.48). Another design variation is shown in the offset molar forceps with a very narrow beak. These forceps are used primarily to remove broken maxillary molar roots but can be used for the removal of narrow premolars and for lower incisors. These forceps, the No. 65 forceps, are also known as *root-tip forceps* (Fig. 7.49).

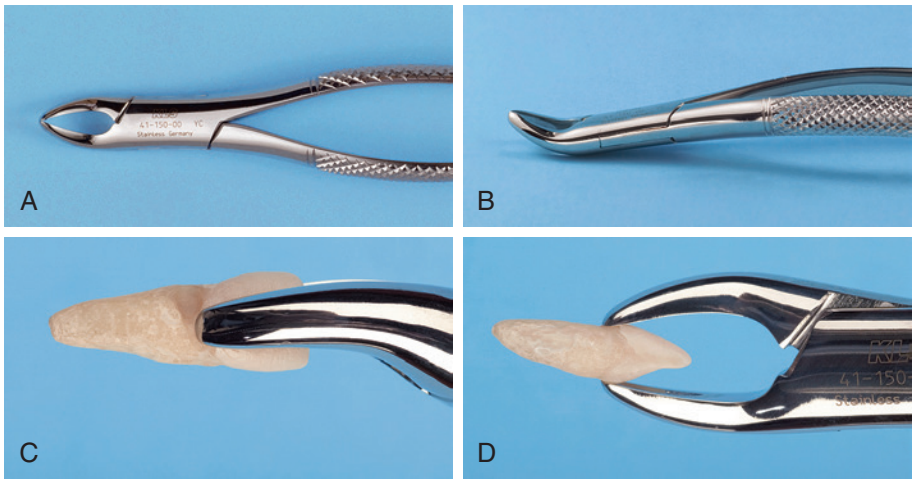


Fig. 7.43 (A) Superior view of No. 150 forceps. (B) Side view of No. 150 forceps. (C–D) No. 150 forceps adapted to the maxillary central incisor.

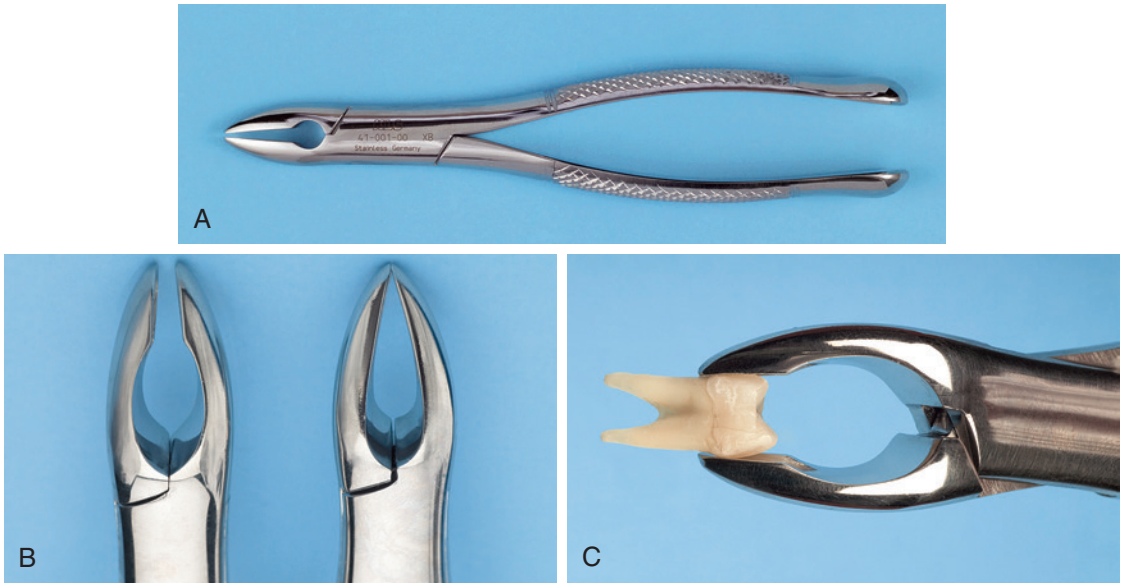


Fig. 7.44 (A) Superior view of No. 150A forceps. (B) No. 150A forceps have parallel beaks that do not touch, in contrast to the No. 150 forceps. (C) Adaptation of No. 150A forceps to the maxillary premolar.

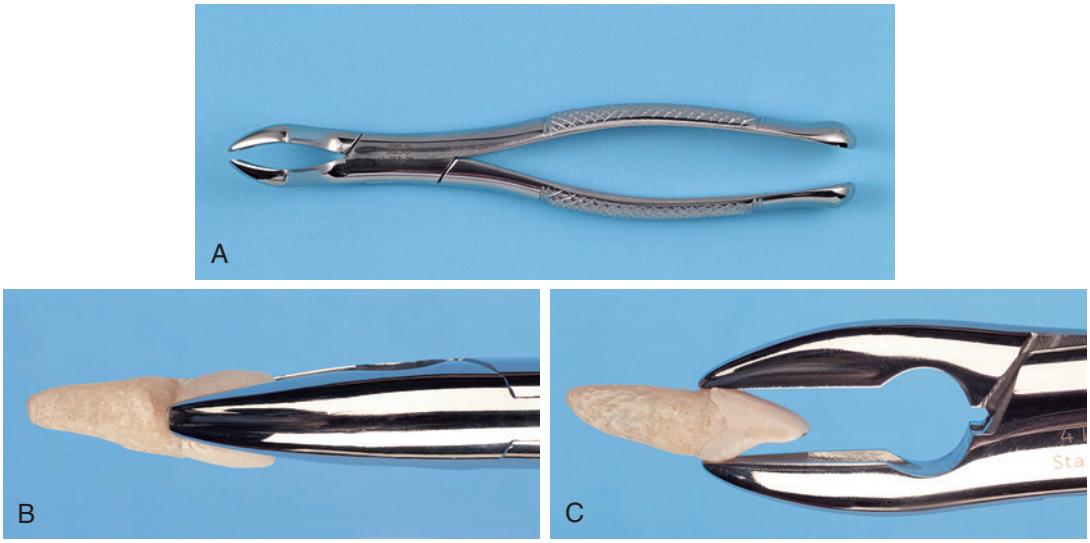


Fig. 7.45 (A) Superior view of No. 1 forceps. (B–C) No. 1 forceps adapted to the incisor.

A smaller version of the No. 150 forceps, the No. 150S forceps, is useful for removing primary teeth (Fig. 7.50). These forceps adapt well to all maxillary primary teeth and can be used as universal primary tooth forceps.

Mandibular Forceps

Extraction of mandibular teeth requires forceps that can be used for single-rooted teeth for the incisors, canines, and premolars as well as for two-rooted teeth for the molars. The forceps most commonly used for the single-rooted teeth are the lower universal forceps, or the No. 151 forceps (Fig. 7.51). These forceps have handles similar in shape to the No. 150 forceps, but the beaks are pointed inferiorly for lower teeth. The beaks are smooth and narrow and meet only at the tip. This allows the beak to fit near the cervical line of the tooth to grasp the root.

The No. 151A forceps have been modified slightly for mandibular premolar teeth (Fig. 7.52). These forceps should not be used for other lower teeth because their form prevents adaptation to the roots of teeth.

The English style of vertical-hinge forceps can be used for the single-rooted teeth in the mandible (Fig. 7.53). Great force can be generated with these forceps. Unless great care is exercised, the incidence of root fracture is higher with this instrument.

Mandibular molars are bifurcated, two-rooted teeth that allow the use of forceps that anatomically adapt to the tooth. Because the bifurcation is on the buccal and the lingual sides, only

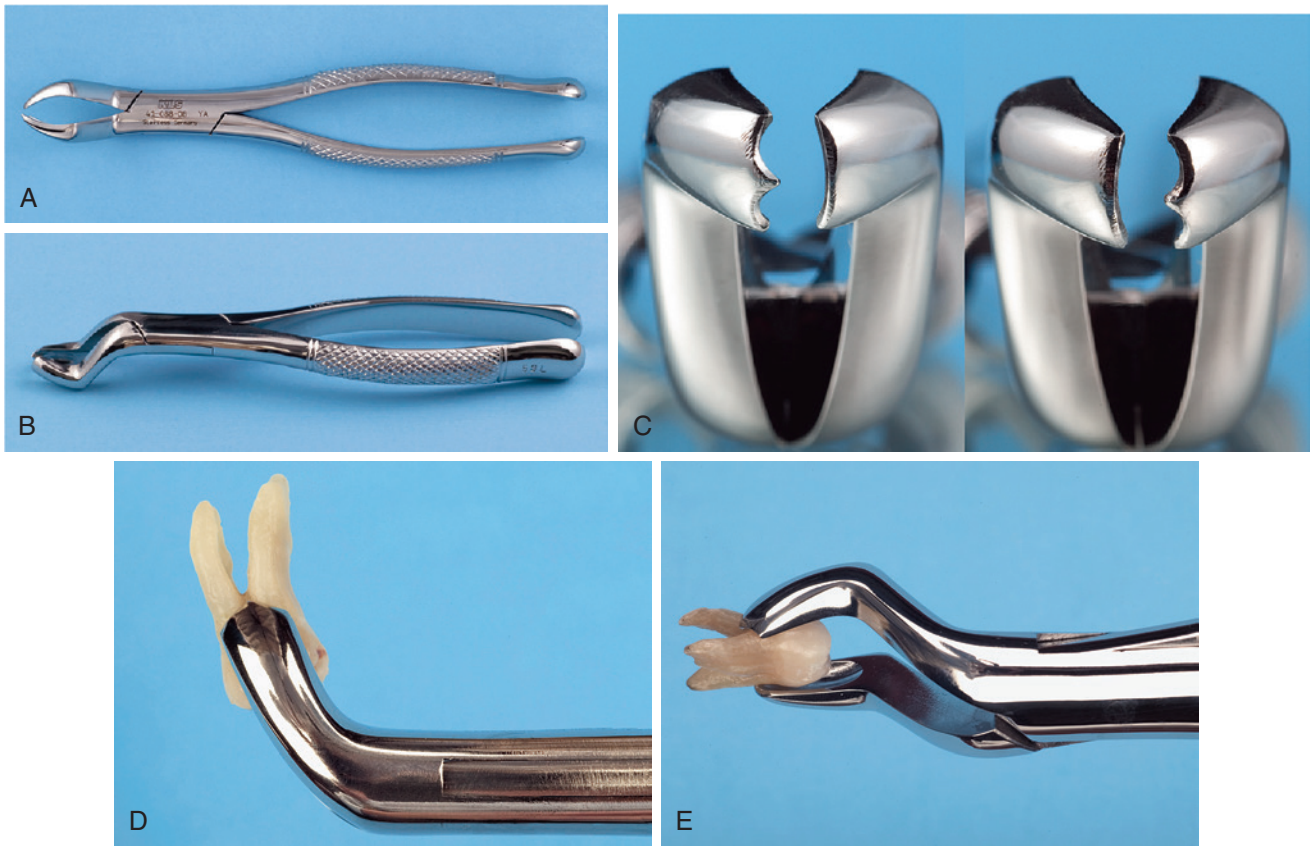


Fig. 7.46 (A) Superior view of No. 53L forceps. (B) Oblique view of No. 53L forceps. (C) *Right*, No. 53L; *left*, No. 53R. (D–E) No. 53L forceps adapted to the maxillary molar.

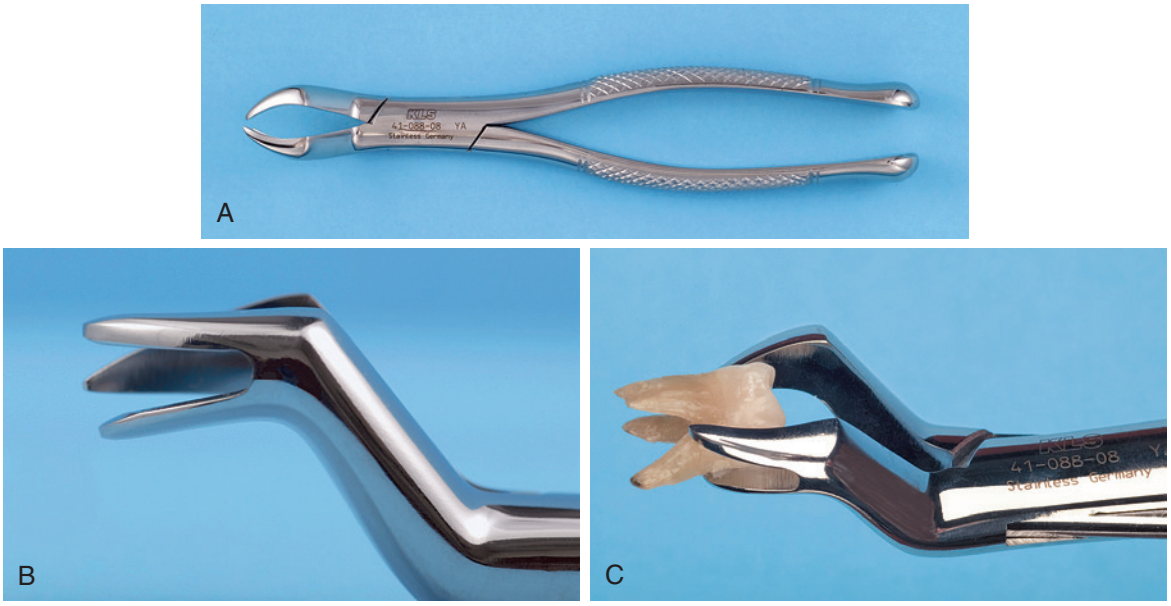


Fig. 7.47 (A) Superior view of No. 88L forceps. (B) Side view of No. 88L forceps. (C) No. 88R forceps adapted to the maxillary molar.

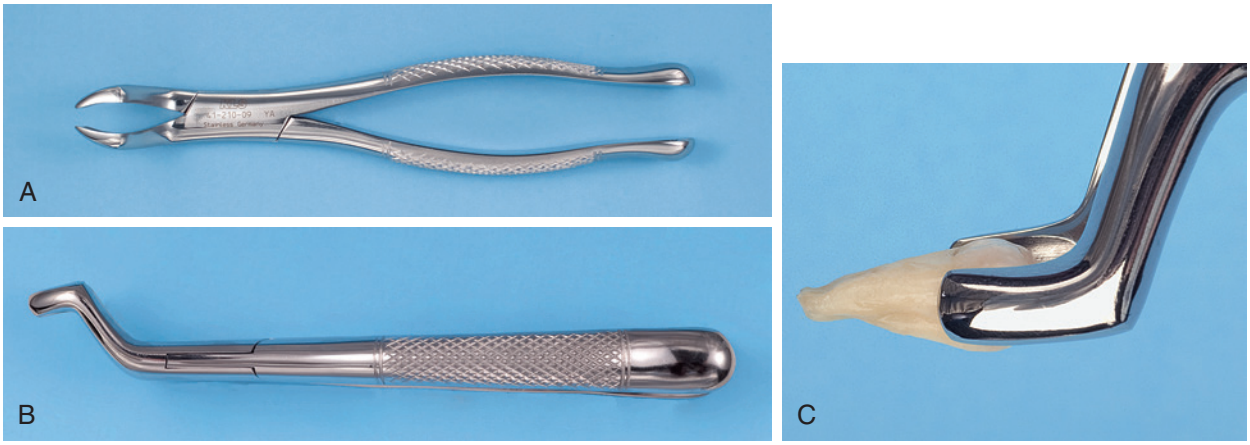


Fig. 7.48 (A) Superior view of No. 210S forceps. (B) Side view of No. 210S forceps. (C) No. 210S forceps adapted to the maxillary molar.

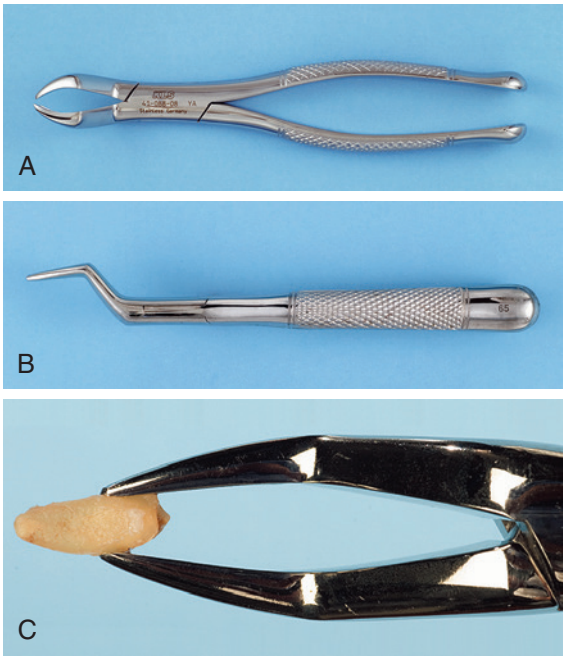


Fig. 7.49 (A) Superior view of No. 65 forceps. (B) Side view of No. 65 forceps. (C) No. 65 forceps adapted to a broken root.

Fig. 7.50 The No. 150S forceps *(bottom)* are a smaller version of the No. 150 forceps *(top)* and are used for primary teeth.

single-molar forceps are necessary for the both sides, in contradistinction to the maxilla, for which a right- and left-paired molar forceps set is required.

Useful lower molar forceps are the No. 17 forceps (Fig. 7.54). These forceps are usually straight-handled, and the beaks are set obliquely downward. The beaks have pointed tips in the center to be set into the bifurcation of lower molar teeth. The remainder of the beak adapts well to the sides of the furcation. Because of the pointed tips, the No. 17 forceps cannot be used for molar teeth, which have fused, conical roots. For this purpose, the No. 151 forceps are used.

A major design variation in lower molar forceps is the No. 87, the so-called *cowhorn forceps* (Fig. 7.55). These instruments are designed with two pointed, heavy beaks that enter the bifurcation of lower molars. After the forceps are seated in the correct position, usually while gently pumping the handles up and down, the tooth is actually elevated by squeezing the handles of the forceps together tightly. As the beaks are squeezed into the bifurcation, they use the buccal and lingual cortical plates as fulcrums and the tooth can be literally squeezed out of the socket. As with the English style of forceps, improper use of the cowhorn forceps can result in an increase in the incidence of untoward effects such as fractures of alveolar bone or damage to maxillary teeth if the forceps are not properly controlled by the surgeon as the molar exits the socket. The beginning surgeon should therefore use the cowhorn forceps with caution.

The No. 151 forceps are also adapted for primary teeth. No. 151S forceps are the same general design as the No. 151 forceps but are scaled down to adapt to primary teeth. These forceps are adequate for the removal of all primary mandibular teeth (Fig. 7.56).

Instrument Tray Systems

Many dentists find it practical to use the tray method to assemble instruments that will be used for specific types of procedures. Standard sets of instruments are packaged together, sterilized, and then unwrapped at surgery. The typical basic extraction pack includes a local anesthesia syringe, a needle, a local anesthesia cartridge, a No. 9 periosteal elevator, a periapical curette, small and large straight elevators, a pair of college pliers, a curved hemostat, a towel clip, an Austin or Minnesota retractor, a suction tip, and 2 × 2 inch or 4 × 4 inch gauze (Fig. 7.57). The required forceps would be added to this tray after it was opened.

A tray used for surgical extractions would include the items from the basic extraction tray plus needle holder and suture, suture scissors, blade handle and blade, Adson tissue forceps, bone file, tongue retractor, Cryer elevators, rongeur, and handpiece and burr (Fig. 7.58). These instruments permit incision and reflection of soft tissue, removal of bone, sectioning of teeth, retrieval of roots, debridement of the wound, and suturing of the soft tissue.

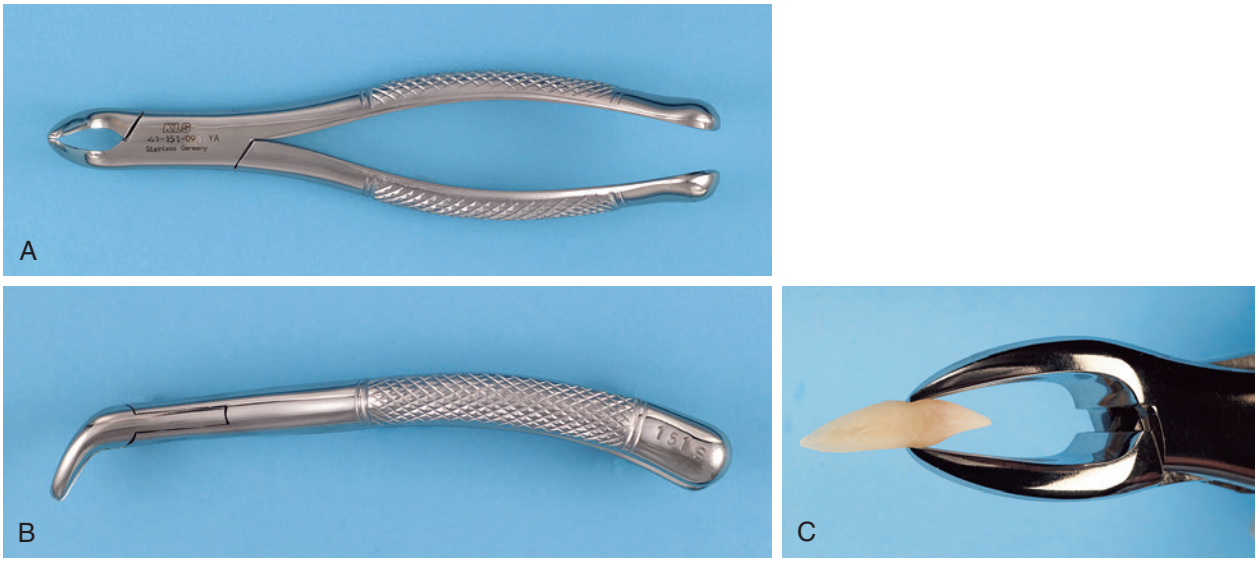


Fig. 7.51 (A) Superior view of No. 151 forceps. (B) Side view of No. 151 forceps. (C) No. 151 forceps adapted to the mandibular incisor.

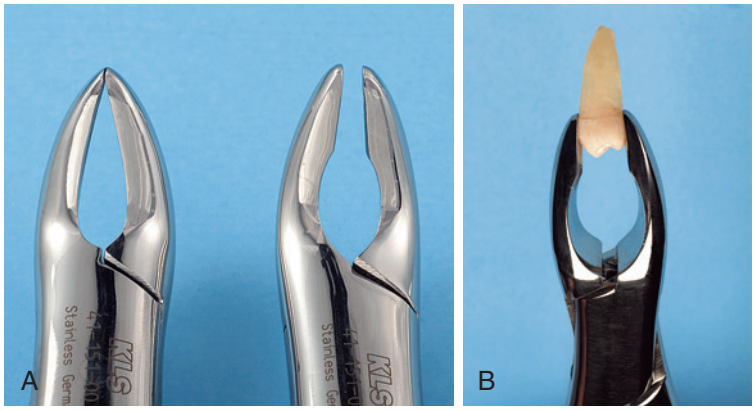


Fig. 7.52 (A) The No. 151A forceps have beaks that are parallel and do not adapt well to the roots of most teeth, in contrast to the beaks of the No. 151 forceps. (B) No. 151A forceps adapted to a lower premolar tooth. The lack of close adaptation of the tips of the beaks to the root of the tooth is shown.

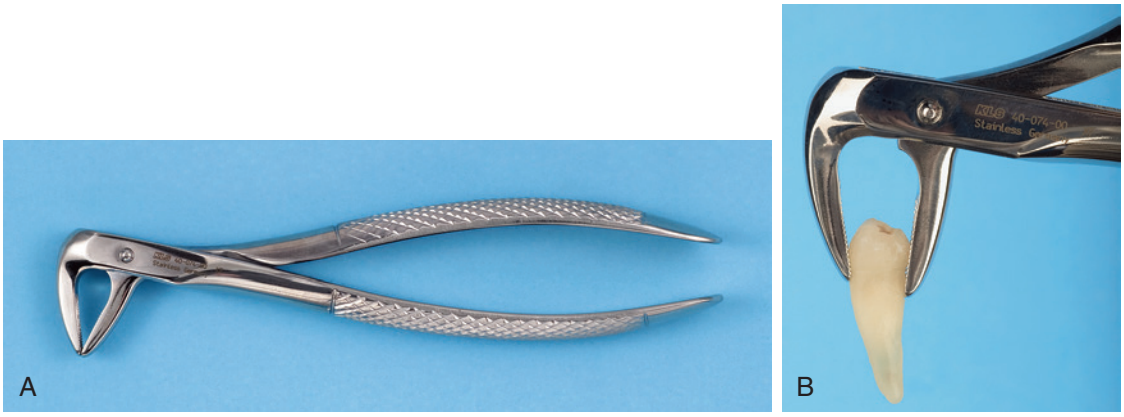


Fig. 7.53 (A) Side view of the English style of forceps. (B) Forceps adapted to the lower premolar.

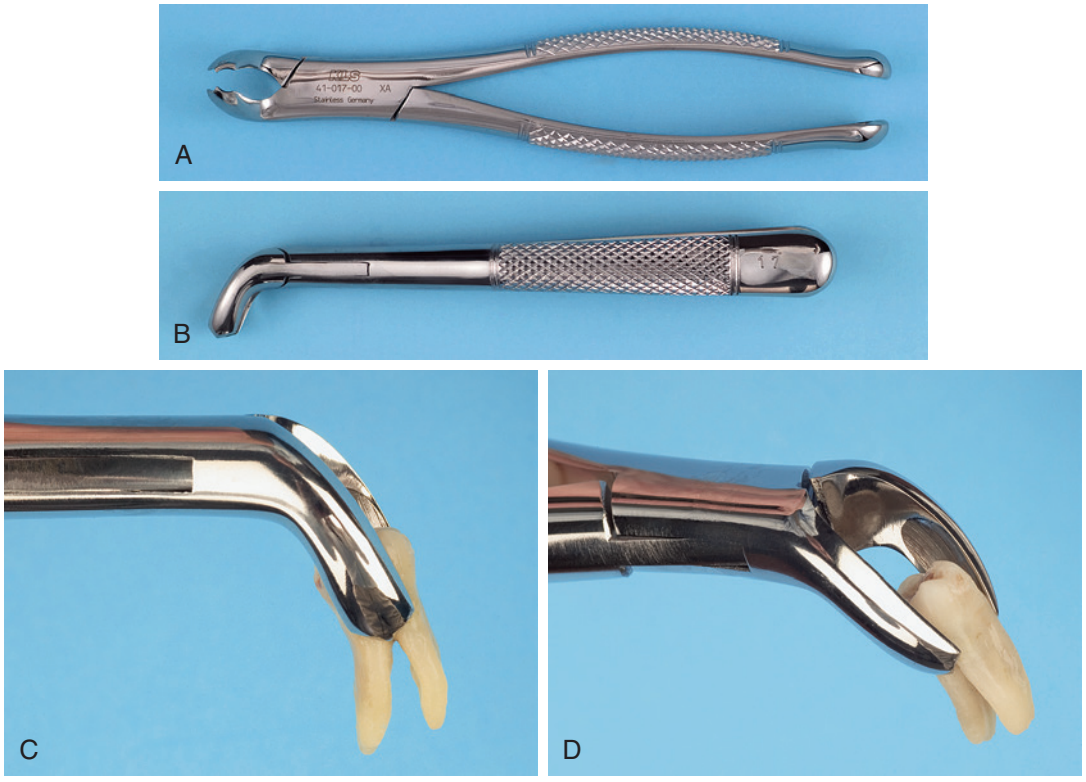


Fig. 7.54 (A) Superior view of No. 17 molar forceps. (B) Side view of No. 17 molar forceps. (C–D) No. 17 forceps adapted to the lower molar.

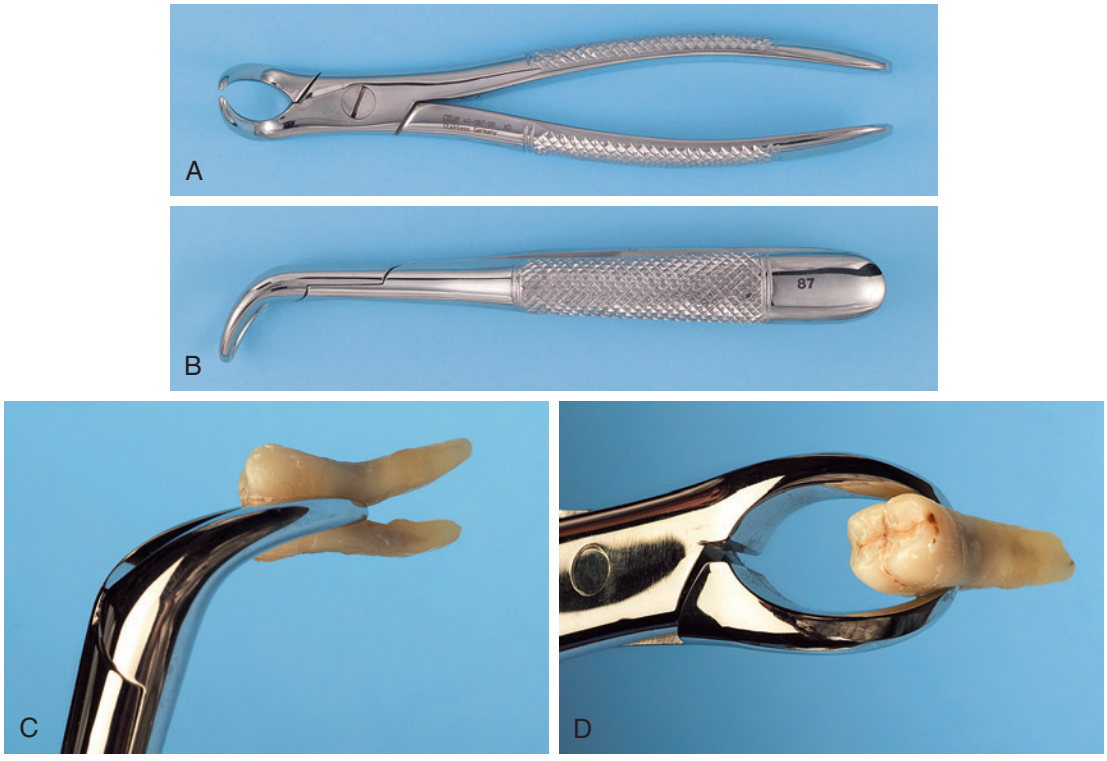


Fig. 7.55 (A) Superior view of cowhorn No. 87 forceps. (B) Side view of cowhorn forceps. (C–D) Cowhorn forceps adapted to the lower molar tooth.

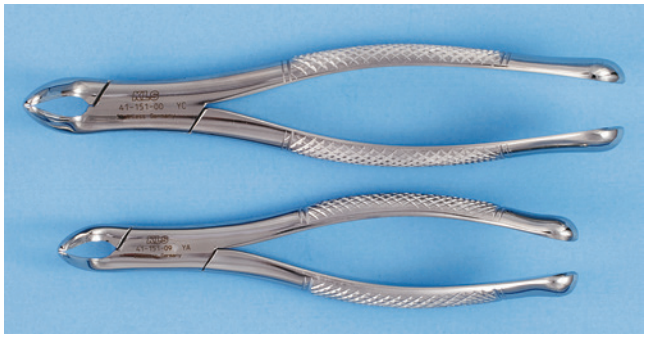


Fig. 7.56 The No. 151S forceps (bottom) are a smaller version of the No. 151 forceps (top) and are used to extract primary teeth.

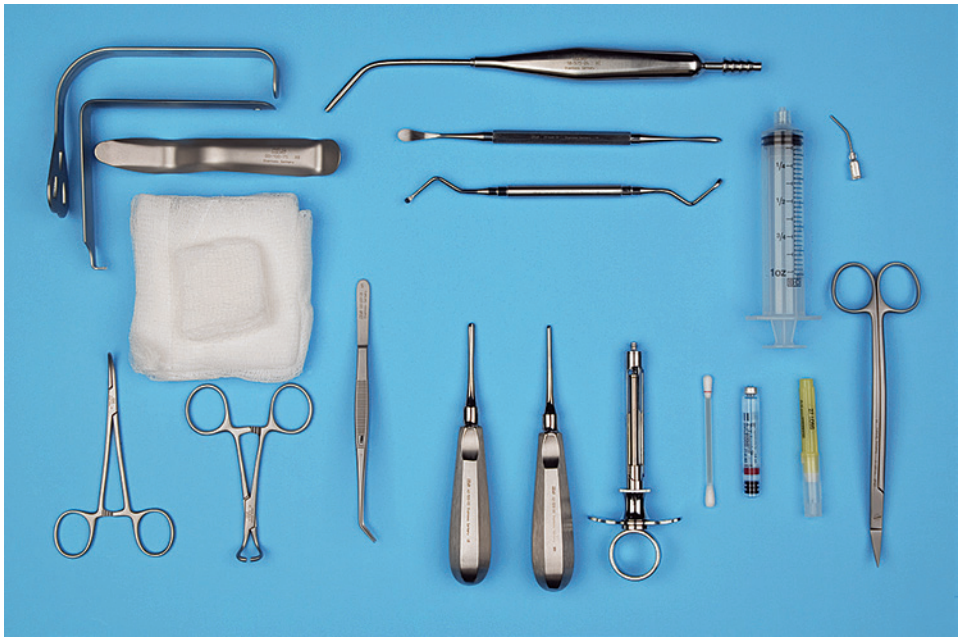


Fig. 7.57 Basic extraction tray.

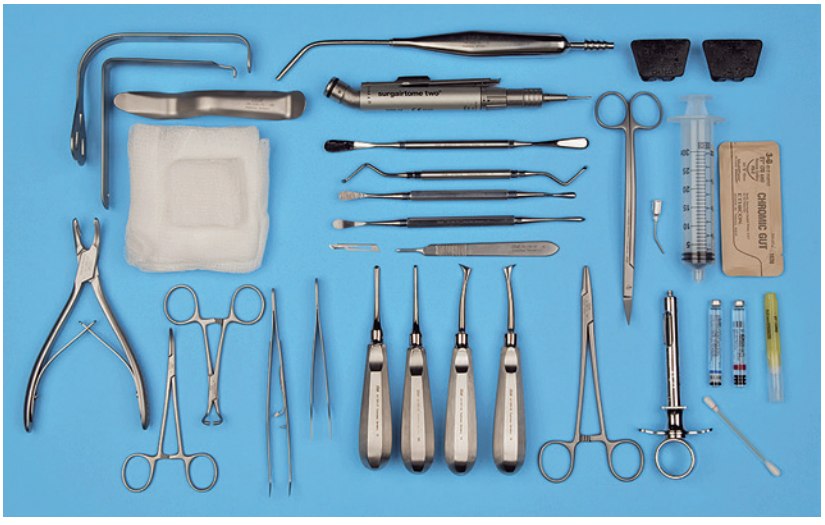


Fig. 7.58 The surgical extraction tray includes the necessary instrumentation to reflect soft tissue flaps, remove bone, section teeth, retrieve roots, and suture flaps back into position.

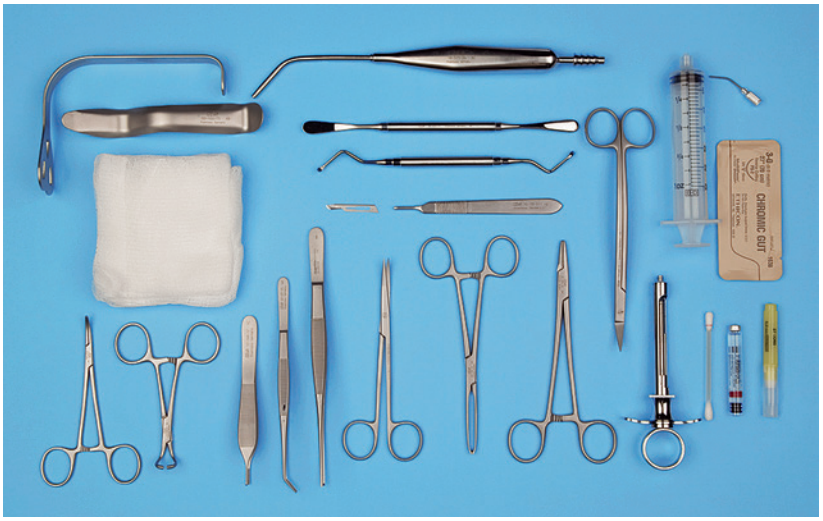


Fig. 7.59 The biopsy tray includes equipment necessary to remove a soft tissue specimen and suture wounds closed.

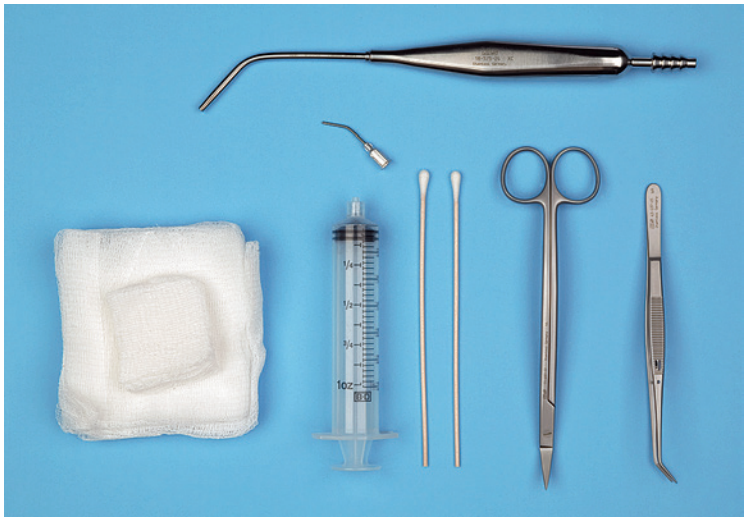


Fig. 7.60 The postoperative tray includes instruments necessary to remove sutures and irrigate the mouth.

The biopsy tray includes the basic tray (minus elevators), blade handle and blade, needle holder and suture, suture scissors, tissue scissors, Allis tissue forceps, Adson tissue forceps, and a curved hemostat (Fig. 7.59). These instruments permit incision and dissection of a soft tissue specimen and closure of the wound with sutures.

The postoperative tray has the necessary instruments to irrigate the surgical site and remove sutures (Fig. 7.60). The tray usually includes scissors, college pliers, irrigation syringe, cotton applicator sticks, gauze, and suction tip.

The instruments may be placed on a flat tray, wrapped with sterilization paper, and sterilized. When ready for use, the tray is taken to the operatory and opened in such a manner as to preserve instrument sterility, and the instruments are used from the tray. This system requires a large autoclave to accommodate the tray.

Alternatively, metal cassettes can be used instead of a tray. Cassettes are more compact but must also be wrapped in sterilization paper.

8

Principles of Routine Exodontia

JAMES R. HUPP

CHAPTER OUTLINE

Extraction of a tooth combines the principles of surgery and elementary physical mechanics. When these principles are applied correctly, a tooth can usually be removed from the alveolar process, even by someone without great strength and without untoward force or sequelae. This chapter presents the principles of surgery and mechanics related to uncomplicated tooth extraction. In addition, there is a detailed description of techniques for removal of specific teeth with specific instruments. Because the crown is already "removed" from the bone in fully erupted teeth, a dental extraction focuses on root extraction. Following this concept prevents the surgeon from untoward focus on using force on the crowns to remove teeth. Ignoring this concept commonly leads to fracturing the crowns or roots of teeth or fracturing the bone around the roots.

Proper tooth removal does not require a large amount of strength; instead, when done properly, it is accomplished with finesse. Removal of an erupted tooth involves the use of controlled force so that the tooth is not pulled from bone, but instead is gently lifted from its socket. During preextraction planning, the degree of difficulty anticipated for removing a particular tooth is assessed. If that assessment leads the surgeon to believe that the degree of difficulty will be high or if initial attempts at tooth removal confirm this, a deliberate surgical approach—not an application of excessive force—should be taken. Excessive force may injure local soft tissue and damage the surrounding bone and teeth. Such force may fracture the crown, usually making the extraction substantially more difficult than it would have been otherwise. Moreover, excessive force and haste during an extraction heightens intraoperative and postoperative patient discomfort and anxiety.

Presurgical Medical Assessment

When conducting the preoperative patient evaluation, it is critical that the surgeon examine the patient's medical status. Patients can have a variety of health problems that require treatment modification or medical management before the surgery can be safely performed.

Special measures may be needed to control bleeding, lessen the chance of infection, or prevent a medical emergency. This information is discussed in detail in Chapter 1, which includes information regarding the specifics of altering surgical treatment for medical management reasons.

Indications for Removal of Teeth

Teeth are extracted for a variety of reasons. This section discusses a variety of general indications for removing teeth. These indications are only guidelines, not absolute rules.

Caries

Perhaps the most common and widely accepted reason to remove a tooth is that it is so severely carious that it cannot be restored. The extent to which the tooth is carious and is considered nonrestorable is a judgment call to be made between the dentist and the patient. Sometimes the complexity and cost required to salvage a severely carious tooth also makes extraction a reasonable choice. This is particularly true with the availability and success of reliable implant-supported prostheses.

Pulpal Necrosis

A second, closely aligned rationale for removing a tooth is the presence of pulpal necrosis or irreversible pulpitis that is not amenable to endodontics. This may be the result of a patient declining endodontic treatment or when a tooth has a root canal that is tortuous, calcified, and untreatable by standard endodontic techniques. Also included in this category of general indications is the case in which endodontic treatment has been done but has failed to relieve pain or provide drainage, and the patient does not desire retreatment.

Periodontal Disease

A common reason for tooth removal is severe and extensive periodontal disease. If severe adult periodontitis has existed for some time, excessive bone loss and irreversible tooth mobility will be found. In these situations, the hypermobile teeth should be extracted. Also, ongoing periodontal bone loss may jeopardize the chance for straightforward implant placement, making extraction a sensible step even before a tooth becomes moderately or severely mobile.

Orthodontic Reasons

Patients who are about to undergo orthodontic correction of crowded dentition with insufficient arch length frequently require the extraction of teeth to provide space for tooth alignment. The most commonly extracted teeth are the maxillary and mandibular premolars, but a mandibular incisor may occasionally need to be extracted for this same reason. Great care should be taken to double-check that extraction is indeed necessary and that the correct tooth or teeth are removed if someone other than the surgeon doing the extraction has planned the extractions.

Malpositioned Teeth

Teeth that are malposed or malpositioned may be indicated for removal in several situations. If they traumatize soft tissue and cannot be repositioned by orthodontic treatment, they should be extracted. A common example of this is the maxillary third molar, which erupts in severe buccal version and causes ulceration and soft tissue trauma of the cheek. Another example is malpositioned teeth that are hypererupted because of the loss of teeth in the opposing arch. If prosthetic rehabilitation is to be carried out in the opposing arch, the hypererupted tooth may interfere with construction of an adequate prosthesis. In this situation, the malpositioned tooth should be considered for extraction.

Cracked Teeth

An uncommon indication for extraction of teeth is a tooth with a cracked crown or a fractured root. The cracked tooth can be painful and be unmanageable by a more conservative technique. Cracked teeth have often already undergone endodontic therapy at some point in the past, which tends to make the crown and root more brittle and difficult to remove.

Impacted Teeth

Impacted teeth should be considered for removal. If it is clear that a partially impacted tooth is unable to erupt into a functional occlusion because of inadequate space, interference from adjacent teeth, or some other reason, it should be considered for surgical removal. See Chapter 10 for a more thorough discussion of this topic.

Supernumerary Teeth

Supernumerary teeth are usually impacted and should be removed. A supernumerary tooth may interfere with the eruption of succedaneous teeth and has the potential for causing their resorption and displacement.

Teeth Associated With Pathologic Lesions

Teeth involved in pathologic lesions may require removal. This is often seen with odontogenic cysts. In some situations, the tooth or teeth can be retained and endodontic therapy performed. However, if maintaining the tooth compromises the complete surgical removal of the lesion when complete removal is critical, the tooth should be removed.

Radiation Therapy

Patients who are to receive radiation therapy for oral, head, or neck cancer should consider removal of teeth that are in the beam of radiation therapy, particularly if the teeth are compromised in some manner. However, many of these teeth can be retained with proper care. See Chapter 19 for a more thorough discussion of the effects of radiation therapy on teeth and jaws.

Teeth Involved in Jaw Fractures

Patients who sustain fractures of the mandible or the alveolar process sometimes must have teeth removed. In some situations, the tooth involved in the line of fracture can be maintained, but if the tooth is injured, infected, or severely luxated from the surrounding bony tissue or interferes with proper reduction and fixation of the fracture, its removal is usually indicated.

Financial Issues

A final indication for removal of a tooth relates to the financial status of the patient. All of the indications for extraction already mentioned may become stronger if the patient is unwilling or unable to financially support the decision to maintain the tooth. The inability of the patient to pay for the procedure may require that the tooth be removed. Also, implant dentistry is often more cost effective for a patient than maintaining a compromised tooth.

Contraindications for Removal of Teeth

Even if a given tooth meets one of the requirements for removal, in some situations, the tooth should not be removed because of other factors or contraindications to extraction. These factors, like the indications, are relative in their strength. In some situations, the contraindication can be modified by the use of additional care or treatment, and the indicated extraction can be performed. In other situations, however, the contraindication may be so significant that the tooth should not be removed without taking special precautions. In general, the contraindications are divided into two groups: systemic and local. Systemic contraindications to routine oral surgery are discussed in Chapter 1.

Local Contraindications

Several local contraindications to the extraction of teeth also exist. The most important and most critical is a history of therapeutic radiation for cancer. Extractions performed in an area of radiation may result in osteoradionecrosis, and therefore the extraction must be done with extreme caution. Chapter 19 discusses this in detail.

Teeth that are located within an area of tumor, especially a malignant tumor, should not be extracted. The surgical procedure for extraction could disseminate malignant cells, thereby seeding local metastases.

Patients who have severe pericoronitis around an impacted mandibular third molar should not have the tooth extracted until the pericoronitis has been treated. Nonsurgical treatment should include irrigations and removal of the maxillary third molar, if necessary, to relieve impingement on the edematous soft tissue overlying the mandibular impaction. Some clinicians will also administer antibiotics. If the mandibular third molar is removed in the face of severe pericoronitis, the incidence of complications increases. However, if the pericoronitis is mild and the tooth can be removed in a straightforward manner, then immediate extraction may be performed.

Finally, the acute dentoalveolar abscess must be mentioned. Many prospective studies have made it abundantly clear that the most rapid resolution of an infection resulting from pulpal necrosis is obtained when the tooth is removed as early as possible. Therefore acute infection is not a contraindication to extraction. However, it may be difficult to extract such a tooth because the patient may not be able to open the mouth sufficiently wide due to trismus, or it may be difficult to reach a state of profound local anesthesia. If access and anesthesia considerations can be met, the tooth should be removed as soon as possible. Otherwise, antibiotic therapy should be started and extraction planned as soon as possible.

Clinical Evaluation of Teeth for Removal

In the preoperative assessment period, the tooth to be extracted should be examined carefully to assess the difficulty of the extraction. A variety of factors must be specifically examined to make the appropriate assessment and treatment plan.

Access to the Tooth

The first factor to be examined in preoperative assessment is the extent to which the patient can open the mouth. Any limitation of opening may compromise the ability of the surgeon to give local anesthesia or perform a routine extraction. If the patient's opening is substantially compromised, the surgeon should consider a surgical approach to the tooth instead of a routine elevator and forceps extraction. This requires placing the patient under deep sedation or general anesthesia. In addition, the surgeon should look for the cause of the reduction of opening. The most likely causes are trismus associated with infection around the muscles of mastication, temporomandibular joint (TMJ) dysfunction, and muscle fibrosis.

The location and position of the tooth to be extracted within a dental arch should be examined. A properly aligned tooth has a normal access for placement of elevators and forceps. However, crowded or otherwise malposed teeth may present difficulty in positioning the usually used forceps onto the tooth for extraction. When access is a problem, a different forceps may be needed or a surgical approach may be indicated.

Mobility of the Tooth

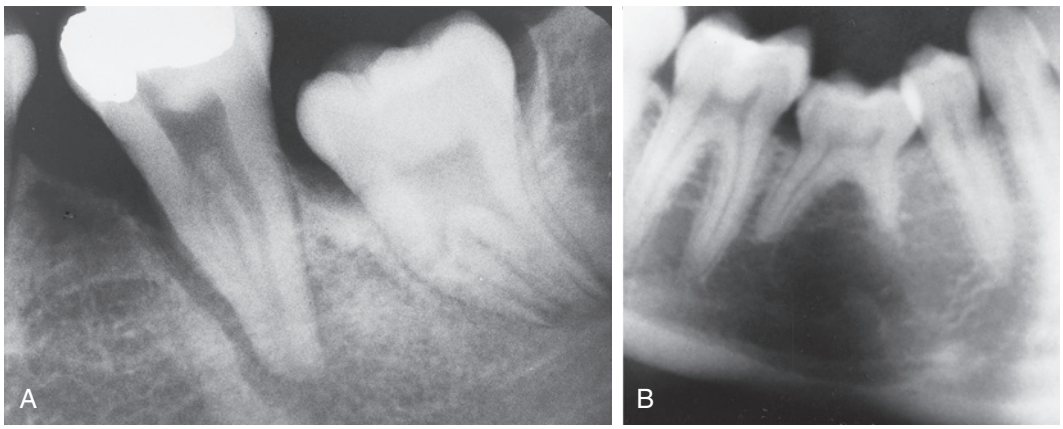
The mobility of the tooth to be extracted should be assessed preoperatively. Greater-than-normal mobility is frequently seen with severe periodontal disease. If the teeth are excessively mobile, uncomplicated tooth removal should be expected, but soft tissue management after the extraction may be more involved (Fig. 8.1A).

Teeth that have less-than-normal mobility should be carefully assessed for the presence of hypercementosis or ankylosis of the roots. Ankylosis is often seen with primary molars that are retained and have become submerged (see Fig. 8.1B). In addition, ankylosis is seen occasionally in nonvital teeth that have had endodontic therapy many years before the extraction. If the clinician believes that the tooth is ankylosed, it is wise to plan for a surgical removal of the tooth as opposed to a forceps extraction. Hypercementosis can create bulbous roots that are more challenging to remove.

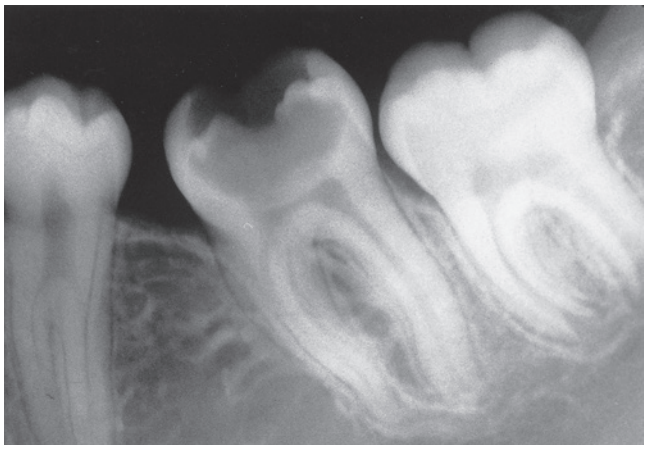
Condition of the Crown

The assessment of the crown of the tooth before the extraction should be related to the presence of large caries or restorations in the crown. If large portions of the crown have been destroyed by caries, the likelihood of crushing the crown during the extraction is increased, thus causing more difficulty in removing the tooth (Fig. 8.2). Similarly, the presence of large amalgam restorations produces weakness in the crown, and the restoration will probably fracture during the extraction process (Fig. 8.3). In addition, an endodontically treated tooth becomes desiccated and typically becomes brittle and crumbles easily when force is applied. In these three situations, it is critical that the tooth be elevated as much as possible and that the forceps then be applied as far apically as possible in order to grasp an intact root portion of the tooth instead of the crown.

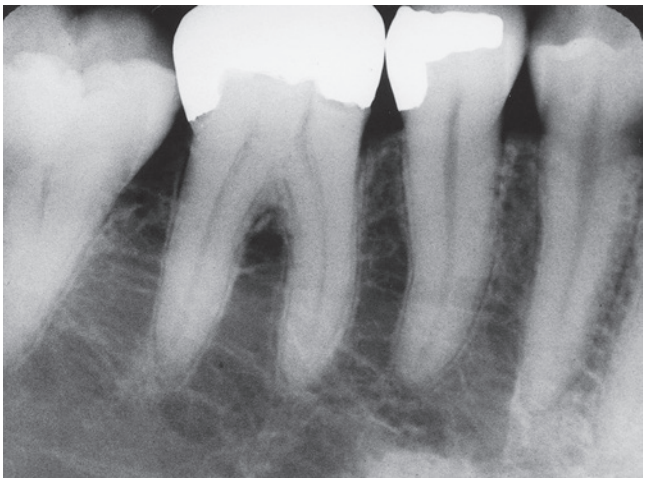
If the tooth to be extracted has a large accumulation of calculus, the gross accumulation should be removed with a scaler or ultrasonic cleaner before extraction. The reasons for this are that calculus interferes with the placement of the forceps in the appropriate



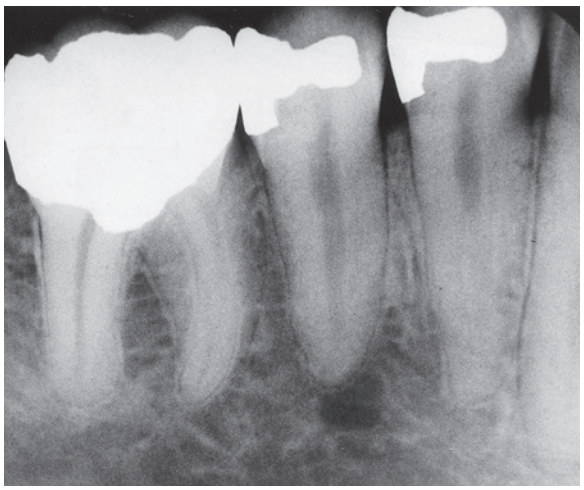
• **Fig. 8.1** (A) Tooth with severe periodontal disease with bone loss and wide periodontal ligament space. This kind of tooth is straightforward to remove. (B) Retained mandibular second primary molar with an absent succedaneous tooth. The molar is partially submerged, and the likelihood for ankylosed roots is high.



• **Fig. 8.2** Teeth with large carious lesions are likely to fracture during extraction, making extraction more difficult.



• **Fig. 8.4** Mandibular first molar. If the molar is to be removed, the surgeon must take care not to fracture amalgam in the second premolar with elevators or forceps.



• **Fig. 8.3** Teeth with large amalgam restorations are likely to be fragile and to fracture when extraction forces are applied.

fashion, and fractured calculus may contaminate the empty tooth socket once the tooth is extracted.

The surgeon should also assess the condition of adjacent teeth. If adjacent teeth have large amalgams or crowns, or have undergone endodontic therapy, it is important to keep this in mind when elevators and forceps are used to mobilize and remove the indicated tooth. If adjacent teeth have large restorations, the surgeon should use elevators with extreme caution because fracture or displacement of the restorations may occur (Fig. 8.4). The patient should be informed before the surgical procedure about possible damage to these restorations during the process of obtaining informed consent.

Radiographic Examination of the Tooth for Removal

It is essential that proper radiographs be taken of any tooth to be removed. In general, periapical radiographs provide the most accurate and detailed information concerning the tooth, its roots, and the surrounding tissue. Panoramic radiographs are used

frequently, but their greatest usefulness is for impacted teeth as opposed to erupted teeth.

For radiographs to have their maximal value, they must meet certain criteria. Most importantly, radiographs must be properly exposed, with adequate penetration and good contrast. The radiographic film or sensor should have been properly positioned so that it shows all portions of the crown and roots of the tooth under consideration without distortion (Fig. 8.5). If digital imaging is not used, the radiograph must be properly processed, with good fixation, drying, and mounting. The mounting should be labeled with the patient's name and the date on which the film was exposed. The radiograph should be mounted in the American Dental Association (ADA) standardized method, which is to view the radiograph as if looking at the patient; the raised dot on the film faces the observer. The radiograph should be reasonably current in order to depict the presently existing situation. Radiographs older than 1 year should probably be retaken before surgery. Finally, nondigital radiographs must be mounted on a view box that is visible to the surgeon during the operation, and digital images should be displayed so the surgeon can look at them during extractions without stopping surgery or degloving. Radiographs that are taken, but not available during surgery, are of limited value.

The relationship of the tooth to be extracted to adjacent erupted and unerupted teeth should be noted. If the tooth is a primary tooth, the relationship of its roots to the underlying succedaneous tooth should be carefully considered. The extraction of a primary tooth can possibly injure or dislodge the underlying tooth. If surgical removal of a root or part of a root is necessary, the relationship of the root structures of adjacent teeth must be known. Bone removal should be performed judiciously whenever necessary, but it is particularly important to be careful if adjacent roots are close to the root being removed.

Relationship to Vital Structures

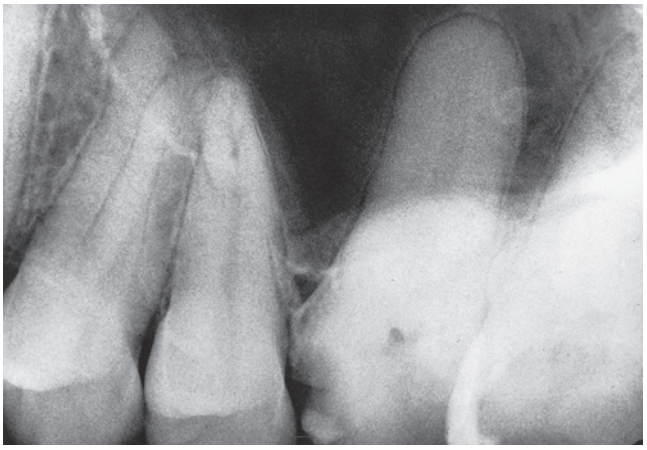
When performing extractions of the maxillary molars, it is essential to be aware of the proximity of the roots of the molars to the floor of the maxillary sinus. If only a thin layer of bone exists between the sinus and the roots of molar teeth, the potential for perforation of the maxillary sinus during the extraction increases. Thus the surgical treatment plan may be altered to an open surgical technique, with division of maxillary molar roots into individual roots before the extraction proceeds (Fig. 8.6).

The inferior alveolar canal may approximate the roots of mandibular molars. Although the removal of an erupted tooth rarely impinges on the inferior alveolar canal, if an impacted tooth is to be removed, it is important that the relationship between molar roots and the canal be assessed. Such an extraction may lead to injury of the canal and cause consequent damage to the inferior alveolar nerve (Fig. 8.7). Cone-beam computed tomography (CBCT) images are often useful in these circumstances.

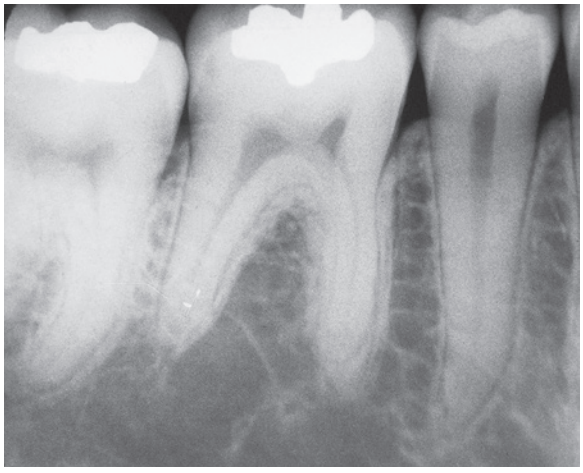
Radiographs taken before the removal of mandibular premolar teeth should include the mental foramen. Should a surgical flap be required to retrieve a premolar root, it is essential that the surgeon know where the mental foramen is to avoid injuring the mental nerve during flap development (Fig. 8.8, see also Fig. 8.3).

Configuration of Roots

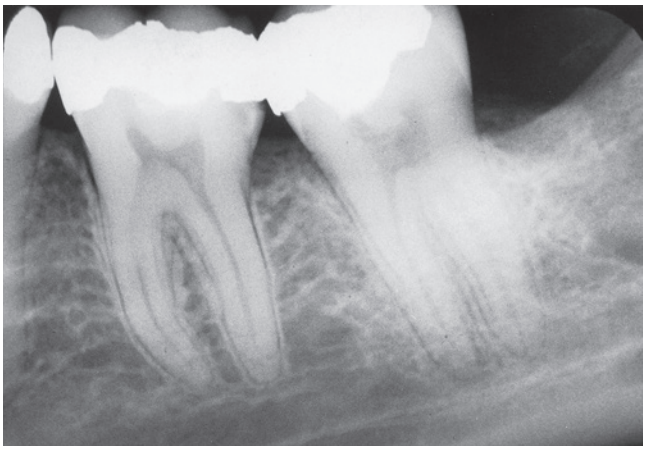
Radiographic assessment of the tooth to be extracted probably contributes the most to the determination of difficulty of the extraction. The first factor to evaluate is the number of roots on the tooth to be extracted. Most teeth have the typical number of roots, in which case the surgical plan can be carried out in the



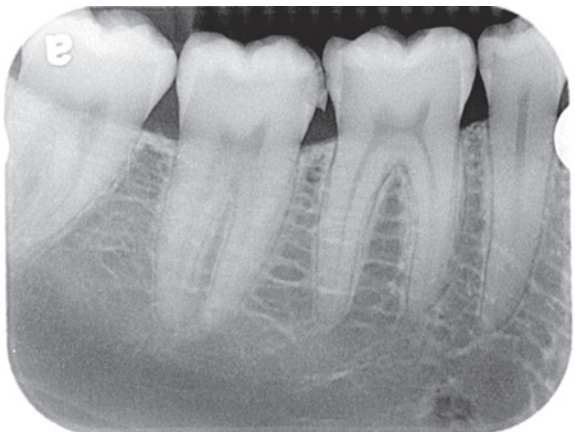
• **Fig. 8.6** Maxillary molar teeth immediately adjacent to the sinus present increased danger of sinus exposure.



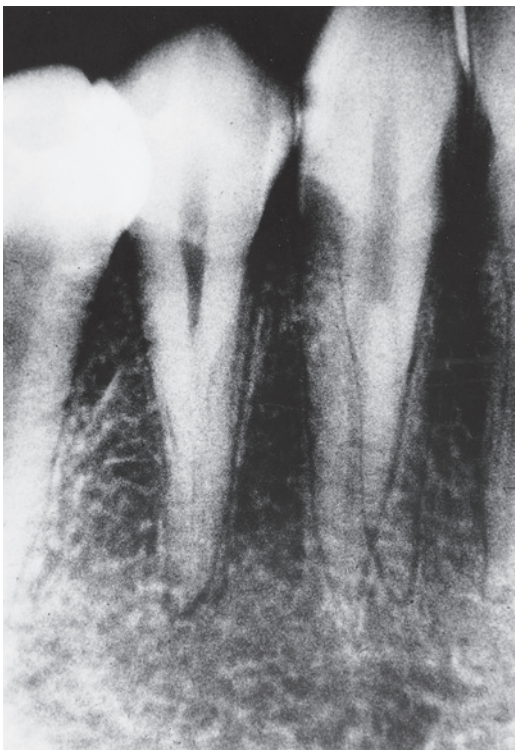
• **Fig. 8.5** Properly exposed radiograph for extraction of mandibular first molar.



• **Fig. 8.7** Mandibular molar teeth that are close to the inferior alveolar canal. Third molar removal is a procedure most likely to result in injury to the nerve.



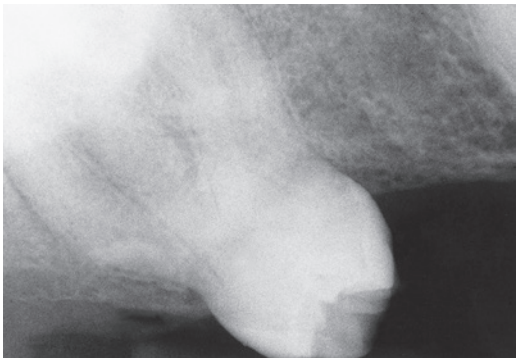
• **Fig. 8.8** Before premolar extractions that require a surgical flap are performed, it is essential to know the relationship of the mental foramen to root apices. Note the radiolucent area at the apex of the second premolar, which represents the mental foramen.



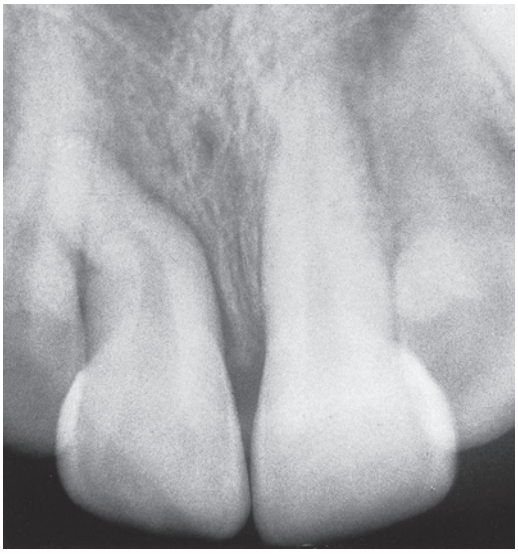
• **Fig. 8.9** Mandibular canine tooth with two roots. Knowledge of this fact preoperatively may result in a less traumatic extraction.

usual fashion; but many teeth have an abnormal number of roots. If the number of roots is known before the tooth is extracted, an alteration in the plan can be made to prevent fracture of any additional roots (Fig. 8.9).

The surgeon must know the curvature of the roots and the degree of root divergence to properly plan the extraction procedure. Roots of the usual number and of average size may still diverge substantially and thus make the total root width so wide that it precludes extraction with forceps. In situations of excess curvature with wide divergence, surgical extraction may be required with planned division of the crown (Fig. 8.10).



• **Fig. 8.10** The widely divergent roots of this maxillary first molar make extraction more difficult.



• **Fig. 8.11** The curvature of the roots of this tooth is unexpected. Preoperative radiographs help the surgeon plan the extraction more carefully.

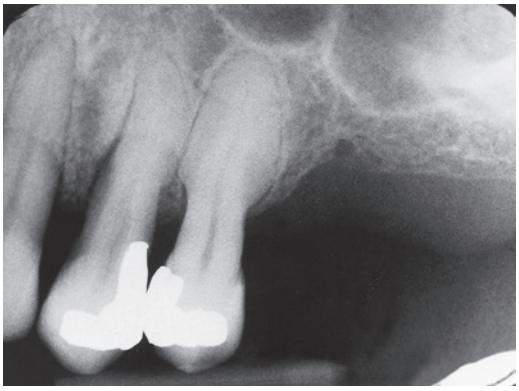
The shape of the individual root must be taken into consideration. Roots may have short, conic shapes that make them easy to remove. However, long roots with severe and abrupt curves or hooks at their apical end are more difficult to remove. The surgeon must have knowledge of the shapes of the roots before surgery to adequately plan the surgery (Fig. 8.11).

The size of the root must be assessed. Teeth with short roots are easier to remove compared with teeth with long roots. A long root that is bulbous as a result of hypercementosis is even more difficult to remove. The periapical radiographs of older patients should be examined carefully for evidence of hypercementosis because this process seems to be a result of aging (Fig. 8.12).

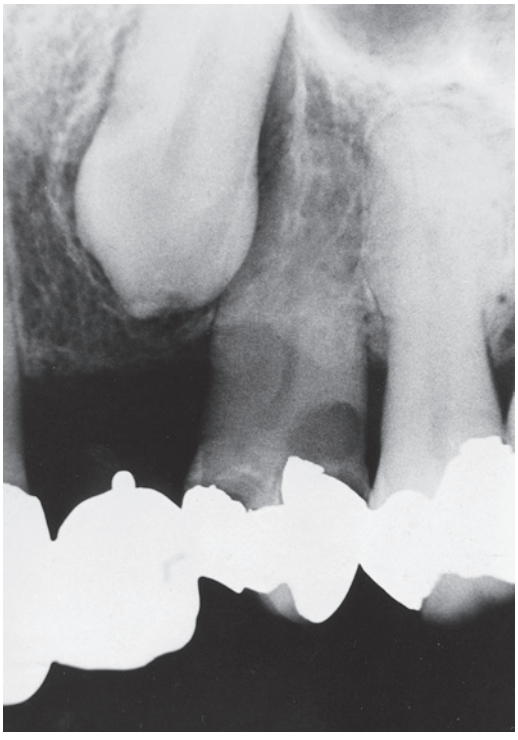
The surgeon should look for evidence of caries extending into the roots. Root caries may substantially weaken the root and make it more liable to fracture when the force of the forceps is applied (Fig. 8.13).

Root resorption, internal or external, should be assessed on examination of the radiograph. Like root caries, root resorption weakens the root structure and renders it more likely to be fractured. Surgical extraction may be considered in situations of extensive root resorption (Fig. 8.14).

The tooth should be evaluated for previous endodontic therapy. If there was endodontic therapy many years before the extraction



• **Fig. 8.12** Hypercementosis increases the difficulty of these extractions because roots are larger at the apical end than at the cervical end. Surgical extraction will probably be required.



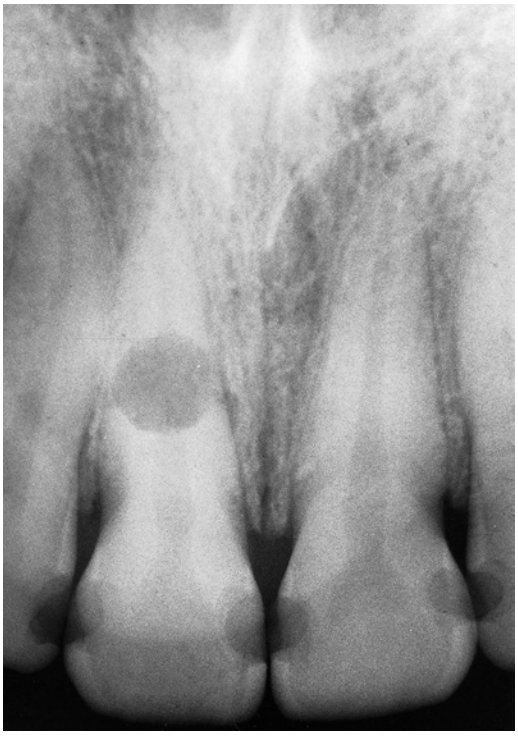
• **Fig. 8.13** Root caries in first premolar tooth make extraction more difficult because fracture of the tooth is likely. Note hypercementosis of the second premolar.

process, there may be ankylosis and the tooth root will be more brittle. In both situations, surgical extraction may be indicated (Fig. 8.15).

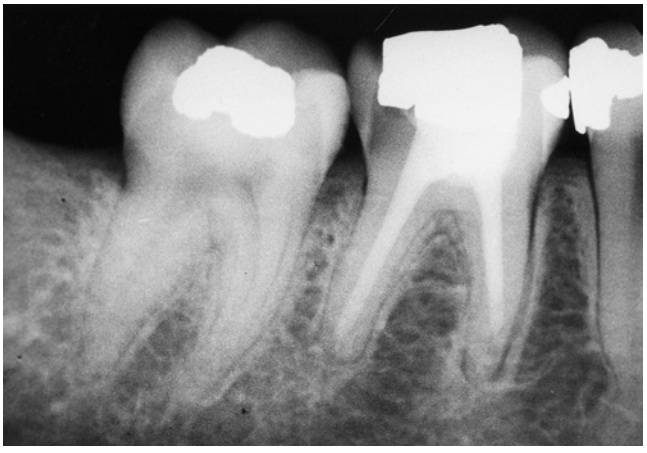
Condition of Surrounding Bone

Careful examination of the periapical radiograph indicates the density of bone surrounding the tooth to be extracted. Bone that is more radiolucent is likely to be less dense, which makes the extraction easier. However, if bone appears to be radiographically opaque (indicating increased density), with evidence of condensing osteitis or other sclerosis-like processes, it will be more difficult to extract.

The surrounding bone should also be examined carefully for evidence of any apical pathology. Teeth that have nonvital pulps



• **Fig. 8.14** Internal resorption of the root makes closed extraction almost impossible because fracture of the root will almost surely occur.

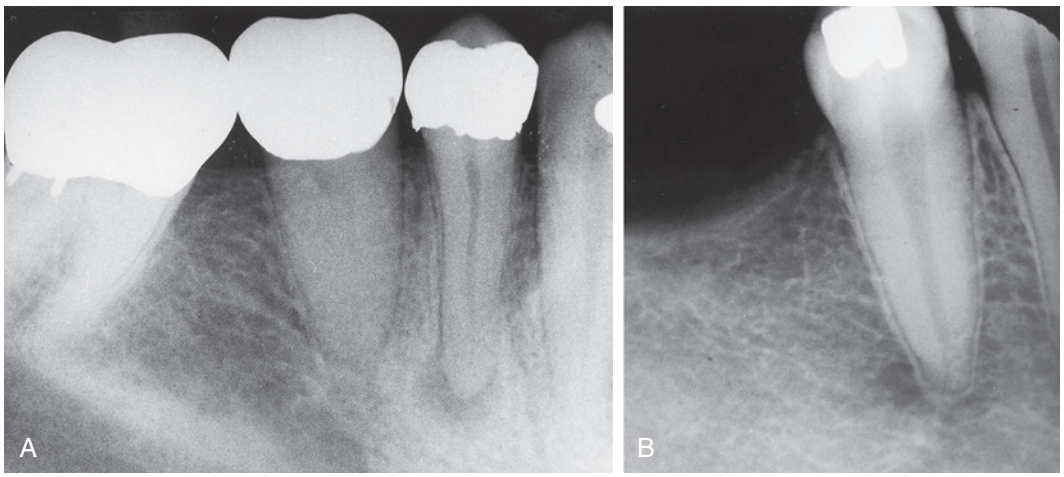


• **Fig. 8.15** Tooth made brittle by previous endodontic therapy. The tooth is thus more difficult to remove.

may have periapical radiolucencies that represent granulomas or cysts. Awareness of the presence of such lesions is important because these lesions should be removed at the time of surgery (Fig. 8.16).

Patient and Surgeon Preparation

Surgeons must prevent inadvertent injury or transmission of infection to their patients or to themselves. The principle of universal precautions states that all patients must be viewed as having bloodborne diseases that can be transmitted to the surgical team and other patients. To prevent this transmission, surgical gloves, surgical mask, and eyewear with side-shields are required. (See Chapter 5 for a detailed discussion of this topic.) In addition, most authorities recommend that the surgical team wear long-sleeved



• **Fig. 8.16** (A) Periapical radiolucency. The surgeon must be aware of this before extraction for proper management. (B) Periapical radiolucency around the mandibular premolar represents the mental foramen. The surgeon must be aware that this is not a pathologic condition. An intact lamina dura is noted in B but not in A.

• **Fig. 8.17** The surgeon is prepared for surgery by wearing protective eyeglasses, mask, and gloves. Surgeons should have short or pinned-back hair and should wear long-sleeved smocks that are changed daily, or sooner if they become soiled. The patient benefits from a waterproof drape.

gowns, which should be changed when they become visibly soiled (Fig. 8.17).

If the surgeon has long hair, it is essential that the hair be held in position with barrettes or other holding devices and be covered with a surgical cap. A major breach in aseptic technique is to allow the surgeon's hair to hang over the patient's face.

Before the patient undergoes the surgical procedure, a minimal amount of draping is necessary. A sterile drape should be put across the patient's chest to decrease the risk of contamination (see Fig. 8.17).

Before the extraction, some surgeons advise patients to rinse their mouths vigorously with an antiseptic mouth rinse such as chlorhexidine. This reduces the bacterial contamination in the patient's mouth to some degree. It is unclear what effect this may have on postoperative problems.

To prevent teeth or fragments of teeth from falling into the patient's mouth and potentially being swallowed or aspirated into the lungs, many surgeons prefer to place a partially unfolded 4 × 4 inch gauze loosely into the back of the mouth. This oral partition serves as a barrier so that should a tooth slip from the forceps or shatter under the pressure of the forceps, it will be caught in the gauze rather than be swallowed or aspirated. The surgeon must take care that the gauze is not positioned so far posteriorly that it triggers the gag reflex. The surgeon should explain the purpose of the partition to gain the patient's acceptance and cooperation for allowing the gauze to be in place.

Chair Position for Extractions

The positions of the patient, the chair, and the operator are critical for the successful completion of an extraction. The best position is one that is comfortable for both the patient and surgeon and allows the surgeon to have maximal control of the force that is being delivered to the patient's tooth through the elevators and forceps. The correct position allows the surgeon to keep the arms close to the body and provides stability and support; it also allows the surgeon to keep the wrists straight enough to deliver the force with the arm and shoulder, and not with the fingers or hand. The force delivered can thus be controlled in the face of sudden loss of resistance from a root or fracture of the bone.

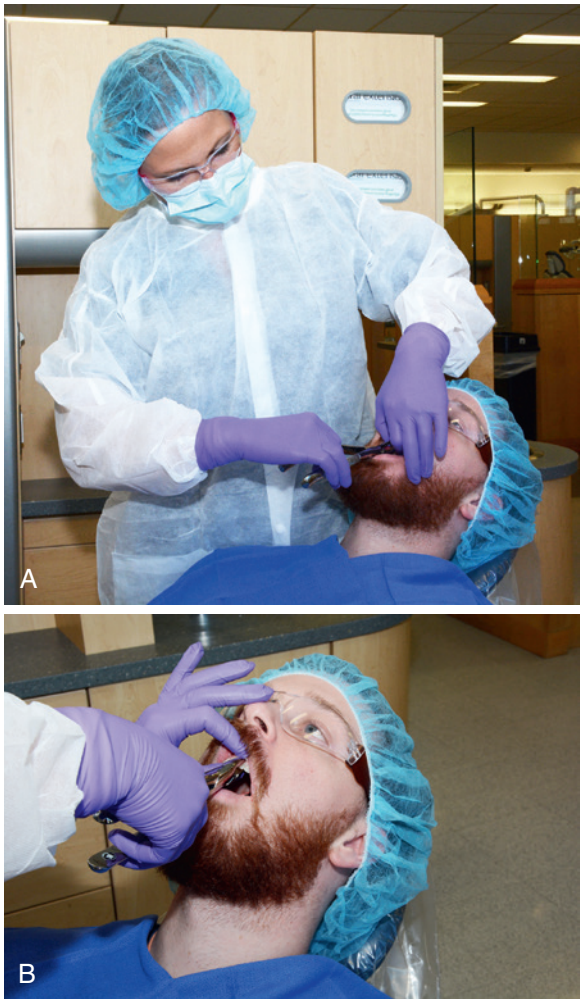
Dentists usually stand during extractions, so the positions for a standing surgeon will be described first. Modifications that are necessary to operate in a seated position will be presented later. Also, descriptions of techniques are for the right-handed operator. Left-handed surgeons should reverse the instructions when working on various quadrants.

The most common error dentists make in positioning the dental chair for extractions is to have the chair too high. This forces the surgeons to operate with their shoulders raised, thereby making it difficult to deliver the correct amount of force to the tooth being extracted in the proper manner. It is also tiring to the surgeon. Another frequent positioning problem is for the dentist to lean over the patient and put his or her face close to the patient's mouth.

This interferes with surgical lighting, is hard on the dentist's back and neck, and also interferes with proper positioning of the rest of the dentist's body.

For a maxillary extraction, the chair should be tipped backward so that the maxillary occlusal plane is at an angle of about 60 degrees to the floor. Raising the patient's legs at the same time helps improve the patient's comfort. The height of the chair should be such that the patient's mouth is at or slightly below the operator's elbow level (Fig. 8.18). As mentioned previously, novices tend to position the chair too high. During an operation on the maxillary right quadrant, the patient's head should be turned substantially toward the operator so that adequate access and visualization can be achieved (Fig. 8.19). For extraction of teeth in the maxillary anterior portion of the arch, the patient should be looking straight ahead (Fig. 8.20). The position for the maxillary left portion of the arch is similar, except that the patient's head is turned slightly toward the operator (Fig. 8.21).

For the extraction of mandibular teeth, the patient should be positioned in a more upright position so that when the mouth is opened wide, the occlusal plane is parallel to the floor (Fig. 8.22). A properly sized bite block should be used to stabilize the mandible

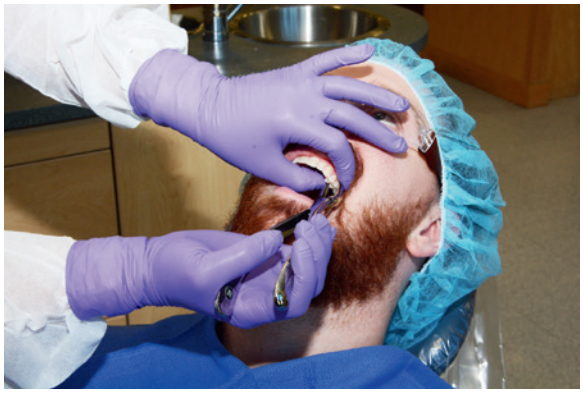


• **Fig. 8.18** Patient positioned for maxillary extraction. The chair is tilted back so that the maxillary occlusal plane is at about a 60-degree angle to the floor. The height of the chair should ensure that the level of the patient's mouth is slightly below the surgeon's elbow.

• **Fig. 8.19** Extraction of teeth in the maxillary right quadrant. Note that patient's head is turned toward the surgeon.

• **Fig. 8.20** Extraction of anterior maxillary teeth. The patient looks straight ahead.

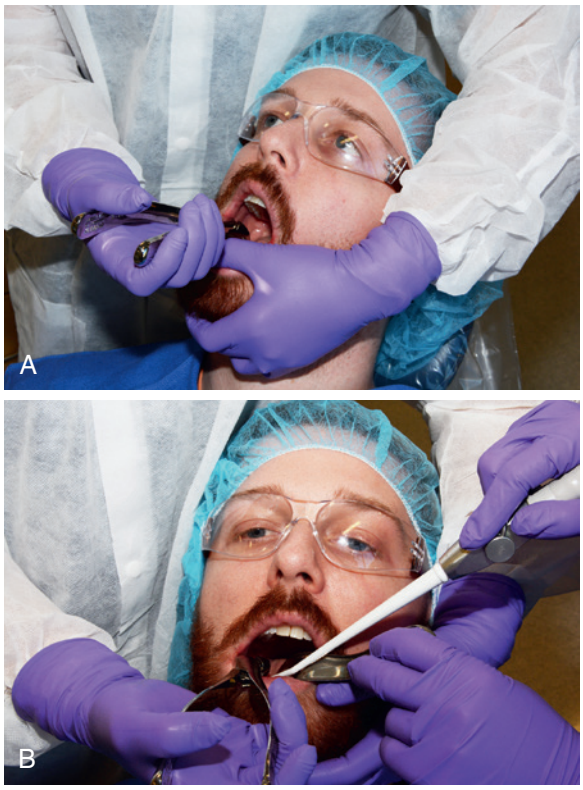
• **Fig. 8.21** Extraction of maxillary left posterior teeth. The patient's head is turned slightly toward the surgeon.



• **Fig. 8.22** For mandibular extractions, the patient is more upright so that the mandibular occlusal plane of the opened mouth is parallel to the floor. The height of the chair is also lower to allow the operator's arm to be straighter.

• **Fig. 8.24** Extraction of mandibular anterior teeth. The surgeon stands at the side of the patient, who looks straight ahead.

• **Fig. 8.23** Extraction of mandibular right posterior teeth. The patient's head is turned toward the surgeon.



• **Fig. 8.25** When English-style forceps are used for extraction of anterior mandibular teeth, the patient's head is positioned straight ahead.

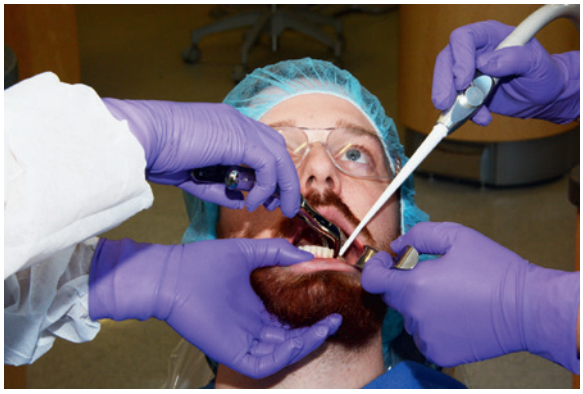
when extraction forceps are used. Even though the surgeon will support the jaw, the additional support provided by the bite block will result in less stress being transmitted to the jaws and allows the patient to rest their muscles of mastication. Care should be taken to avoid using too large a bite block because large ones can overstretch the TMJ ligaments and cause patient discomfort. Typically pediatric bite blocks are the best to use, even in adults.

During removal of mandibular right posterior teeth, the patient's head should be turned acutely toward the surgeon to allow adequate access to the jaw, and the surgeon should maintain the proper arm and hand positions (Fig. 8.23). When removing teeth in the anterior region of the mandible, the surgeon should be to the side of the patient (Figs. 8.24 and 8.25). When operating on the left posterior mandibular region, the surgeon should move to the side of the patient, but the patient's head should not turn so acutely toward the surgeon (Fig. 8.26).

Some surgeons prefer to approach maxillary and mandibular teeth from a posterior position. This allows the left hand of the surgeon to support the mandible better, but it requires that the forceps be held in an underhand grip and that the surgeon view the field with an upside-down perspective. The left hand of the surgeon goes around the patient's head and supports the mandible.

• **Fig. 8.26** Extraction of mandibular posterior teeth. The patient turns slightly toward the surgeon.

• **Fig. 8.28** Behind-the-patient approach for extraction of posterior left mandibular teeth. The surgeon's hand is positioned under the forceps.



• **Fig. 8.27** Behind-the-patient approach for extraction of posterior right mandibular teeth. This allows the surgeon to be in a comfortable, stable position.

• **Fig. 8.29** In the surgeon-seated position, the patient is positioned as low as possible so that the mouth is at or below the level of the surgeon's elbow.

The usual behind-the-patient approach is seen in Figs. 8.27 and 8.28. Note the surgeon's right arm is held closely to their body, increasing the arm's strength.

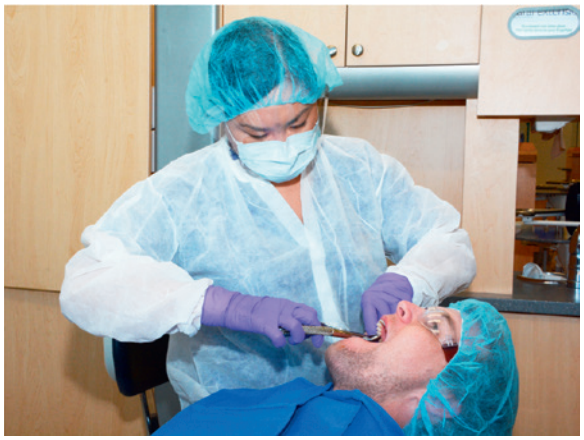
If the surgeon chooses to sit while performing extractions, several modifications must be made. For maxillary extractions, the patient is positioned in a semireclining position similar to that used when the surgeon is standing. However, the patient is not reclined as much; therefore the maxillary occlusal plane is not perpendicular to the floor as it is when the surgeon is standing. The patient should be lowered as far as possible so that the level of the patient's mouth is as near as possible to the surgeon's elbow (Fig. 8.29). The arm and hand positions for extraction of maxillary anterior and posterior teeth are similar to the positions used for the same extractions performed while standing (Fig. 8.30).

As when the surgeon is standing, for extraction of teeth in the lower arch, the patient is slightly more upright than for extraction of maxillary teeth. The surgeon can work from the front of the patient (Figs. 8.31 and 8.32) or from behind the patient (Figs. 8.33 and 8.34). When the English-style forceps are used, the surgeon's position is usually behind the patient (Fig. 8.35). It should be noted that the surgeon and the assistant have hand and arm positions similar to those used when the surgeon is in the standing position.

Mechanical Principles Involved in Tooth Extraction

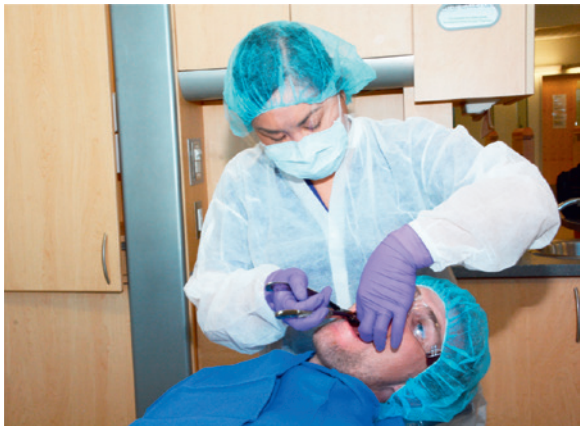
The removal of teeth from the alveolar process requires the use of the following mechanical principles and simple machines: the lever, the wedge, and the wheel and axle.

Elevators are used primarily as levers. A lever is a mechanism for transmitting a modest force—with the mechanical advantages



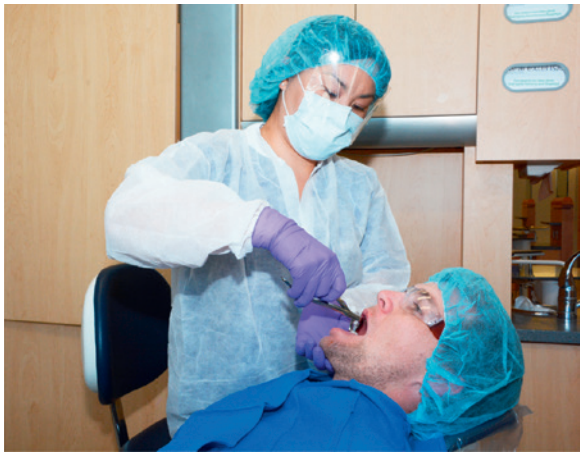
• **Fig. 8.30** For extraction of maxillary teeth, the patient is reclined approximately 60 degrees. Hand and forceps positions are the same as for the standing position.

• **Fig. 8.33** For removal of anterior teeth, the surgeon moves to a position behind the patient so that the patient's mandible and alveolar process can be supported by the surgeon's other hand.



• **Fig. 8.31** For extraction of maxillary teeth, the operator can hold the forceps in an underhand position.

• **Fig. 8.34** The behind-the-patient position can be used for removal of mandibular posterior teeth. The surgeon's hand is positioned under the forceps for maximum control.



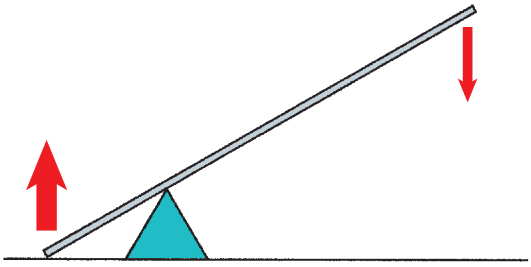
• **Fig. 8.32** For extraction of mandibular anterior teeth, the operator can hold the forceps in an overhand manner.

• **Fig. 8.35** When English-style forceps are used, a behind-the-patient position is preferred.

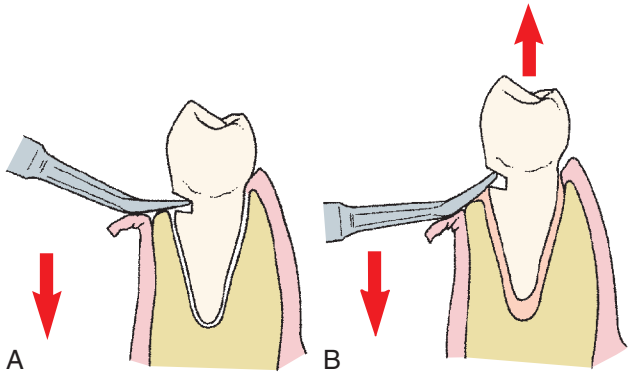
of a long lever arm and a short effector arm—into a small movement against great resistance (Fig. 8.36). An example of the use of a lever is when a Crane pick is inserted into a purchase point placed in a tooth and then is used to elevate the tooth (Fig. 8.37).

The second simple machine that is useful is the wedge (Fig. 8.38). The wedge is useful in several different ways for the extraction of teeth. First, the beaks of extraction forceps are usually narrow at their tips; they broaden as they go superiorly. When forceps are used, there should be a conscious effort made to force the tips of the forceps into the periodontal ligament space at the bony crest. This uses the tooth root as a wedge to expand the bone; as the beaks of the forceps are pressed apically on the root, they will help force the tooth out of the socket (Fig. 8.39). The wedge principle is also useful when a straight elevator is used to luxate a tooth from its socket. A small elevator is wedged into the periodontal ligament space, which displaces the root toward the occlusion and thus out of the socket (Fig. 8.40).

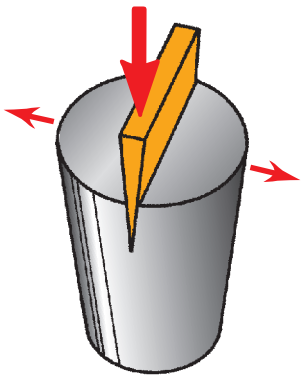
The third machine used in tooth extraction is the wheel and axle, which is most closely identified with the triangular, or pennant-shaped, elevator. When one root of a multiple-rooted tooth is left in the alveolar process, the pennant-shaped elevator, such as a Cryer, is positioned into the socket and turned. The handle then serves as the axle, and the tip of the triangular elevator acts as a wheel and engages and elevates the tooth root from the socket (Fig. 8.41).



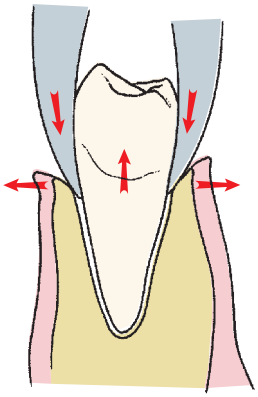
• **Fig. 8.36** The first-class lever transforms small force and large movement to small movement and large force.



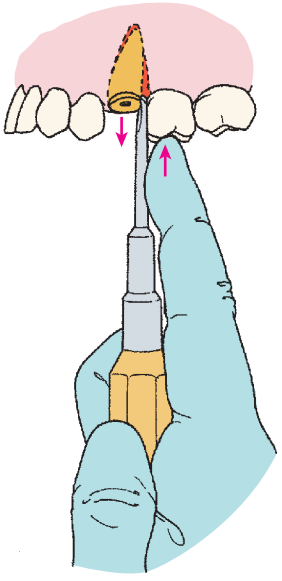
• **Fig. 8.37** In removal of a mandibular premolar tooth, the purchase point is placed in the tooth, which creates a first-class lever situation. When the Crane pick is inserted into the purchase point and the handle is depressed apically (A), the tooth is elevated occlusally out of the socket with buccoalveolar bone used as the fulcrum (B).



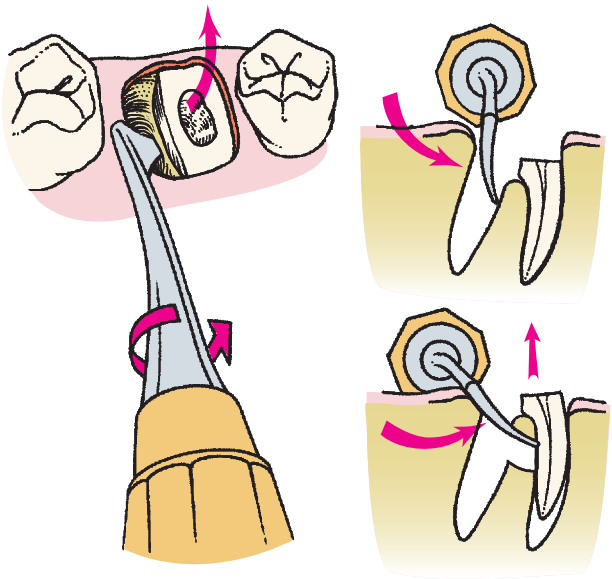
• **Fig. 8.38** A wedge can be used to expand, split, and displace portions of the substance that receives it.



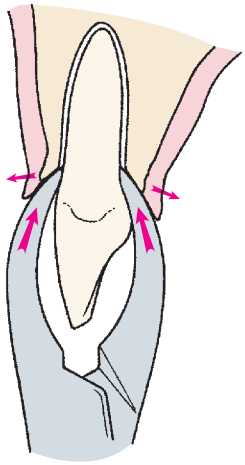
• **Fig. 8.39** Beaks of the forceps act as wedges to expand alveolar bone and displace the tooth in the occlusal direction.



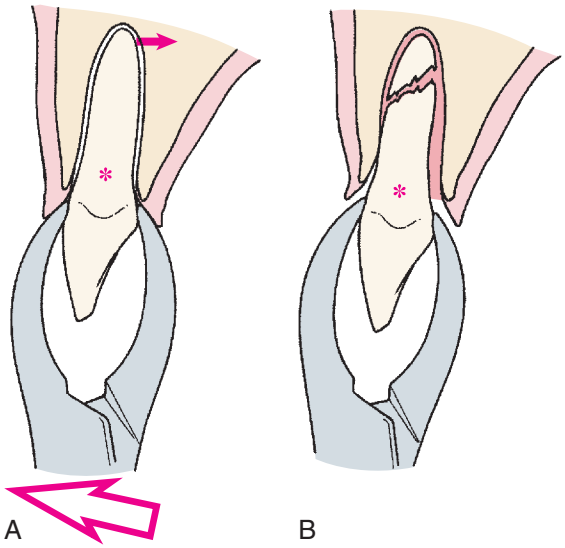
• **Fig. 8.40** Small, straight elevator used as wedge to displace the tooth root from its socket by driving the elevator apically in the periodontal ligament space.



• **Fig. 8.41** Triangular elevator in the role of a wheel-and-axle machine used to retrieve the root from the socket.



• **Fig. 8.42** Extraction forceps should be seated with strong apical pressure to expand crestal bone and to displace the center of rotation as far apically as possible.



• **Fig. 8.43** (A) If the center of rotation *(asterisk)* is not far enough apically, it is too far occlusally, which results in excess movement of tooth apex. (B) Excess motion of the root apex caused by a high center of rotation results in fracture of the root apex.

Principles of Elevator and Forceps Use

The primary instruments used to remove a tooth from the alveolar process are the elevator and extraction forceps. Elevators help in the luxation of a tooth, and forceps continue that process through bone expansion and disruption of periodontal attachments. The goal of forceps use is threefold: (1) expansion of the bony socket by use of the wedge-shaped beaks of the forceps and the movements of the tooth itself with the forceps, (2) twisting of conical roots to disrupt periodontal ligaments, and (3) removal of the tooth from the socket.

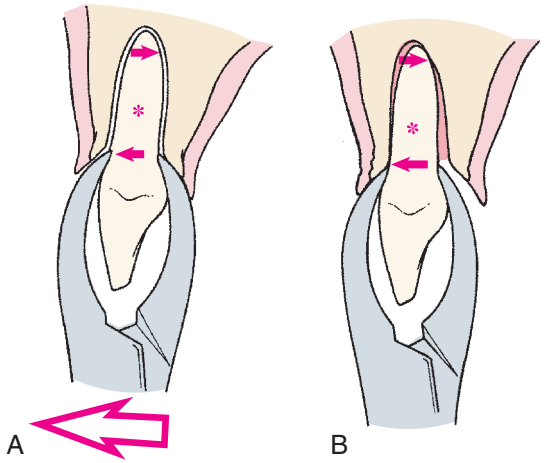
The dental elevator consists of a handle, a shank, and a blade. The handle of the elevator is usually in line with the shank and is enlarged to allow it to be grasped in the palm of the hand. The elevator may also have flattened areas for fingers to grasp to help guide the elevator. The handle can also be set perpendicular to the shank (cross bar–type elevators). The shank connects the handle to the blade. Blades can be straight, triangular (Cryer), curved (Potts), or pointed (Crane pick).

Forceps can apply five major motions to luxate teeth. The first is apical pressure, which accomplishes two goals. (1) Although the tooth moves in an apical direction minimally, the tooth socket is expanded by the insertion of the beaks down into the periodontal ligament space (Fig. 8.42). Thus the apical pressure of the forceps on the tooth causes bony expansion. (2) A second accomplishment of apical pressure is that the center of rotation of the tooth is displaced apically. Because the tooth is moving in response to the force placed on it by the forceps, the forceps become the instrument of expansion. If the fulcrum is high (Fig. 8.43), a larger amount of force is placed on the apical region of the tooth, which increases the chance of fracturing the root end. If the beaks of the forceps are forced into the periodontal ligament space, the center of rotation is moved apically, which results in greater movement of the expansion forces at the crest of the ridge and less force moving the apex of the tooth lingually (Fig. 8.44). This process decreases the chance for apical root fracture.

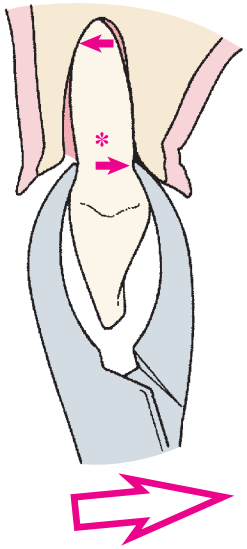
The second major pressure or movement applied by forceps is the buccal force. Buccal pressures result in expansion of the buccal plate, particularly at the crest of the ridge (Fig. 8.45). Although buccal pressure causes expansion forces at the crest of the ridge, it is important to remember that it also causes lingual apical pressure. Thus excessive force can fracture buccal bone or cause fracturing of the apical portion of the root.

Third, lingual or palatal pressure is similar to the concept of buccal pressure but is aimed at expanding the linguocrestal bone and, at the same time, avoiding excessive pressures on the buccal apical bone (Fig. 8.46). Because lingual bone tends to be thicker than buccal bone in posterior areas of the mouth, limited bone expansion occurs.

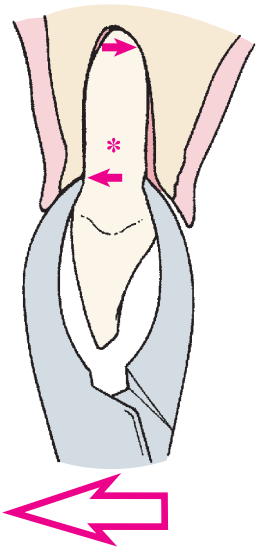
Fourth, rotational pressure, as the name implies, rotates the tooth, which causes some internal expansion of the tooth socket



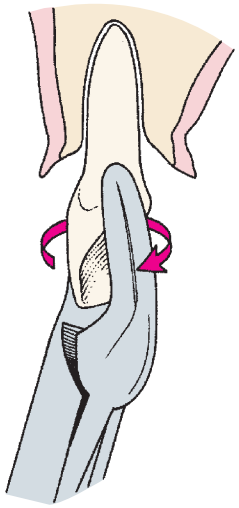
• **Fig. 8.44** (A) If the forceps are apically seated, the center of rotation *(asterisk)* is displaced apically, and smaller apical pressures are generated. (B) This results in greater expansion of the buccal cortex, less movement of the apex of the tooth, and therefore less chance of fracture of the root.



• **Fig. 8.46** Lingual pressure will expand the linguocortical plate at the crestal area and slightly expand buccal bone at the apical area. *Asterisk* notes the center of rotation.



• **Fig. 8.45** Buccal pressure applied to the tooth will expand the buccocortical plate toward crestal bone, with some lingual expansion at the apical end of the root. *Asterisk* notes the center of rotation.

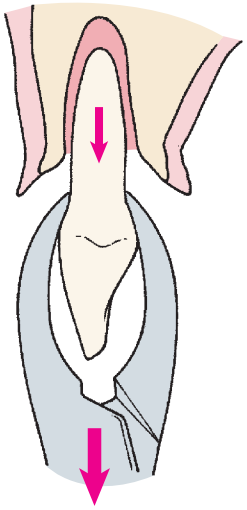


• **Fig. 8.47** Rotational forces are useful for teeth with conical roots, such as maxillary incisors and mandibular premolars.

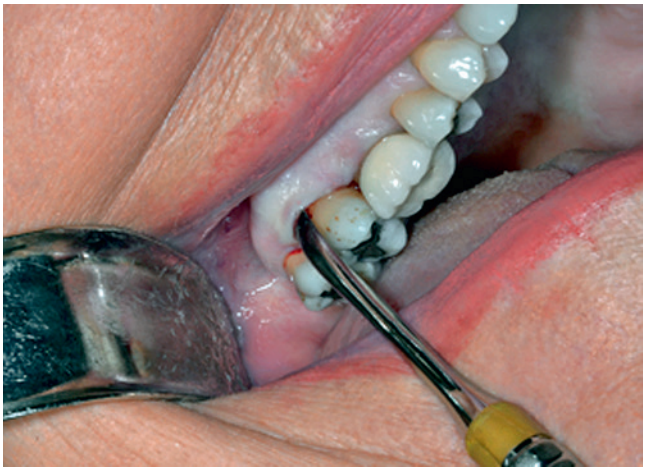
and tearing of periodontal ligaments. Teeth with single, conical roots (such as incisors, canines, and mandibular premolars) and those with roots that are not curved are most amenable to luxation by this technique (Fig. 8.47). Teeth that have other than conical roots or that have multiple roots—especially if those roots are curved—are more likely to fracture under this type of pressure.

Finally, tractional forces are useful for delivering the tooth from the socket once adequate bony expansion is achieved. As mentioned previously, teeth should not be pulled from their sockets. Tractional forces should be limited to the final portion of the extraction process and should be gentle (Fig. 8.48). If excessive force is needed, other maneuvers should be performed to improve root luxation.

In summary, a variety of forces can be used to remove teeth. A strong apical force is always useful and should be applied whenever forceps are adapted to the tooth. Most teeth are removed by a combination of buccal and lingual (palatal) forces. Because maxillary buccal bone is usually thinner and palatal bone is a thicker cortical bone, maxillary teeth are usually removed by stronger buccal forces and less vigorous palatal forces. In the mandible, buccal bone is thinner from the midline posteriorly to the area of molars. Therefore incisors, canines, and premolars are removed primarily as a result of strong sustained buccal force and less vigorous lingual pressures. As mentioned before, rotational forces are useful for single-rooted teeth that have conic roots and no severe curvatures at the root end. The maxillary incisors, particularly the central incisor and mandibular premolars, are most amenable to rotational forces.



• **Fig. 8.48** Tractional forces are useful for the final removal of the tooth from the socket. These should always be small forces because teeth are not pulled.



• **Fig. 8.49** Periosteal elevator used to loosen the gingival attachment from the tooth and the interdental papilla. (Courtesy Dr. Edward Ellis III.)

Procedure for Closed Extraction

An erupted root can be extracted using one of two major techniques: closed or open. The closed technique is also known as the *routine technique*. The open technique is also known as the *surgical technique*, or *flap technique*. This section discusses the closed extraction technique; the open (surgical) technique is discussed in Chapter 9.

The closed technique is the most frequently used technique and is given primary consideration for almost every extraction. The open technique is used when the clinician believes that excessive force would be necessary to remove the tooth, when a substantial amount of the crown is missing or covered by tissue, or when access to the root of a tooth is difficult, such as when a fragile crown is present.

The correct technique for any situation should lead to an atraumatic extraction; the wrong technique commonly results in an excessively traumatic and lengthy extraction.

Whatever technique is chosen, the three fundamental requirements for a good extraction remain the same: (1) adequate access and visualization of the field of surgery, (2) an unimpeded pathway for the removal of the tooth, and (3) the use of controlled force to luxate and remove the tooth.

For the tooth to be removed from the bony socket, it is usually necessary to expand the alveolar bony walls to allow the tooth root an unimpeded pathway, and it is necessary to tear the periodontal ligament fibers that hold the tooth in the bony socket. The use of elevators and forceps as levers and wedges with steadily increasing force can accomplish these two objectives.

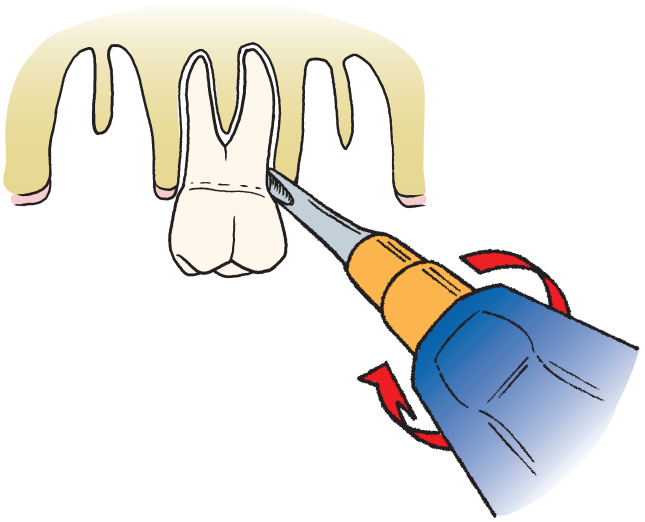
Five general steps make up the closed extraction procedure. *Step 1* involves loosening of the soft tissue attachment from the cervical portion of the tooth. The first step in removing a tooth by the closed extraction technique is to loosen the soft tissue from around the tooth with a sharp instrument such as a scalpel blade or the sharp end of the No. 9 periosteal elevator (Fig. 8.49). The purpose of loosening the soft tissue from the tooth is twofold: (1) First, it allows the surgeon to ensure that profound anesthesia has been achieved. When this step has been performed, the dentist informs the patient that the surgery is about to begin and that the first step will be to push the soft tissue away from the tooth. A small amount of pressure is felt at this step, but there should be no sensation of sharpness or discomfort if profound local anesthesia is in place. The surgeon then begins the soft tissue loosening procedure, gently at first and then with increasing force. (2) The second reason that soft tissue is loosened is to allow the elevator and tooth extraction forceps to be positioned more apically, without interference from or impingement on the gingiva. As the soft tissue is loosened away from the tooth, it is slightly reflected, which thereby increases the width of the gingival sulcus and allows easy entrance of the beveled tip of the forceps beaks. The adjacent gingival papilla of the tooth should also be reflected to avoid damage by the insertion of the straight elevator.

Step 2 involves luxation of the tooth with a dental elevator. The luxation of the tooth begins with a dental elevator, usually the straight elevator. In most situations, elevation from the lingual or palatal aspects of roots is limited due to poor access and is of limited efficacy. Elevation should occur at the mesial and distal buccal aspects of the root. No elevation should be attempted along buccal bone because it can be easily fractured or the surgeon can lose control and cause soft tissue injury.

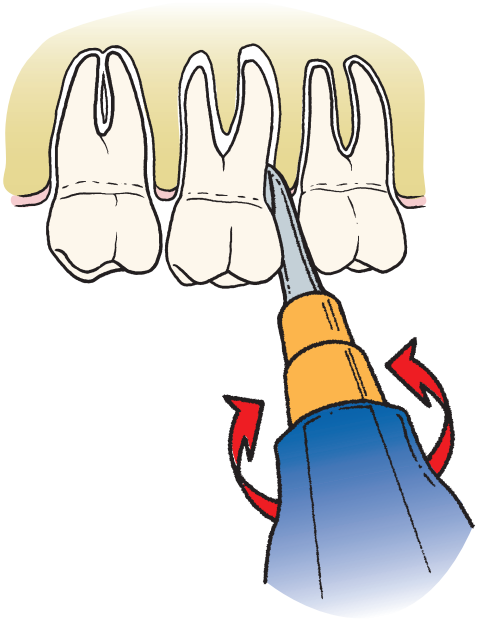
Expansion and dilation of the alveolar bone and tearing of the periodontal ligament require that the tooth be luxated in several ways. The straight elevator is inserted perpendicular to the tooth into the interdental space, after reflection of the interdental papilla (Figs. 8.50 to 8.52). The elevator is then moved to direct the blade in an apical direction. The elevator is then rotated in small motions back and forth, while apical pressure is placed to advance the blade into the periodontal ligament space. A straight elevator with a small blade should be used initially. Once some tooth movement is noted, a larger straight elevator is inserted and used in a similar manner. If the tooth is intact and in contact with stable teeth anterior and posterior to it, the amount of movement achieved with the straight elevator will be minimal. The usefulness of this step is greater if the patient does not have a tooth posterior to the tooth being extracted or it is broken down to an extent that the crowns do not inhibit movement of the tooth, or if the adjacent tooth is also planned for extraction at the same appointment.

Luxation of teeth with a straight elevator should be performed with caution. Excessive forces can damage and even displace the

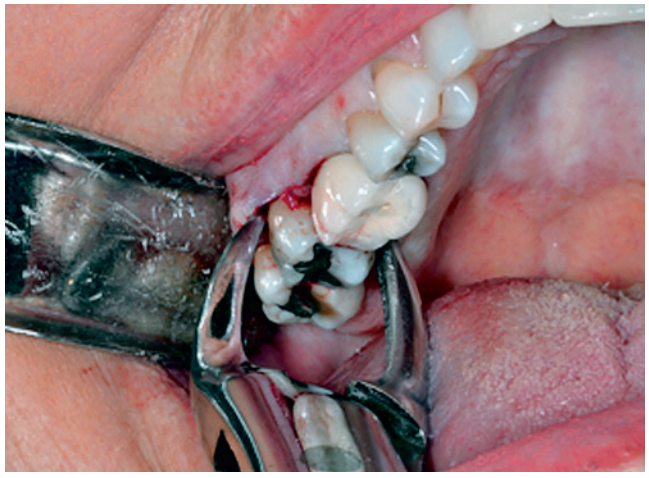
• **Fig. 8.50** Small, straight elevator, inserted perpendicular to the tooth after the papilla has been reflected. (Courtesy Dr. Edward Ellis III.)



• **Fig. 8.51** The handle of the small, straight elevator is turned such that the occlusal side of the elevator blade is turned toward the tooth. The handle is also moved apically to help elevate the tooth.



• **Fig. 8.52** The handle of the elevator may be turned in the opposite direction to displace the tooth further from the socket. This can be accomplished only if no tooth is adjacent posteriorly.

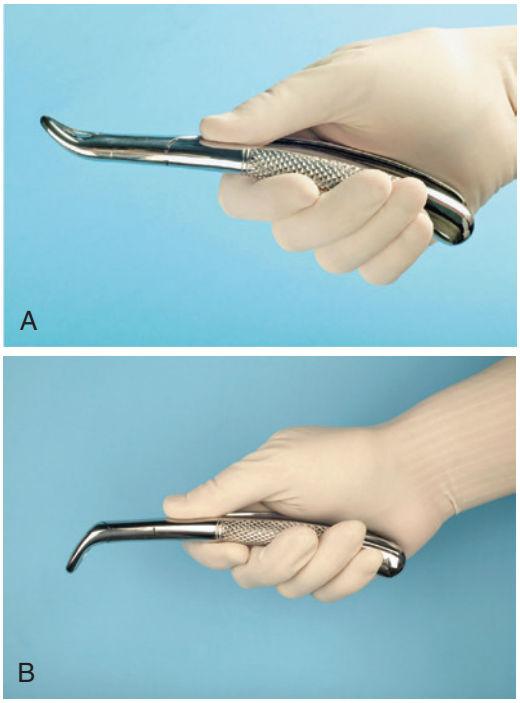


• **Fig. 8.53** Tips of forceps beak, forced apically under soft tissue. (Courtesy Dr. Edward Ellis III.)

teeth adjacent to those being extracted. This is especially true if the adjacent tooth has a large restoration or carious lesion. This is only the initial step in the elevation process. Next, the small, straight elevator is inserted into the periodontal ligament space at the mesial–buccal line angle. The elevator is advanced apically while being rotated back and forth, helping luxate the tooth with its wedge action as it is advanced apically. A similar action with the elevator can then be done at the distal-buccal line angle. When a small, straight elevator becomes too easy to twist, a larger-sized elevator is used to do the same apical advancement. Often the tooth will loosen sufficiently to be removed easily with forceps.

Step 3 involves adaptation of the forceps to the tooth. The proper forceps are now chosen for the tooth to be extracted. The beaks of the forceps should be shaped to adapt anatomically to the tooth, apical to the cervical line, that is, to the root surface. (A few exceptions to this include the cowhorn forceps.) The forceps are then seated onto the tooth so that the tips of the forceps beaks grasp the root underneath loosened soft tissue (Fig. 8.53). The lingual beak is usually seated first and then the buccal beak. Care must be taken to confirm that the tips of the forceps beaks are beneath the soft tissue and not engaging an adjacent tooth. Once the forceps have been positioned on the tooth, the surgeon grasps the handles of the forceps at the ends to maximize mechanical advantage and control (Fig. 8.54). If the tooth is malposed in such a fashion that the usual forceps cannot grasp the tooth without injury to adjacent teeth, another forceps with narrower beaks should be used. Maxillary root forceps can often be useful for crowded lower anterior teeth.

The beaks of the forceps must be held parallel to the long axis of the tooth so that the forces generated by the application of pressure to the forceps handle can be delivered along the



• **Fig. 8.54** Forceps handles, held at the ends to maximize mechanical advantage and control. (A) Maxillary universal forceps. (B) Mandibular universal forceps.

long axis of the tooth for maximal effectiveness in dilating and expanding alveolar bone. If the beaks are not parallel to the long axis of the tooth, it is increasingly likely that the tooth root will fracture.

The forceps are then forced apically as far as possible to grasp the root of the tooth as apically as possible. This accomplishes two things: (1) The beaks of the forceps act as wedges to dilate the crestal bone on the buccal and lingual aspects, and (2) by forcing the beaks apically, the center of rotation (or fulcrum) of the forces applied to the tooth is displaced toward the apex of the tooth, which results in greater effectiveness of bone expansion and less likelihood of fracturing the apical end of the tooth.

At this point, the surgeon's hand should be grasping the forceps firmly, with the wrist locked and the arm held against the body; the surgeon should be prepared to apply force with the shoulder and upper arm without any wrist pressure. The surgeon should be standing upright, with feet comfortably apart.

Step 4 involves luxation of the tooth with forceps. The surgeon begins to luxate the tooth by using the motions discussed earlier. The major portion of the force is directed toward the thinnest and therefore weakest bone. Thus, with all teeth in the maxilla and all but molar teeth in the mandible, the major movement is labial and buccal (i.e., toward the thinner layer of bone). The surgeon uses slow, sustained, steady force to displace the tooth buccally, rather than a series of rapid, small movements that do little to expand bone. The motion is deliberate and slow, and it gradually increases in force. The tooth is then moved again toward the opposite direction with slow, deliberate, strong pressure. As the alveolar bone begins to expand, the forceps are reseated apically with a strong, deliberate motion, which causes additional expansion of alveolar bone and further displaces the center of the rotation apically. Buccal and lingual pressures continue to expand the alveolar socket. For some teeth, small rotational motions are then used to help expand the tooth socket and tear the periodontal ligament attachments. Beginning surgeons have a tendency to apply inadequate pressure for insufficient amounts of time.

The following three factors must be reemphasized: (1) The forceps must be apically seated as far as possible and reseated periodically during the extraction; (2) the forces applied in the buccal and lingual directions should be slow, deliberate pressures and not jerky wiggles; and (3) the force should be held for several seconds to allow the bone time to expand. It must be remembered that teeth are not pulled; rather, they are gently lifted from the socket once the alveolar process has been sufficiently expanded.

Step 5 involves removal of the tooth from the socket. Once alveolar bone has expanded sufficiently and the tooth has been luxated, a slight tractional force, usually directed buccally, can be used. Tractional forces should be minimized because this is the last motion that is used once the alveolar process is sufficiently expanded and the periodontal ligament is completely severed.

It should be remembered that luxation of the tooth with forceps and removal of the tooth from bone are separate steps in the extraction. Luxation is directed toward expansion of bone and disruption of the periodontal ligament. The tooth is not removed from bone until these two goals are accomplished. The novice surgeon should realize that the major role of forceps is not to remove the tooth, but rather to expand the bone so that the root(s) can be removed.

For teeth that are malposed or have unusual positions in the alveolar process, luxation with forceps and removal from the alveolar process will be in unusual directions. The surgeon must develop a sense for the direction the tooth wants to move and then be able to move it in that direction. Careful preoperative assessment and planning help guide this determination during the extraction.

Role of the Opposite Hand

While using forceps and elevators to luxate and remove teeth, it is important that the surgeon's opposite hand play an active role in the procedure. For the right-handed operator, the left hand has a variety of functions. The left hand is responsible for reflecting the soft tissues of the cheeks, lips, and tongue to provide adequate visualization of the area of surgery. The left hand helps protect other teeth from the forceps, should it release suddenly from the tooth socket. The left hand, and sometimes arm, helps stabilize the patient's head during the extraction process. In some situations, greater amounts of force are required to expand heavy alveolar bone; therefore the patient's head requires active assistance to be held steady. The opposite hand plays an important role in supporting and stabilizing the jaw when mandibular teeth are being extracted. The opposite hand is often necessary to apply considerable pressure to expand heavy mandibular bone, and such forces can cause discomfort and even injury to the TMJ unless a steady hand counteracts them. A bite block placed on the contralateral side is also used to help open the jaw in this situation. Finally, the opposite hand supports the alveolar process and provides tactile information to the operator concerning the expansion of the alveolar process during the luxation period. In some situations, it is impossible for the opposite hand to perform all of these functions at the same time, so the surgeon requires an assistant to help with some of the functions.

Role of the Assistant During Extraction

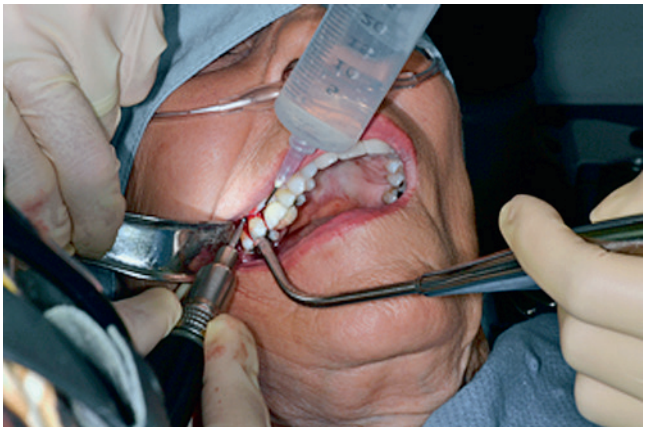
To achieve a successful outcome in any surgical procedure, it is useful to have a skilled assistant. During extraction, the assistant plays a variety of important roles that contribute to making the surgical experience atraumatic for the patient. The assistant helps the surgeon visualize and gain access to the operative area by retracting the soft tissue of the cheeks and tongue so that the surgeon can have an unobstructed view of the surgical field. Even during a closed extraction, the assistant can retract the soft tissue so that the surgeon can apply the instruments to loosen the soft tissue attachment and adapt the forceps to the tooth in the most effective manner.

Another major activity of the assistant is to suction away blood, saliva, and the irrigating solutions used during the surgical procedure. This prevents fluids from accumulating and makes proper visualization of the surgical field possible. Suctioning is also important for patient comfort because most patients are unable to tolerate any accumulation of blood or other fluids in their throats (Fig. 8.55).

During extraction, the assistant should also help with protecting the teeth of the opposite arch, which is especially important when removing lower posterior teeth. If traction forces are necessary to remove a lower tooth, occasionally the tooth releases suddenly and the forceps strike maxillary teeth and may fracture a tooth cusp. The assistant should hold a suction tip or a finger against maxillary teeth to protect them from an unexpected blow.

During the extraction of mandibular teeth, the assistant may play an important role by supporting the mandible during the application of the extraction forces. A surgeon who uses the hand to reflect soft tissue may not be able to support the mandible. If this is the case, the assistant plays an important role in stabilizing the mandible to prevent TMJ discomfort. Most often the surgeon stabilizes the mandible, which makes this role less important for the assistant.

The assistant also provides psychological and emotional support for the patient by helping alleviate patient anxiety during anesthesia administration and surgery. The assistant is important in gaining the patient's confidence and cooperation by using positive language and physical contact with the patient during the preparation and performance of the surgery. The assistant should avoid making casual, offhand comments that may increase the patients' anxiety and lessen their cooperation.



• **Fig. 8.55** While the surgeon holds the surgical hand piece and Minnesota retractor, the assistant provides cooling irrigation and suction. (Courtesy Dr. Edward Ellis III.)

Specific Techniques for the Removal of Each Tooth

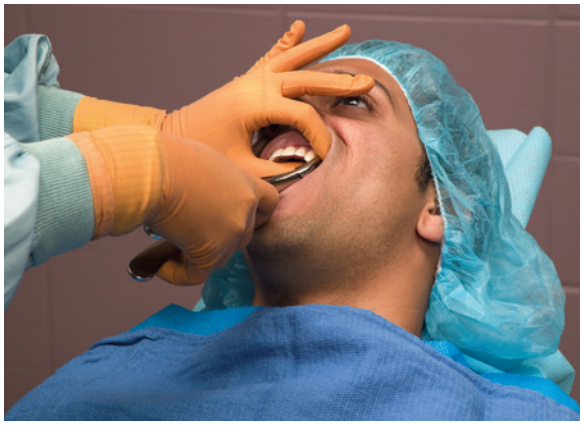
This section describes specific techniques for the removal of each tooth in the mouth after being elevated. In some situations, several teeth are grouped together (e.g., the maxillary anterior teeth) because the technique for their removal is essentially the same. The reader should take note of the role of the left hand in each instance.

Maxillary Teeth

In the correct position for the extraction of maxillary left or anterior teeth, the left index finger of the surgeon should reflect the lip and cheek tissues, while the thumb rests on the palatal alveolar process (Fig. 8.56). In this way, the left hand is able to reflect the soft tissue of the cheek, stabilize the patient's head, support the alveolar process, and provide tactile information to the surgeon regarding the progress of the extraction. When such a position is used during the extraction of a maxillary molar, the surgeon can frequently feel with the left hand the palatal root of the molar becoming free in the alveolar process before feeling it with the forceps or the extracting hand. For the right side, the index finger is positioned on the palate, with the thumb on the buccal aspect.

Incisors

The maxillary incisor teeth are extracted with the upper universal forceps (No. 150), although other forceps can be used such as the straight forceps (No. 1). Maxillary incisors generally have conic roots, with the lateral ones being slightly longer and more slender. The lateral incisor is more likely also to have a distal curvature on the apical one third of the root, so this must be checked radiographically before the tooth is extracted. Alveolar bone is thin on the labial side and heavier on the palatal side, which indicates that the major expansion of the alveolar process will be in the labial direction. The initial movement is slow, steady, and firm in the labial direction, which expands the crestal buccal bone. A less vigorous palatal force is then used, followed by a slow, firm, rotational force. Rotational movement should be minimized for the lateral incisor, especially if a curvature exists on the tooth. The



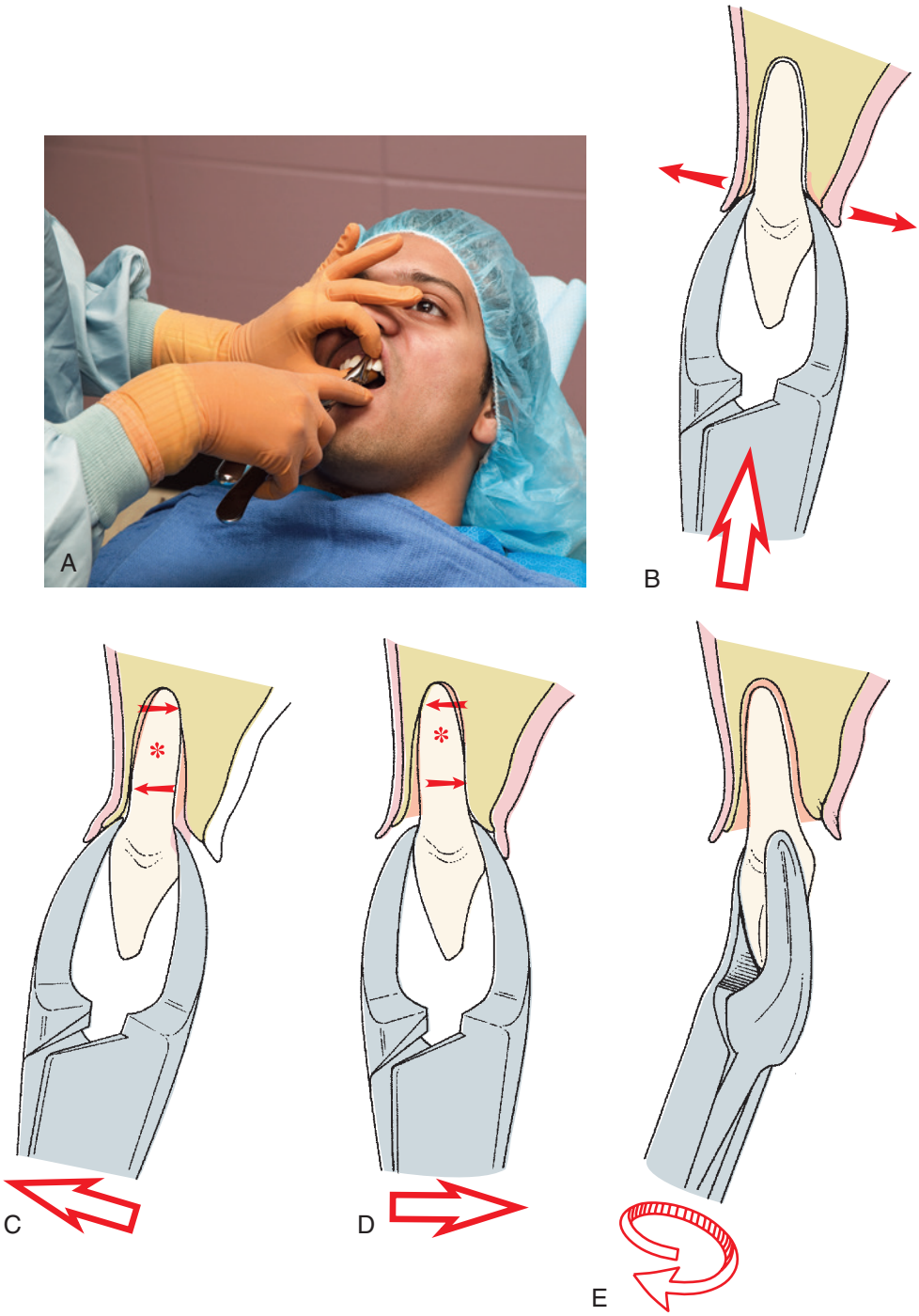
• **Fig. 8.56** Extraction of maxillary left posterior teeth. The left index finger retracts the lip and cheek and supports the alveolar process on the buccal aspect. The thumb is positioned on the palatal aspect of the alveolar process and supports the alveolar process. The head is steadied by this grip, and tactile information about the tooth and bone movement is gained.

tooth is delivered in the labial-incisal direction with a small amount of tractional force (Fig. 8.57).

Canines

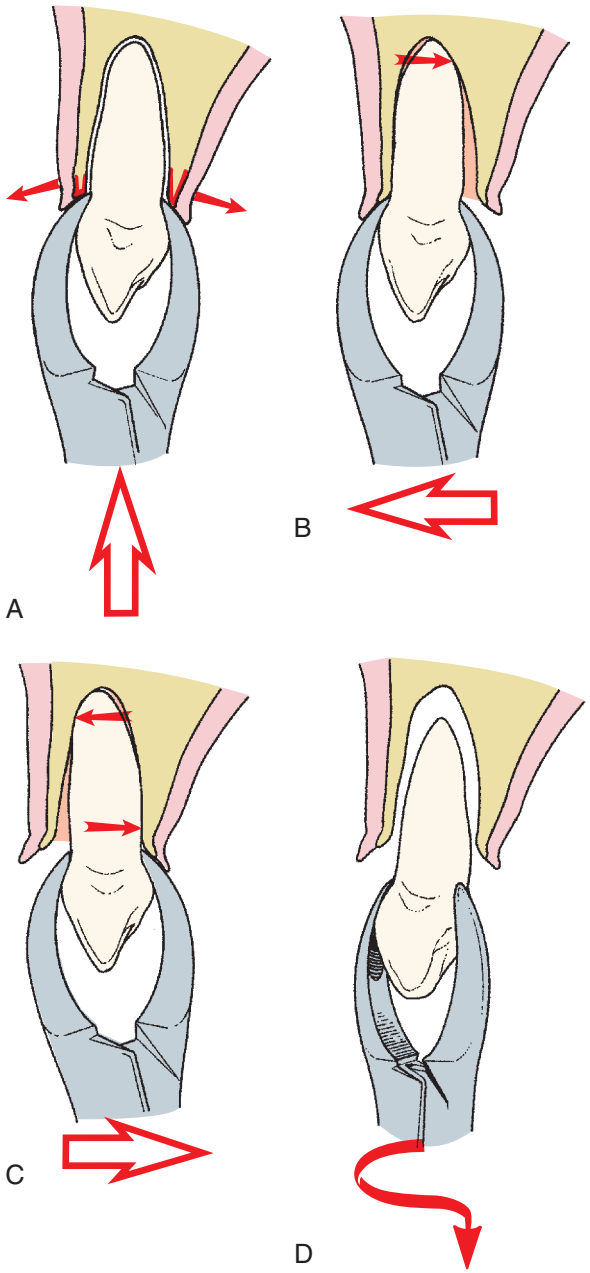
The maxillary canine is usually the longest tooth in the mouth. The root is oblong in cross section and usually produces a bulge called the *canine eminence* on the anterior surface of the maxilla. The result is that the bone over the labial aspect of the maxillary canine is usually thin. In spite of the thin labial bone, this tooth can be difficult to extract simply because of its long root and large surface area available for periodontal ligament attachments. In addition, it is not uncommon for a segment of labial alveolar bone to fracture from the labial plate and be removed with the tooth.

The upper universal (No. 150) forceps are the preferred instrument for removing the maxillary canine, after elevation. As with



• **Fig. 8.57** (A) Maxillary incisors are extracted with No. 150 forceps. The left hand grasps the alveolar process. (B) The forceps are seated as far apically as possible. (C) Luxation is begun with labial force. (D) Slight lingual force is used. (E) The tooth is delivered to the labial incisor with a rotational, tractional movement. *Asterisk* notes the center of rotation.

all extractions, the initial placement of the beaks of the forceps on the canine tooth should be as far apically as possible. The initial movement is apical and then to the buccal aspect, with return pressure to the palatal. As the bone is expanded and the tooth mobilized, the forceps should be repositioned apically. A small amount of rotational force may be useful in expanding the tooth socket, especially if adjacent teeth are missing or have just been extracted. After the tooth has been well luxated, it is delivered from the socket in a labial-incisal direction with labial tractional forces (Fig. 8.58).



• **Fig. 8.58** (A) Hand and forceps positions for removal of the maxillary canine are similar to those for removal of incisors. The forceps are seated as far apically as possible. (B) The initial movement is in the buccal direction. (C) Small amounts of lingual force are applied. (D) The tooth is delivered in the labial-incisal direction with a slight rotational force.

During the luxation process with the forceps, if the surgeon feels a portion of the labial bone fracturing, the surgeon must make a decision concerning the next step. If the palpating finger indicates that a small amount of bone has fractured free and is attached to the canine tooth, the extraction should continue in the usual manner, with caution taken not to tear the soft tissue. However, if the palpating finger indicates that a large portion of labial alveolar plate has fractured, the surgeon should stop the surgical procedure. Usually the fractured portion of bone is still attached to periosteum and therefore is viable. The surgeon should use a thin periosteal elevator to raise a small amount of mucosa from around the tooth, down to the level of the fractured bone. The canine tooth should then be stabilized with the extraction forceps, and the surgeon should attempt to free the fractured bone from the tooth, with the periosteal elevator as a lever to separate the bone from the tooth root. If this can be accomplished, the tooth can be removed and the bone left in place attached to the periosteum. Normal healing should occur. If bone becomes detached from the periosteum during these attempts, it should be removed because it is probably nonvital and may actually prolong wound healing. This same procedure can be used whenever alveolar bone is fractured during extraction.

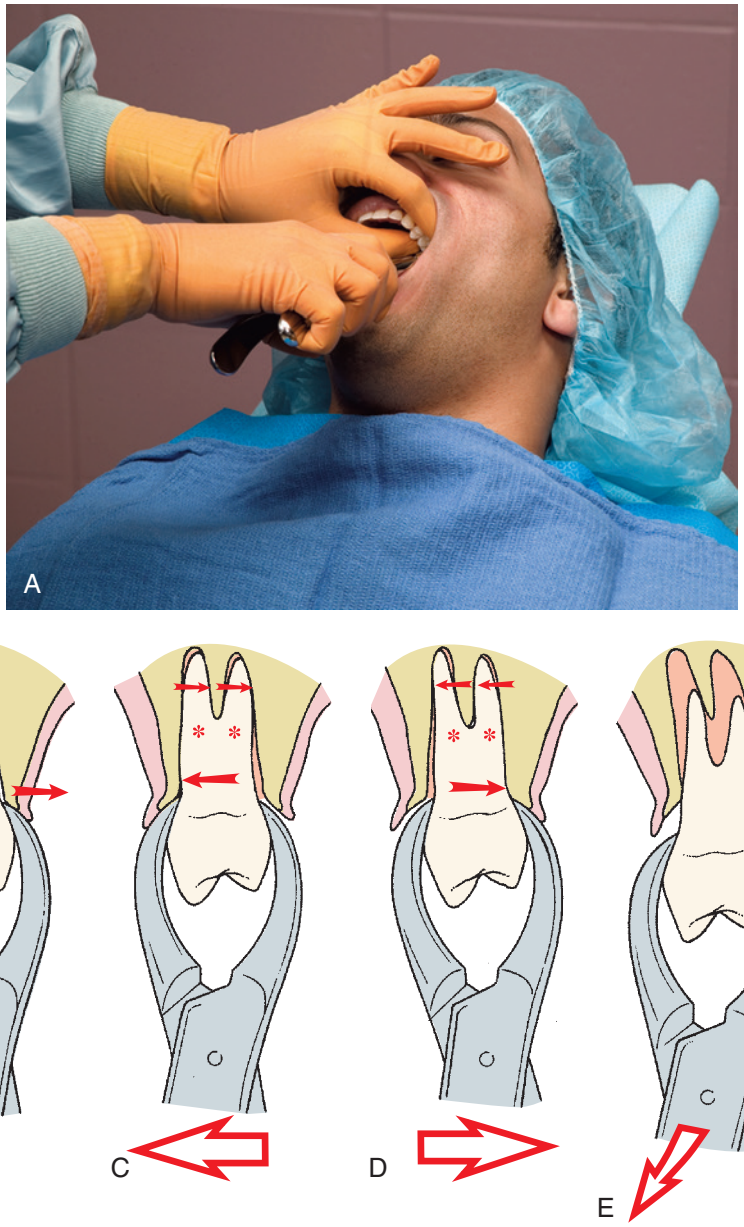
Prevention of labial plate fracture is important. After elevation and during the luxation process with the forceps, if a normal amount of pressure has not resulted in any movement of the tooth, the surgeon should seriously consider doing an open extraction. By reflecting a soft tissue flap and removing a small amount of bone, the surgeon may be able to remove the stubborn canine tooth without fracturing a large amount of labial bone. By using the open technique, there will be an overall reduction in bone loss and in postoperative healing time.

First Premolar

The maxillary first premolar is a single-rooted tooth in its first two thirds, with a bifurcation into a buccolingual root usually occurring in the apical one third to one half. These roots may be extremely thin and are subject to fracture, especially in older patients in whom bone density is great and bone elasticity is diminished. Perhaps the most common root fracture when extracting teeth in adults occurs with this tooth. As with other maxillary teeth, buccal bone is thin compared with palatal bone.

The upper universal (No. 150) forceps are the instrument of choice. Alternatively, the No. 150A forceps can be used for removal of the maxillary first premolar. Because of the high likelihood of root fracture, the tooth should be luxated as much as possible with the straight elevator. If root fracture does occur, a mobile root tip can be removed more easily than one that has not been well luxated via elevation.

Because of the bifurcation of the tooth into two thin root tips, extraction forces should be carefully controlled during removal of the maxillary first premolar. Initial movements should be buccal. Palatal movements are made with small amounts of force to prevent fracture of the palatal root tip, which is harder to retrieve. When the tooth is luxated buccally, the most likely tooth root to break is the labial root. When the tooth is luxated in the palatal direction, the most likely root to break is the palatal root. Of the two root tips, the labial is easier to retrieve because of the thin, overlying bone. Therefore, as for other maxillary teeth, buccal pressures should be greater than palatal pressures. Any rotational force should be avoided. Final delivery of the tooth from the tooth socket is with tractional force in the occlusal direction and slightly buccal (Fig. 8.59).



• **Fig. 8.59** (A) Maxillary premolars are removed with the No. 150 forceps. The hand position is similar to that used for anterior teeth. (B) Firm apical pressure is applied first to the lower center of rotation as far as possible and to expand crestal bone. (C) Buccal pressure is applied initially to expand the buccocortical plate. The apices of roots are pushed lingually and are therefore subject to fracture. (D) Palatal pressure is applied, but less vigorously than buccal pressure. (E) The tooth is delivered in the bucco-occlusal direction with a combination of buccal and tractional forces.

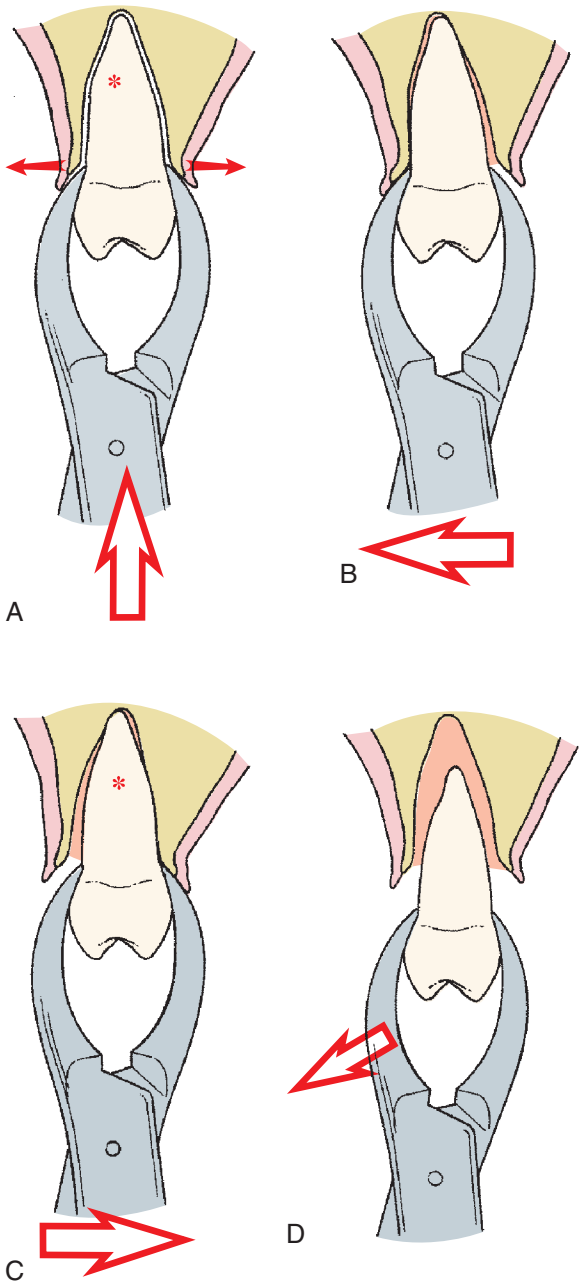
Second Premolar

The maxillary second premolar is a single-rooted tooth for the entire length of the root. The root is thick and has a blunt end. Consequently, the root of the second premolar rarely fractures. The overlying alveolar bone is similar to that of other maxillary teeth in that it is thin toward the buccal aspect, with a heavy palatal-alveolar palate.

The recommended forceps are the maxillary universal forceps, or the No. 150 forceps; some surgeons prefer the No. 150A forceps. The forceps are forced as far apically as possible so as to gain maximal mechanical advantage in removing this tooth. Because the tooth root is strong and blunt, the extraction requires strong movements to the buccal back to the palate, and then in the bucco-occlusal direction with a rotational, tractional force (Fig. 8.60).

Molars

The maxillary first molar has three large and strong roots. Buccal roots are usually close together, and the palatal root diverges widely toward the palate. If the two buccal roots are also widely divergent, it becomes difficult to remove this tooth by closed extraction. Once again, the overlying alveolar bone is similar to that of other teeth in the maxilla; the buccal plate is thin and the palatal–cortical plate is thick and heavy. When evaluating this tooth radiographically, the dentist should note the size, curvature, and apparent divergence



• **Fig. 8.60** (A) When extracting the maxillary second premolar, the forceps are seated as far apically as possible. (B) Luxation is begun with buccal pressure. (C) Very slight lingual pressure is used. (D) The tooth is delivered in the bucco-occlusal direction. *Asterisk* notes the center of rotation.

of the three roots. In addition, the dentist should look carefully at the relationship of the tooth roots to the maxillary sinus. If the sinus is in proximity to the roots and the roots are widely divergent, sinus perforation caused by removal of a portion of the sinus floor during tooth removal is increasingly likely. If this appears to be likely after preoperative evaluation, the surgeon should strongly consider a surgical extraction.

The paired forceps No. 53R and No. 53L are usually used for extraction of the maxillary molars. These two forceps have tip projections on the buccal beaks to fit into the buccal bifurcation. Some surgeons prefer to use the No. 89 and No. 90 forceps. These two forceps are especially useful if the crown of the molar tooth has serious caries or large restorations.

The upper molar forceps are adapted to the tooth and are seated apically as far as possible in the usual fashion (Fig. 8.61). The basic extraction movement is to use strong buccal and palatal pressures, with stronger forces toward the buccal than toward the palate. Rotational forces are not useful for extraction of this tooth because of its three roots. As mentioned in the discussion of the extraction of the maxillary first premolar, it is preferable to fracture a buccal root rather than a palatal root (because it is easier to retrieve the buccal roots). Therefore, if the tooth has widely divergent roots and the dentist suspects that one root may be fractured, the tooth should be luxated in such a way as to prevent fracturing of the palatal root. The dentist must minimize palatal force because this is the force that fractures the palatal root. Strong, slow, steady buccal pressure expands the buccocortical plate and tears the periodontal ligament fibers that hold the palatal root in its position. Palatal forces should be used but kept to a minimum.

The anatomy of the maxillary second molar is similar to that of the maxillary first molar except that the roots tend to be shorter and less divergent, with the buccal roots more commonly fused into a single root. This means that the tooth is more easily extracted by the same technique described for the first molar.

The erupted maxillary third molar frequently has conic roots and is usually extracted with the No. 210S forceps, which are universal forceps used for the left and right sides. The tooth is usually readily removed because buccal bone is thin and the roots are usually fused and conical. The erupted third molar is also frequently extracted by the use of elevators alone. Clear visualization of the maxillary third molar on the preoperative radiograph is important because the root anatomy of this tooth is variable, and often small, dilacerated, hooked roots exist in this area. Retrieval of fractured roots in this area is difficult due to more limited access.

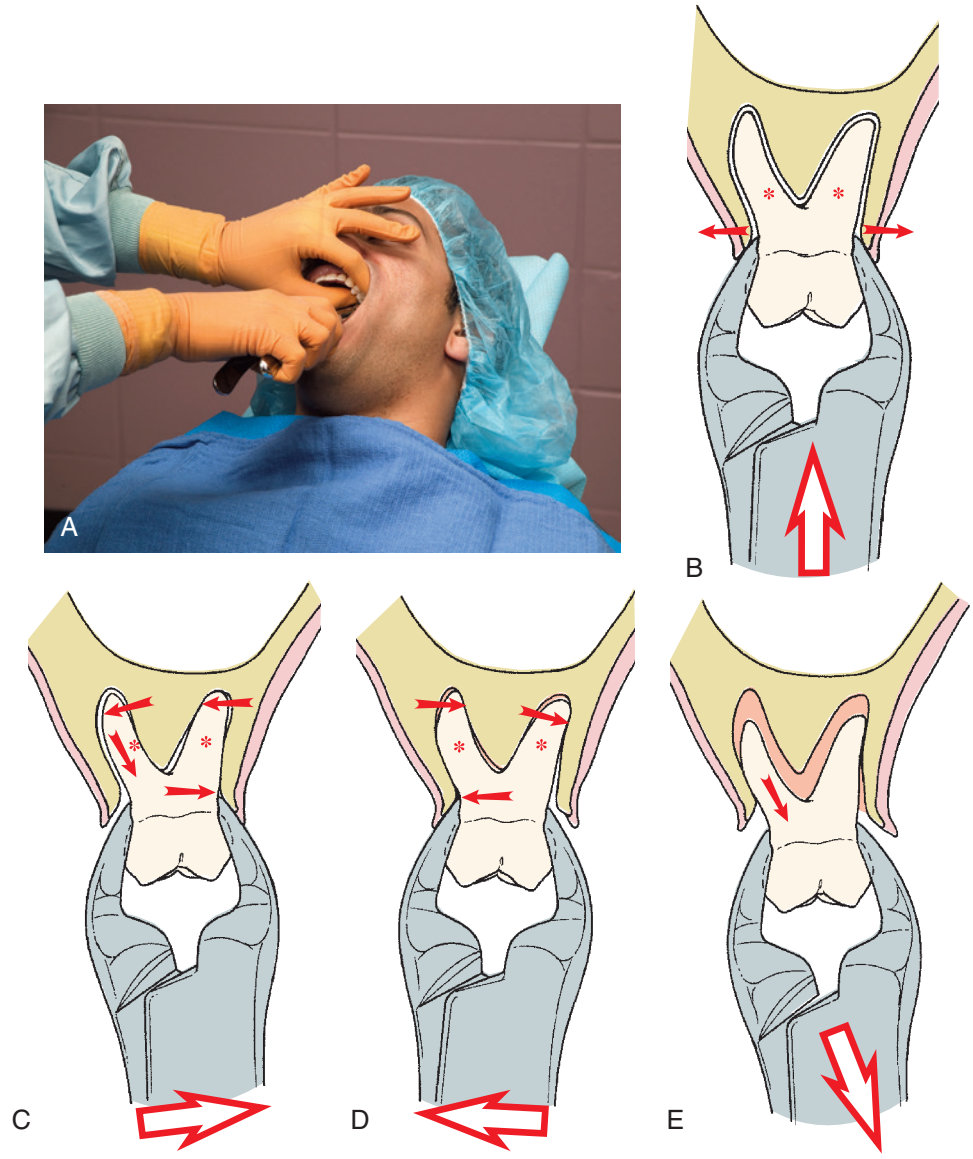
Mandibular Teeth

When removing lower molar teeth, the index finger of the left hand is in the buccal vestibule, and the second finger is in the lingual vestibule, reflecting the lip, cheek, and tongue (Fig. 8.62). The thumb of the left hand is placed below the chin so that the mandible is held between the fingers and the thumb, which support the mandible and minimize TMJ pressures. This technique provides less tactile information, but during extraction of mandibular teeth, the need to support the mandible supersedes the need to support the alveolar process. A useful alternative is to place a bite block between the teeth on the contralateral side (Fig. 8.63). The bite block allows the patient to help provide stabilizing forces to limit the pressure on the TMJs. The surgeon's or assistant's hand should continue to provide additional support to the inferior portion of the mandible.

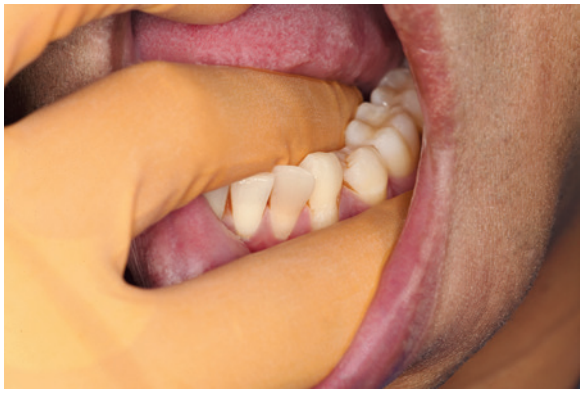
Anterior Teeth

Mandibular incisors and canines are similar in shape, with the incisors being shorter and slightly thinner, and the canine roots being longer and heavier. The incisor roots are more likely to be fractured because they are thin, and therefore they should be removed only after adequate preextraction luxation. Alveolar bone that overlies incisors and canines is thin on the labial and lingual sides. Bone over the canine may be thicker, especially on the lingual aspect.

The lower universal (No. 151) forceps are usually used to remove these teeth. Other choices include the No. 151A or the English-style



• **Fig. 8.61** (A) Extraction of maxillary molars. Soft tissues of the lips and cheek are retracted, and the alveolar process is grasped with the opposite hand. (B) Forceps beaks are seated apically as far as possible. (C) Luxation is begun with strong buccal force. (D) Lingual pressures are used only moderately. (E) The tooth is delivered in the bucco-occlusal direction. *Asterisk* notes the center of rotation.



• **Fig. 8.62** Extraction of mandibular left posterior teeth. The surgeon's left index finger is positioned in the buccal vestibule, retracting the cheek, and the second finger is positioned in the lingual vestibule, retracting the tongue. The thumb is positioned under the chin. The mandible is grasped between the fingers and the thumb to provide support during extraction.

• **Fig. 8.63** A rubber bite block can be placed between the patient's teeth on the contralateral side to provide support for the mandible and prevent excessive temporomandibular joint pressures.

Ashe forceps. The forceps beaks are positioned on teeth and seated apically with strong force. The extraction movements are generally in the labial and lingual directions, with equal pressures both ways. Once the tooth has become luxated and mobile, rotational movement may be used to expand alveolar bone further. The tooth is removed from the socket with tractional forces in a labial-incisal direction (Fig. 8.64).

Premolars

Mandibular premolars are among the most straightforward teeth to extract. The roots tend to be straight and conic, albeit sometimes slender. The overlying alveolar bone is thin on the buccal aspect and heavier on the lingual side.

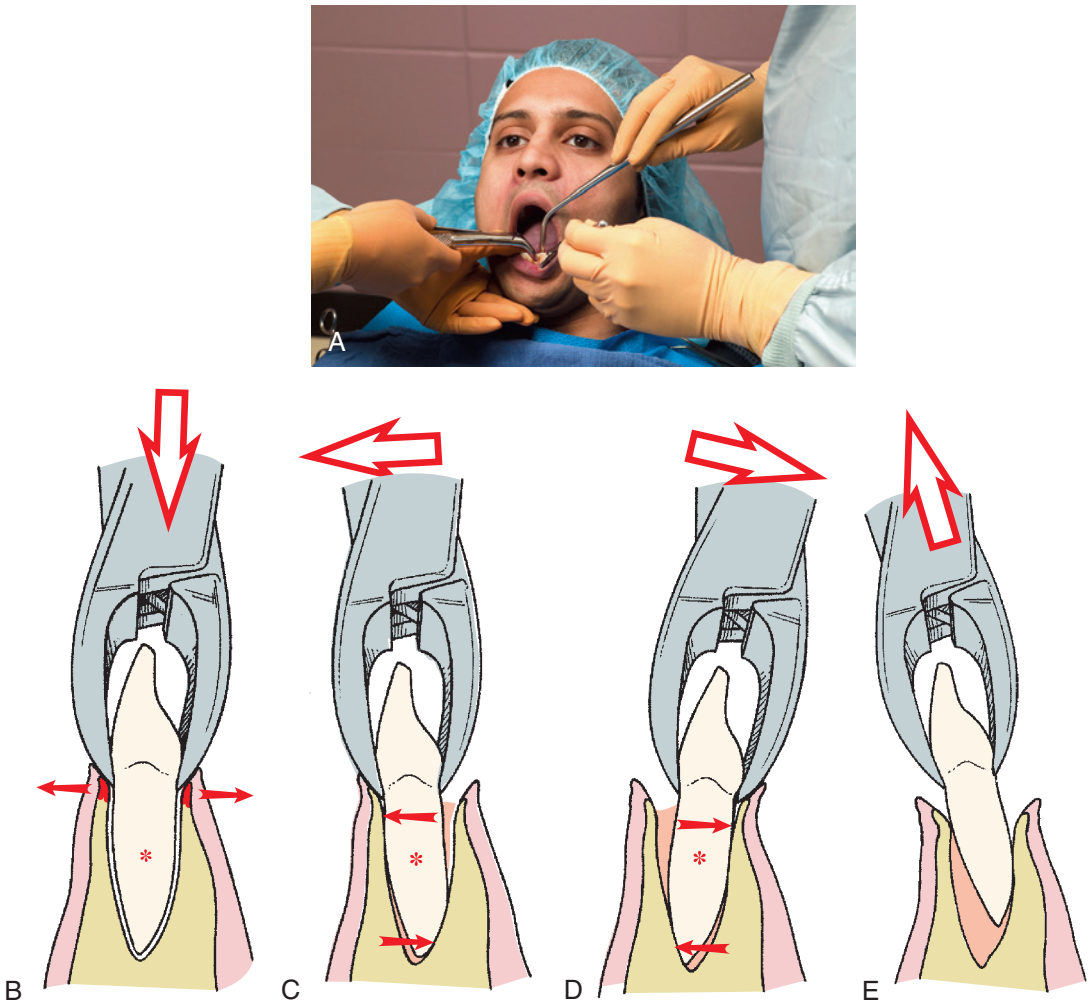
The lower universal (No. 151) forceps are usually chosen for the extraction of the mandibular premolars. The No. 151A forceps and the English-style forceps are popular alternatives for extraction of these teeth.

The forceps are apically forced as far as possible, with the basic movements directed toward the buccal aspect, returning to the lingual aspect, and finally rotating. Rotational movement is used more when extracting these teeth than for any others, except perhaps the maxillary central incisor. The tooth is then delivered in the occlusobuccal direction (Fig. 8.65). Careful preoperative radiographic assessment must be performed to confirm that no root curvature exists in the apical third of the tooth. If such a curvature does exist, the rotational movements should be reduced or eliminated from the extraction procedure (Fig. 8.66).

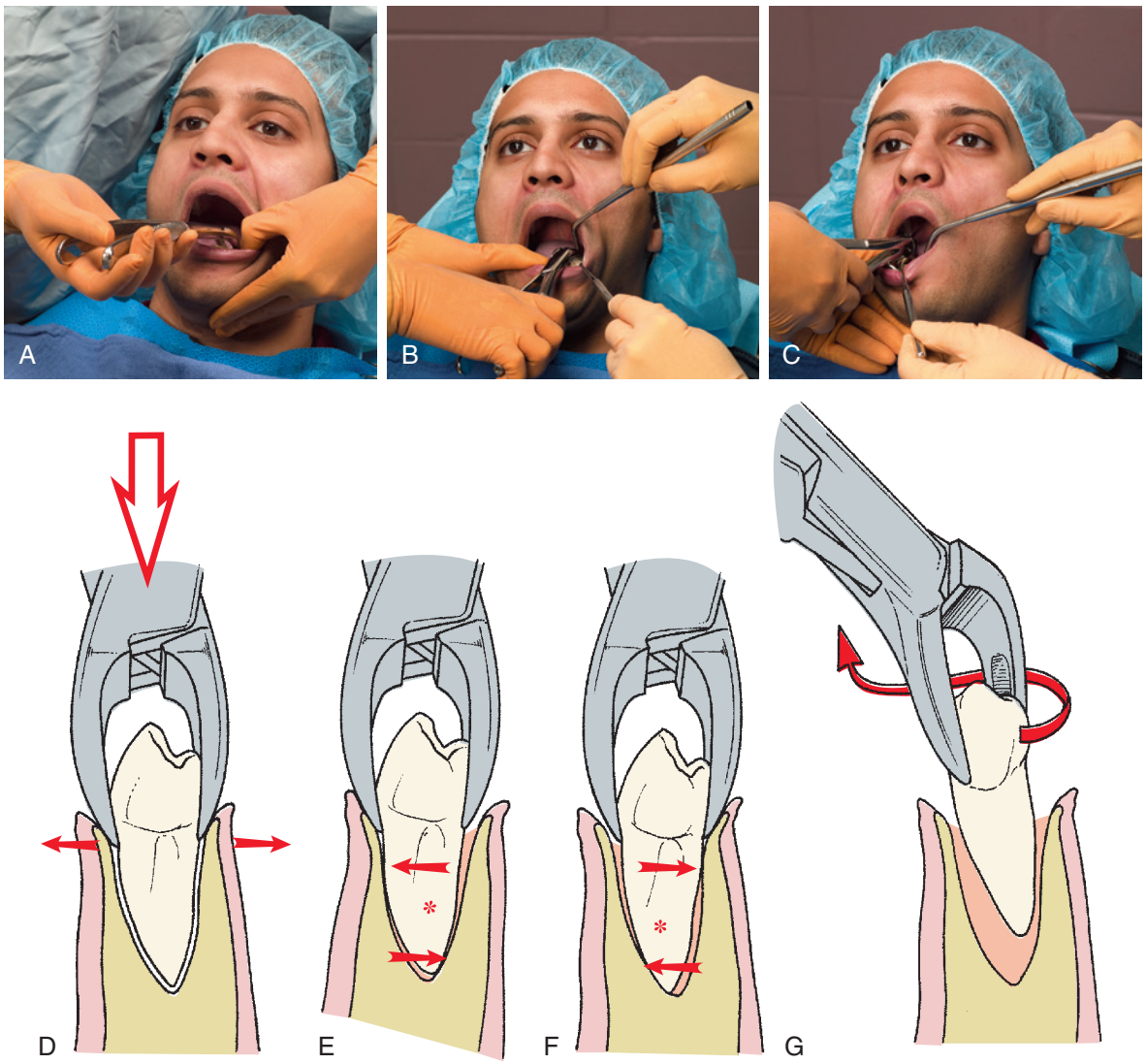
Molars

Mandibular molars usually have two roots, with the roots of the first molar more widely divergent than those of the second molar. In addition, the roots may converge at the apical one.

The No. 17 forceps are usually used for extraction of mandibular molars; these forceps have small tip projections on both beaks to fit into the bifurcation of the tooth roots. The forceps are adapted to the root of the tooth in the usual fashion, and strong apical pressure is applied to set the beaks of the forceps apically as far as possible. Strong buccolingual motion is then used to expand the tooth socket and allow the tooth to be delivered in the buccoocclusal direction. Linguoalveolar bone around the second molar



• **Fig. 8.64** (A) When extracting mandibular anterior teeth, No. 151 forceps are used. The assistant retracts the patient's cheek and provides suction. (B) The forceps are seated apically as far as possible. (C) Moderate labial pressure is used to initiate the luxation process. (D) Lingual force is used to continue the expansion of bone. (E) The tooth is delivered in the labial-incisal direction. *Asterisk* notes the center of rotation.



• **Fig. 8.65** (A) Extraction of the mandibular premolar. The mandible is stabilized, soft tissue is retracted, and No. 151 forceps are positioned. (B) The hand position is modified slightly for the behind-the-patient technique. (C) English-style forceps can also be used. (D) The forceps are seated apically as far as possible to displace the center of rotation and to begin the expansion of crestal bone. (E) Buccal forceps are applied to begin the luxation process. (F) Slight lingual pressure is used. (G) The tooth is delivered with a rotational, tractional force. *Asterisk* notes the center of rotation.

is thinner than the buccal plate, so the second molar can be removed more easily with stronger lingual pressure than buccal pressure (Fig. 8.67). An English-style lower molar forceps is also available.

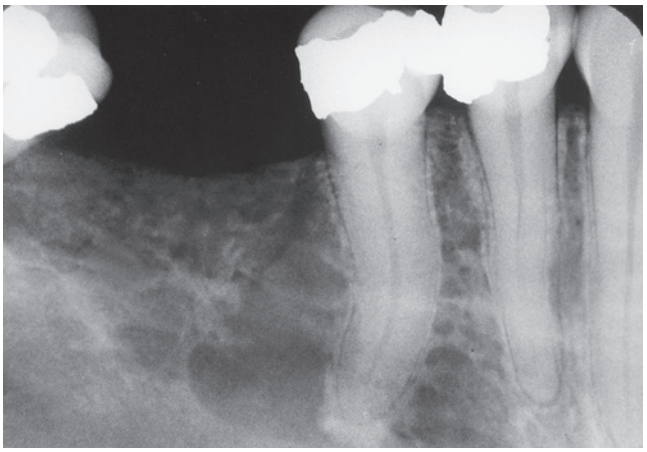
If the tooth roots are clearly bifurcated, the No. 23 forceps, or cowhorn forceps, can be used. This instrument is designed to be closed forcefully with the handles, thereby squeezing the beaks of the forceps into the bifurcation. This creates force against the crest of the alveolar ridge on the buccolingual aspects and literally forces the tooth superiorly directly out of the tooth socket (Fig. 8.68). If this is not successful initially, the forceps are given buccolingual movements to expand alveolar bone, and the forceps handles are moved up and down to seat the beaks more fully into the furcation. More squeezing of the handles is performed. Care must be taken with these forceps to prevent damaging maxillary teeth because the lower molar may actually pop out of the socket and thus release the forceps to strike upper teeth.

Erupted mandibular third molars usually have fused conic roots. Because a bifurcation is not likely, the No. 222 forceps—a short-beaked, right-angled forceps—are used to extract this tooth. The lingual plate of bone is definitely thinner than the buccocortical plate, so most of the extraction forces should be delivered to the lingual aspect. The third molar is delivered in the linguo-occlusal direction. The erupted mandibular third molar that is in function can be a deceptively difficult tooth to extract. The dentist should give serious consideration to using the straight elevator and achieve a moderate degree of luxation before applying the forceps. Pressure should be gradually increased, and attempts to mobilize the tooth should be made before the final strong pressures are delivered.

Modifications for Extraction of Primary Teeth

Rarely is it necessary to remove primary teeth before substantial root resorption has occurred. However, when removal is required,

it must be done with a great deal of care because the roots of the primary teeth are long and delicate and are subject to fracture. This is especially true because the succedaneous tooth causes resorption of coronal portions of the root structure and thereby weakens it. The forceps usually used are an adaptation of the upper and lower universal forceps, the No. 150S and the No. 151S. They are adapted and forced apically in the usual fashion, with slow, steady pressures toward the buccal aspect and return movements toward the lingual aspect.



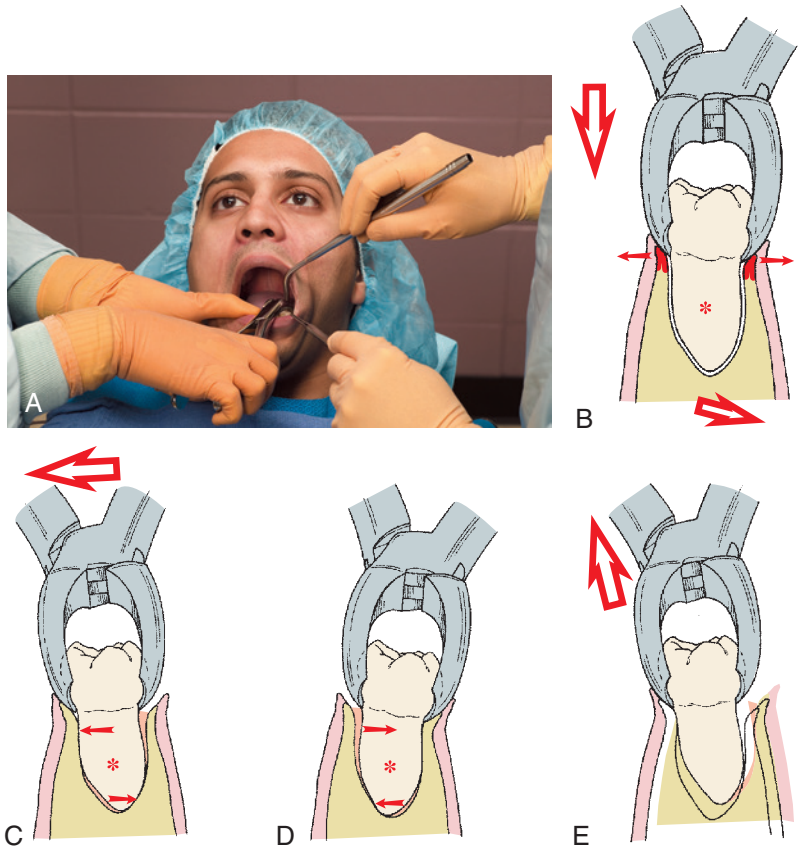
• **Fig. 8.66** If any curvature of the premolar root exists, rotational extraction forces will result in fracture of the curved portion of the root; therefore such forces should be minimized.

Rotational motions may be used but should be minimal and should be used judiciously with multirooted teeth. The dentist should pay careful attention to the direction of least resistance and deliver the tooth into that path. If the roots of the primary molar tooth embrace the crown of the permanent premolar, the surgeon should consider sectioning the tooth. Rarely, the roots hold the crown of the permanent premolar firmly enough in their grasp to cause it to be loosened or extracted.

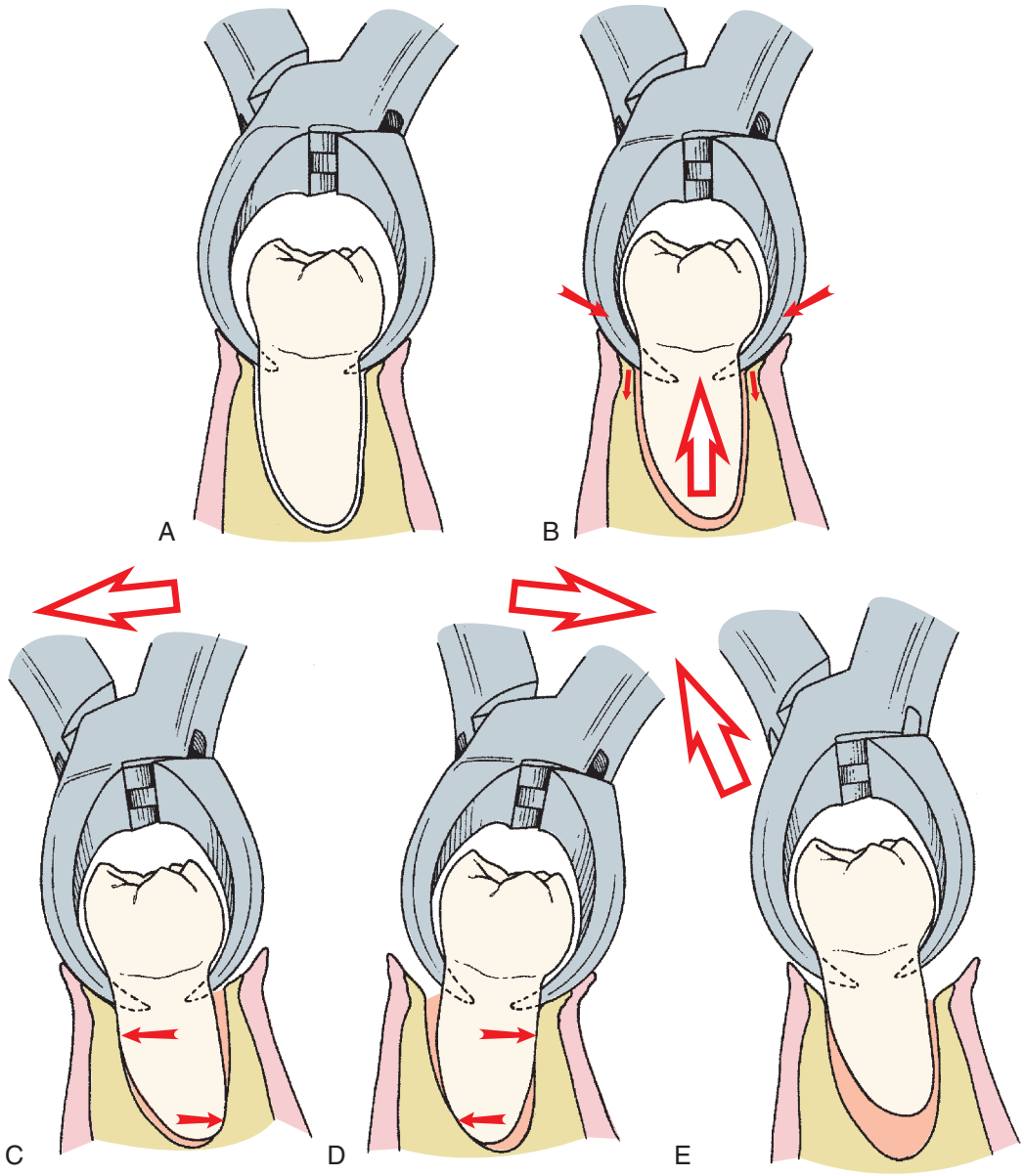
Once a primary tooth with substantial root resorption is removed, the extraction site should be carefully inspected to help ensure no small pieces of tooth remain.

Postextraction Tooth Socket Care

Once the tooth has been removed, the socket requires proper care. The socket should be debrided only if necessary. If a periapical lesion is visible on the preoperative radiograph and there was no granuloma attached to the tooth when it was removed, the periapical region should be carefully curetted with a periapical curette to remove the granuloma or cyst. If any debris is obvious, such as calculus, amalgam, or tooth fragment remaining in the socket, it should be gently removed with a curette or suction



• **Fig. 8.67** (A) Mandibular molars are extracted with No. 17 or No. 23 forceps. The hand positions of the surgeon and the assistant are the same for both forceps. (B) No. 17 forceps are seated as far apically as possible. (C) Luxation of the molar is begun with a strong buccal movement. (D) Strong lingual pressure is used to continue the luxation. (E) The tooth is delivered in the bucco-occlusal direction. *Asterisk* notes the center of rotation.



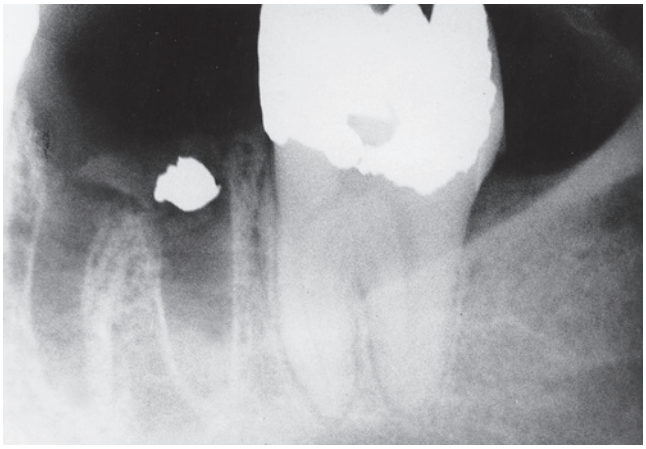
• **Fig. 8.68** (A) No. 23 forceps are carefully positioned to engage the bifurcation area of the lower molar. (B) The handles of the forceps are squeezed forcibly together, which causes the beaks of the forceps to be forced into the bifurcation and exerts tractional forces on tooth. (C) Strong buccal forces are then used to expand the socket. (D) Strong lingual forces are used to luxate the tooth further. (E) The tooth is delivered in the bucco-occlusal direction with buccal and tractional forces.

tip (Fig. 8.69). However, if neither a periapical lesion nor debris is present, the socket should not be curetted. The remnants of the periodontal ligament and the bleeding bony walls are in the best condition to provide for rapid healing. Vigorous curettage of the socket wall merely produces additional injury and may delay healing.

The expanded buccolingual plates should be compressed back to their original configuration. Finger pressure should be applied to the buccolingual cortical plate to compress the plates gently, but firmly, to their original position. This helps prevent bony undercuts that may have been caused by excessive expansion of the buccocortical plate, especially after extraction of the first molar. Care should be taken to not overreduce the socket if implant placement is planned or possible in the future. In some cases, no reduction should be done if implants are planned.

If teeth were removed because of periodontal disease, there may be an accumulation of excess granulation tissue around the gingival cuff. If this is the case, special attention should be given to removing this granulation tissue with a curette, tissue scissors, or a hemostat. The arterioles of granulation tissue have little or no capacity to retract and constrict, which leads to bothersome bleeding if excessive granulation tissue is left in place.

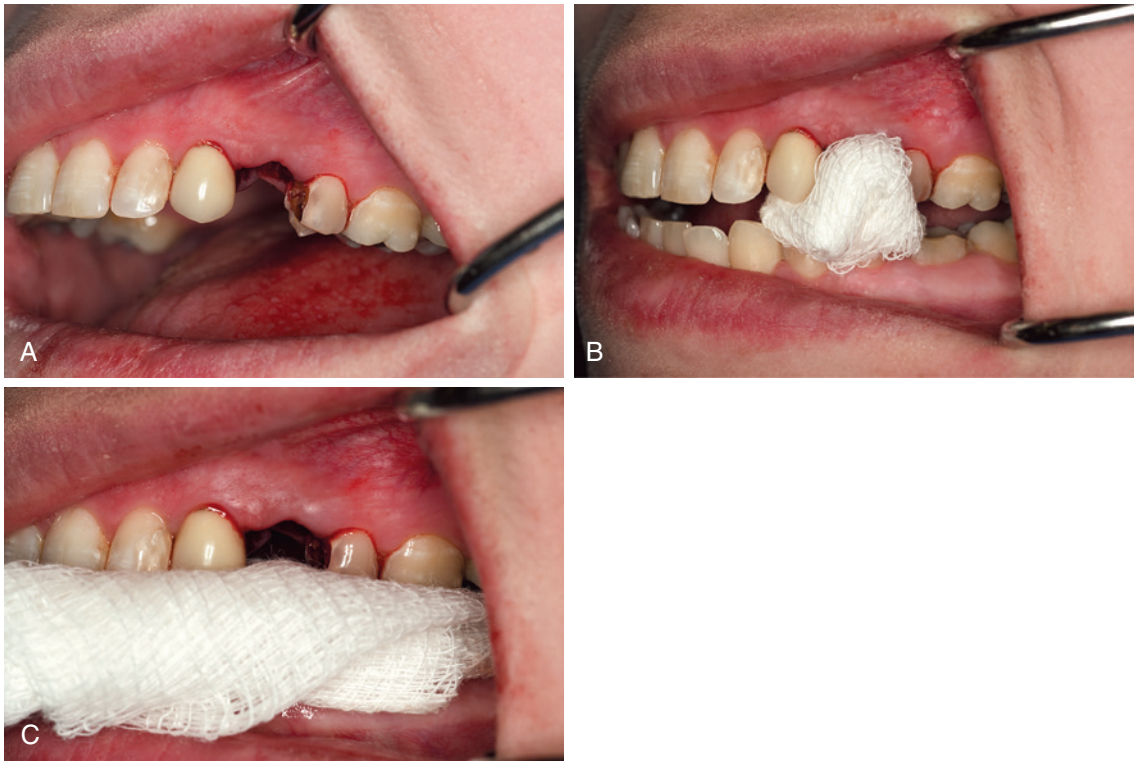
Finally, the bone should be palpated through the overlying mucosa to check for any sharp, bony projections. If any exist, the mucosa should be reflected and the sharp edges smoothed judiciously with a bone file or trimmed with a rongeur.



• **Fig. 8.69** An amalgam fragment has been left in this tooth socket after extraction because the surgeon failed to inspect and debride the surgical field.

Initial control of hemorrhage is achieved by use of a moistened 2 × 2 inch gauze placed over the extraction socket. The gauze should be positioned such that when the patient closes his or her teeth together, it fits into the space previously occupied by the crown of the tooth. Biting of teeth together places pressure on the gauze, and the pressure is then transmitted to the socket. This pressure results in hemostasis. If the gauze is simply placed on the occlusal table, the pressure applied to the bleeding socket is insufficient to achieve adequate hemostasis (Fig. 8.70). A larger gauze sponge (4 × 4 inches) may be required if multiple teeth have been extracted or if the opposing arch is edentulous.

The extraction of multiple teeth at one sitting is a more involved and complex procedure and is discussed in Chapter 9.



• **Fig. 8.70** (A) After extraction of a single tooth, a small space exists where the crown of the tooth was located. (B) A gauze pad (2 × 2 inch) is folded in half twice and placed into the space. When the patient bites on the gauze, pressure is transmitted directly to the gingiva and the socket. (C) If a large piece of gauze is used, the pressure goes on teeth, not on the gingiva or the socket.

9

Principles of More Complex Exodontia

JAMES R. HUPP

CHAPTER OUTLINE

The removal of most erupted teeth can be achieved by closed delivery, but occasionally these techniques do not provide adequate surgical access. The open or surgical extraction technique is the method used when greater access is necessary to safely remove a tooth or its remaining roots. In addition, removal of multiple teeth during one surgical session requires more than the routine techniques of tooth removal described in Chapter 8. In addition, the surgical approach for extractions is commonly required for recontouring and smoothing bone after multiple extractions.

This chapter discusses techniques for surgical tooth extraction. The principles of flap design, development, management, and suturing are explained, as are the principles of open extraction of single-rooted and multirooted teeth. The principles involved in multiple extractions and concomitant alveoloplasty are also discussed.

Principles of Flap Design, Development, and Management

The word *flap,* when used to describe a surgical procedure, indicates an area of tissue that will be surgically moved from one site in the body to another or temporarily moved to improve surgical access. Flapped tissue can be comprised of soft tissue only or can include bone and/or other tissues to be relocated. Oral-maxillofacial surgeons often create flaps that contain bone and adjacent soft tissues to reconstruct the jaws (see Chapter 29).

Flap, as used in this chapter, indicates a section of soft tissue that (1) is outlined by a surgical incision, (2) carries its own blood supply, (3) allows surgical access to underlying tissues, (4) can be replaced in the original position, and (5) is maintained with sutures. Soft tissue flaps are frequently used in oral surgical, periodontal, and endodontic procedures to gain access to underlying tooth and bone structures. The dental surgeon routinely extracting teeth must have a clear understanding of the principles of design, development, and management of soft tissue flaps.

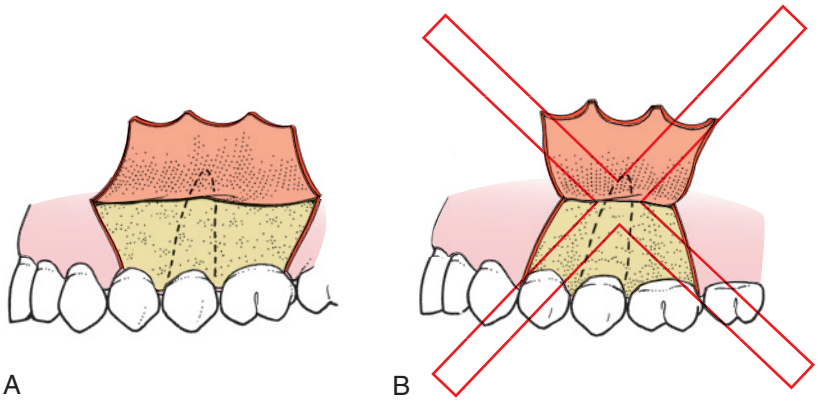
Design Parameters for Soft Tissue Flaps

To provide adequate exposure and promote proper healing, the flap must be correctly designed. The surgeon must remember that several parameters exist when designing a flap that vary based on the clinical situation.

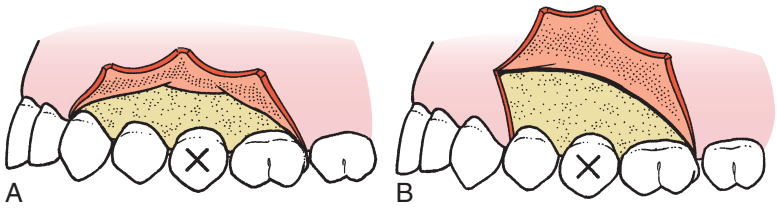
When the flap is outlined, the base of the flap must usually be broader than the free margin to preserve an adequate blood supply. This means that all areas of the flap must have a source of uninterrupted vasculature to prevent ischemic necrosis of the entire flap or portions of it (Fig. 9.1).

When flaps are used to gain surgical access, they must be of adequate size for several reasons. Sufficient soft tissue reflection is required to provide excellent visualization of the surgical site. Adequate access also must exist for the insertion of instruments required to perform the surgery. In addition, the flap must be held out of the surgeon's line of sight by a retractor that should rest on intact bone. There must be enough flap reflection to permit the retractor to hold the flap without tension. Furthermore, soft tissue heals across the incision, not along the length of the incision, and sharp incisions heal more rapidly than torn tissue. Therefore a long, straight incision with adequate flap reflection heals more rapidly than a short, torn incision, which heals slowly by secondary intention. For an envelope flap to be of adequate size, the length of the flap in the anteroposterior dimension usually extends two teeth anterior and one tooth posterior to the area of surgery (Fig. 9.2A). Alternatively, if an anterior releasing incision is planned, the flap only needs to extend one tooth anterior and one tooth posterior to the tooth or teeth planned to be removed (Fig. 9.2B).

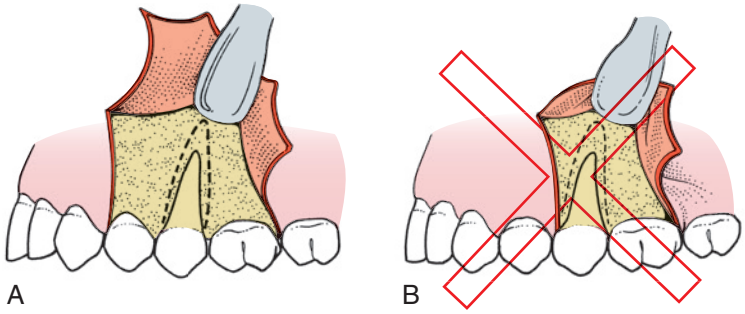
Flaps for tooth removal should be full-thickness mucoperiosteal flaps. This means that the flap includes the surface mucosa, the submucosa, and the periosteum. Because the goal of the surgery is to remove or reshape bone, all overlying tissue must be reflected from it. In addition, full-thickness flaps are necessary because the periosteum is the primary tissue responsible for bone healing, and



• **Fig. 9.1** (A) The flap must have a base that is broader than the free gingival margin. (B) If the flap is too narrow at its base, blood supply may be inadequate, which can lead to flap necrosis.



• **Fig. 9.2** (A) To have sufficient access to root of second premolar, the envelope flap should extend anteriorly, mesial to the canine, and posteriorly, distal to the first molar. (B) If a releasing incision (i.e., three-cornered flap) is used, the flap extends mesial to the first premolar.



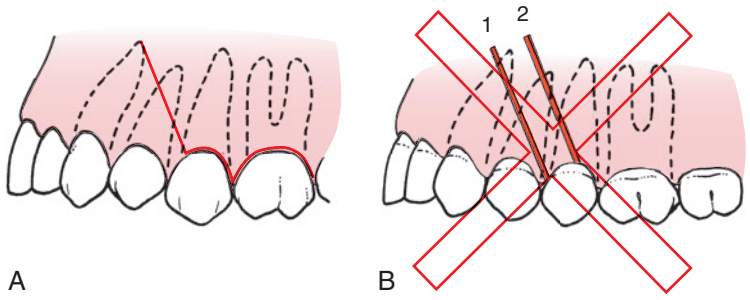
• **Fig. 9.3** (A) When designing a flap, it is necessary to anticipate how much bone will be removed so that after surgery is completed, the incision rests over sound bone. In this situation, the vertical release was one tooth anterior to bone removal, and left an adequate margin of sound bone. (B) When a releasing incision is made too close to bone removal, delayed healing results.

replacement of the periosteum in its original position hastens that healing process. Also, torn, split, or macerated tissue heals more slowly compared with a cleanly reflected, full-thickness flap. Furthermore, the tissue plane between bone and periosteum is relatively avascular, so less bleeding is produced when a full-thickness flap is elevated.

The incisions that outline the flap must be made over bone that will remain intact after the surgical procedure is complete. If the pathologic condition has eroded the buccocortical plate, the incision should be at least 6 to 8 mm away from it in an area of intact bone. In addition, if bone is to be removed over a particular tooth, the incision must be sufficiently distant from it so that after bone is removed, the incision is 6 to 8 mm away from the bony defect created by surgery. If the incision line is unsupported by intact bone, it tends to collapse into the bony defect, which results in wound dehiscence and delayed healing (Fig. 9.3).

The flap should be designed to avoid injury to local vital structures in the area of the surgery. The two most important structures that can be damaged are located in the mandible; these are the *lingual nerve* and the *mental nerve*. When making incisions in the posterior mandible, especially in the region of the third molar, incisions should be well away from the lingual aspect of the mandible. In the lower third molar area, the lingual nerve may closely adhere to the lingual aspect of the mandible or even run on the superior aspect of the retromolar area. Incisions in this area may result in damaging or even severing that nerve, with consequent prolonged temporary or permanent anesthesia of part of the tongue. In the same way, surgery in the apical area of mandibular premolar teeth should be carefully planned and executed to avoid injury to the mental nerve. Envelope incisions should be used, if at all possible, and releasing incisions should be well anterior or posterior from where the mental nerve exits the mandible.

Flaps in the maxilla rarely endanger any vital structures. On the facial aspect of the maxillary alveolar process there are no nerves or arteries that are likely to be damaged. When reflecting a palatal flap, the surgeon must remember that the major blood supply to the palatal soft tissue comes through the greater palatine artery, which emerges from the greater palatine foramen at the posterior lateral aspect of the hard palate. This artery courses forward and overlaps, to some degree, with the nasopalatine artery. The nasopalatine nerves and arteries exit the incisive foramen to supply the anterior palatal gingiva. If the anterior palatal tissue must be reflected, the artery and the nerve can be incised at the level of the foramen without serious consequences. In the area of the incisive neurovascular bundle, the likelihood of bothersome bleeding is small, and the nerve typically regenerates. The temporary numbness usually does not bother the patient. However, vertical-releasing incisions in the posterior aspect of the palate should be avoided because they usually sever the greater palatine artery within the tissue, which results in pulsatile bleeding that may be difficult to control.



• **Fig. 9.4** (A) The correct position for the end of the vertical-releasing incision is at the line angle (mesiobuccal angle in this figure) of the tooth. Likewise, the incision does not cross the canine eminence. Crossing such bony prominences results in increased chance for wound dehiscence. (B) These two incisions are made incorrectly. *(1)* The incision crosses the prominence over the canine tooth, which increases the risk of delayed healing; the incision through the papilla results in unnecessary damage. *(2)* The incision crosses the attached gingiva directly over the facial aspect of the tooth, which is likely to result in soft tissue defect as well as periodontal and aesthetic deformities.

Releasing incisions are used only when necessary and not routinely. Envelope incisions usually provide the adequate visualization required for tooth extraction in most areas. When vertical-releasing incisions are necessary, only a single vertical incision is usually required, which is usually at the anterior end of the envelope component. The vertical-releasing incision is not a straight vertical incision but an oblique incision, allowing the base of the flap to be broader than the free gingival margin. A vertical-releasing incision is made so that it does not cross bony prominences such as the canine eminence; to do so would increase the likelihood of tension in the suture line, which could result in wound dehiscence.

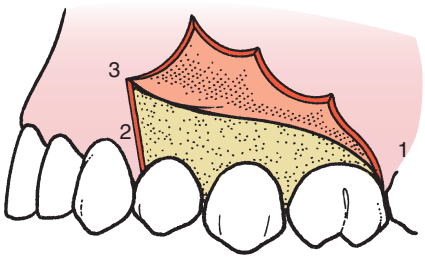
Vertical-releasing incisions should cross the free gingival margin at the line angle of a tooth and should not be directly on the facial aspect of the tooth, nor should it be directly in the papilla (Fig. 9.4). Incisions that cross the free margin of the gingiva directly over the facial aspect of the tooth do not heal properly because of tension; the result is a defect in the attached gingiva. Because facial bone around teeth is frequently thin, such incisions also result in vertical clefting of the bone. Incisions that cross the gingival papilla damage the papilla unnecessarily and increase the chances for localized periodontal problems; such incisions should be avoided.

Types of Mucoperiosteal Flaps

A variety of intraoral tissue flaps exists. The most common incision is the sulcular incision, which, when not combined with a releasing incision, produces the envelope flap. In the dentulous patient, the incision is made in the gingival sulcus down to crestal bone, through the periosteum, and the full-thickness mucoperiosteal flap is reflected apically (see Fig. 9.2A). This flap usually provides sufficient access to perform the necessary surgery.

If the patient is edentulous, the envelope incision is usually made along the scar at the crest of the ridge. No vital structures are found in this area, and the envelope incision can be as long as is required to provide adequate access. The only exception occurs in extremely atrophic mandibles where the inferior alveolar nerve may rest on top of the residual alveolar ridge. Once the incision is made, tissue can be reflected buccally or lingually, as necessary, for recontouring of the ridge or the removal of a mandibular torus. Note that flaps created through a crestal scar require extra care during elevation due to the presence of fibrous tissue in the scar that interferes with elevation.

If the sulcular incision has a vertical-releasing incision, it is a three-cornered flap with corners at the posterior end of the envelope incision, at the inferior aspect of the vertical incision, and at the superior aspect of the vertical-releasing incision (Fig. 9.5). This incision provides greater access with a shorter sulcular incision. When greater access is necessary in an apical direction, especially in the posterior aspect of the mouth, this incision is frequently necessary. The vertical component can be more difficult to close



• **Fig. 9.5** The vertical-releasing incision converts the envelope incision into a three-cornered flap (corners numbered).

and may cause some mildly prolonged healing, but if care is taken when suturing, the healing period is not noticeably lengthened. Placing the first suture at corner number 2 will properly align other parts of the incision, making the placement of the other sutures more straightforward.

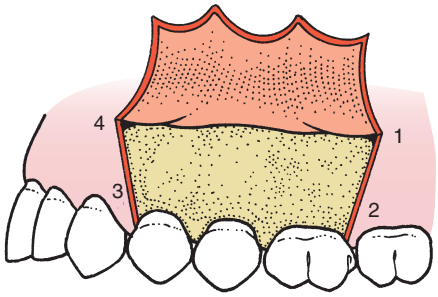
The four-cornered flap is an envelope incision with two releasing incisions. Two corners are at the superior aspect of the releasing incision, and two corners are at either end of the envelope component of the incision (Fig. 9.6). Although this flap provides substantial access in areas that have limited anteroposterior dimension, it is rarely indicated. When releasing incisions are necessary, a three-cornered flap usually suffices.

An incision that is used occasionally to approach the root apex is a semilunar incision (Fig. 9.7). This incision avoids trauma to the papillae and gingival margin but provides limited access because the entire root of the tooth is not visible. This incision is most useful for periapical surgery of a limited extent.

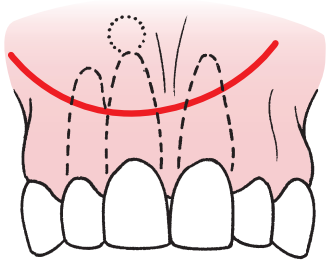
An incision useful on the palate is the Y-incision, which is named for its shape. This incision is useful for surgical access to the bony palate for removal of a palatal torus. The tissue overlying a torus is usually thin and must be carefully reflected. The anterolateral extensions of the midline incision are anterior to the region of the canine teeth. The extensions are anterior enough in this position that they do not sever major branches of the greater palatine artery; therefore bleeding is usually not a problem (Fig. 9.8).

Developing a Mucoperiosteal Flap

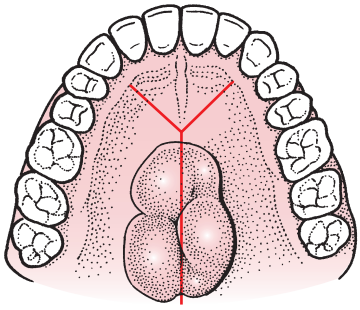
Several specific considerations are involved in developing flaps for surgical extractions. The first step is to incise soft tissue to allow reflection of the flap. The No. 15 blade is used on a No. 3 scalpel handle, and it is held in the pen grasp (Fig. 9.9). The blade is held at a slight angle to the tooth, and the incision is made posteriorly to anteriorly in the gingival sulcus by drawing the knife toward the operator. One smooth continuous stroke is used while keeping the knife blade in contact with bone throughout the entire incision (Figs. 9.10 and 9.11).



• **Fig. 9.6** Vertical-releasing incisions at the other end of the envelope incision convert the envelope incision into a four-cornered flap (corners numbered).

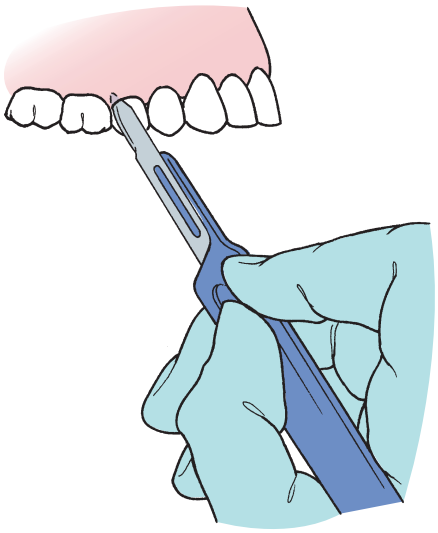


• **Fig. 9.7** Semilunar incision, designed to avoid marginal attached gingiva when working on a root apex. The incision is most useful when only a limited amount of access is necessary.



• **Fig. 9.8** The Y-incision is useful on the palate for adequate access to remove a palatal torus. Two anterior limbs serve as releasing incisions to provide for greater access.

• **Fig. 9.9** The scalpel handle is held in a pen grasp for maximal control and tactile sensitivity.



• **Fig. 9.10** A No. 15 blade is used to incise the gingival sulcus.

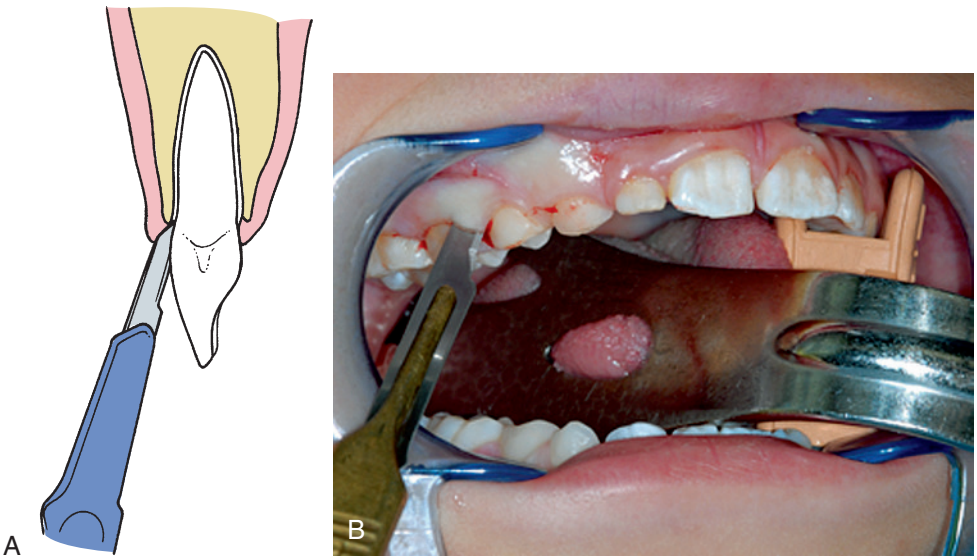
The scalpel blade is an extremely sharp instrument, but it dulls rapidly when it is pressed against bone, such as when making a mucoperiosteal incision. If more than one flap is to be reflected, the surgeon should consider changing blades between incisions.

If a vertical-releasing incision is made, the tissue is apically reflected, with the opposite hand tensing the alveolar mucosa so that the incision can be made cleanly through it. If the alveolar mucosa is not tensed, the knife will not incise cleanly through the mucosa, and a jagged incision will result.

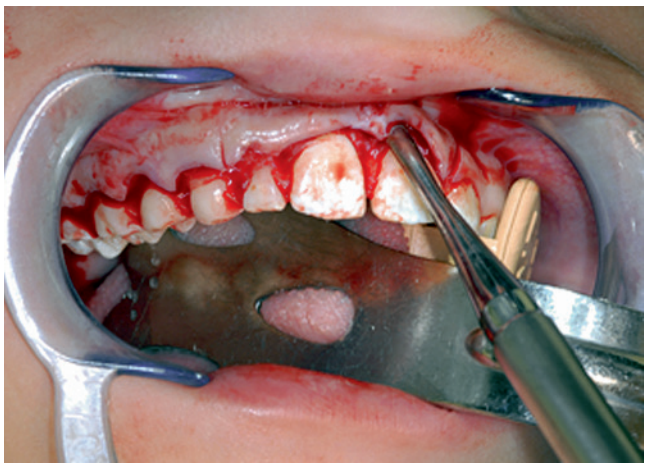
Reflection of the flap begins at a papilla. The sharp end of the No. 9 periosteal elevator begins a reflection (Fig. 9.12). The sharp end is slipped underneath the papilla in the area of the incision and is turned laterally to pry the papilla away from underlying bone. This technique is used along the entire extent of the gingival incision. If it is difficult to elevate the tissue at any one spot, the incision is probably incomplete, and that area should be reincised. Once the entire free edge of the flap has been reflected with the sharp end of the elevator, the broad end is used to reflect the mucoperiosteal flap to the extent desired, taking care to keep the edge of the elevator on bone and under the periosteum.

If a three-cornered flap is used, the initial reflection is accomplished with the sharp end of the No. 9 elevator on the first papilla only. Once the flap reflection is started, the broad end of the periosteal elevator is inserted at the middle corner of the flap, and the dissection is carried out with a pushing stroke, posteriorly and apically. This facilitates the rapid and atraumatic reflection of the soft tissue flap (Fig. 9.13).

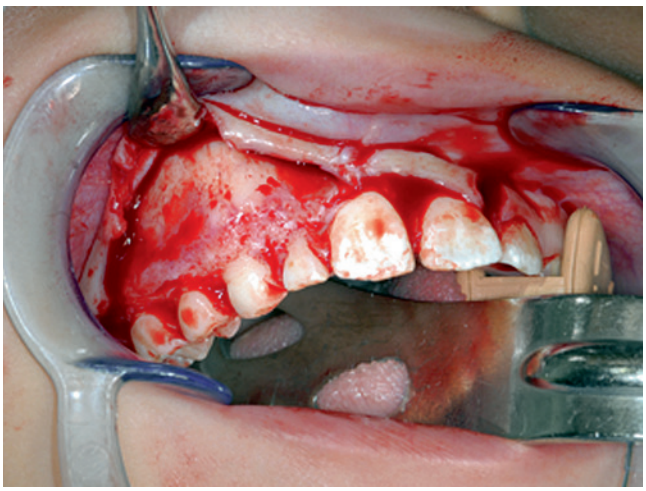
Once the flap has been reflected as desired, the periosteal elevator can be used as a retractor to hold the flap in its proper reflected position. To accomplish this effectively, the elevator is held perpendicular to the bone tissue while resting on sound bone and not trapping soft tissue between the retractor and bone. The periosteal elevator is therefore maintained in its proper position, and the soft tissue flap is held without tension (Fig. 9.14). The Seldin elevator, or the Minnesota or Austin retractors, can be used in a similar manner when broader exposure is necessary. The retractor should not be forced against soft tissue in an attempt to pull tissue out of the field. Instead, the retractor is positioned in the proper place and held firmly against bone. By retracting in this fashion, the surgeon primarily focuses on the surgical field rather



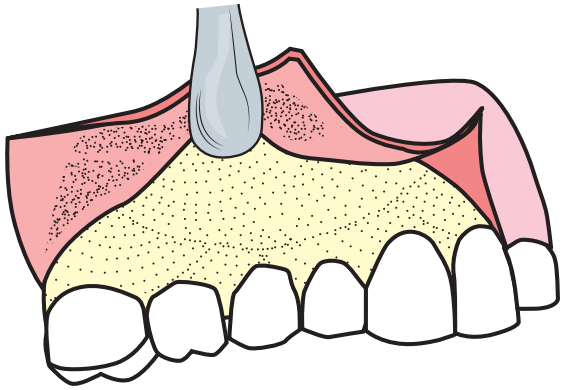
• **Fig. 9.11** (A) The knife is angled slightly away from the tooth and incises soft tissue, including the periosteum, at crestal bone. (B) The incision is started posteriorly and is carried anteriorly, with care taken to incise completely through the interdental papilla.



• **Fig. 9.12** The reflection of the flap is begun by using the sharp end of the periosteal elevator to pry away the interdental papilla.



• **Fig. 9.14** A periosteal elevator is used to retract the mucoperiosteal flap. The elevator is placed perpendicular to the bone and held in place by pressing firmly against the bone, not by pushing it apically against soft tissue. Notice the vertical releasing incision located at the distal line angle of tooth #9.



• **Fig. 9.13** When a three-cornered flap is used, only the anterior papilla is reflected with the sharp end of the elevator. The broad end is then used with a push stroke to elevate posterosuperiorly.

than on the retractor; thus the chance of inadvertently tearing the flap is lessened.

Principles of Suturing

Once the surgical procedure is completed and the wound is properly irrigated and debrided, the surgeon must return the flap to its original position or, if necessary, place it in a new position; the flap should be held in place with sutures. Sutures perform multiple functions. The most obvious and important function that sutures perform is to coapt wound margins; that is, to hold the flap in position and approximate the opposing wound edges. The sharper the incision and the less trauma inflicted on the wound margin, the more probable healing occurs by primary intention. If the space between the two wound edges is minimal, wound healing will be rapid and complete. If tears or excessive trauma to the wound edges occur, wound healing will need to occur by secondary intention.

Sutures also aid in hemostasis. If underlying tissue is bleeding, the surface mucosa or skin should not be closed because continued bleeding may result in the formation of a hematoma. Surface sutures aid in hemostasis but only as a tamponade in a generally oozing area, such as a tooth socket. Overlying tissue should never be sutured tightly in an attempt to gain hemostasis in a bleeding tooth socket.

Sutures help hold a soft tissue flap over bone. This is an important function because bone that is not covered with soft tissue becomes nonvital and requires an excessively long time to heal. When mucoperiosteal flaps are reflected from alveolar bone, it is important that the extent of the bone be recovered with soft tissue flaps. Unless appropriate suture techniques are used, the flap may retract away from bone, exposing it and resulting in delayed healing.

Sutures may aid in maintaining a blood clot in the alveolar socket. A special suture, such as a figure-of-eight, can provide a barrier to clot displacement (Fig. 9.15). However, it should be emphasized that suturing across an open wound socket plays a minor role in maintaining a blood clot in the tooth socket.

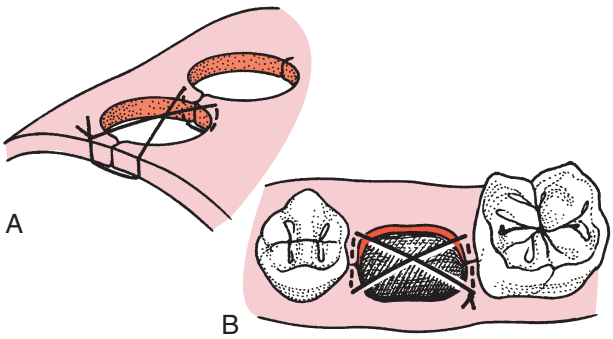
The armamentarium for suturing includes a needle holder, a suture needle, and suture material. The needle holder of choice is 15 cm (about 6 inches) in length and has a locking handle. The needle holder is held with the thumb and ring finger through the rings and with the index finger along the length of the needle holder to provide stability and control (Fig. 9.16).

The suture needle usually used in the mouth is a small three-eighths to one-half circle with a reverse cutting edge. The cutting edge helps the needle readily pass through the tough mucoperiosteal flap tissue. Needle sizes and shapes have been assigned numbers. The most common needle shapes used for oral surgery are the three-eighths and half-circle cutting needles (Fig. 9.17).

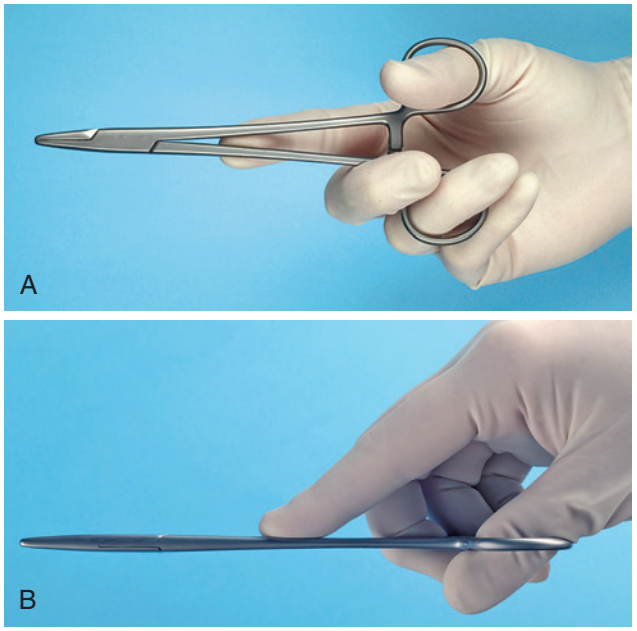
The technique used for suturing is deceptively difficult. The use of the needle holder and the technique that is necessary to pass the curved needle through tissue are difficult to learn. The following discussion presents the technique used in suturing; practice is necessary before suturing can be performed with skill and finesse.

When an envelope flap is repositioned into its correct location, it is held in place with sutures that are placed through the papillae only. Sutures are not placed across the empty tooth socket because the edges of the wound would not be supported over sound bone (Fig. 9.18). When reapproximating the flap, the suture is passed first through mobile (usually facial) tissue; the needle is regrasped with the needle holder and is passed through the attached tissue of the lingual papilla. Note that the tip of the needle should never be grasped by the needle holders. If the two margins of the wound are close together, the experienced surgeon may be able to insert the needle through both sides of the wound in a single pass. However, for better precision, it is best to use two passes in most situations (Fig. 9.19).

When passing the needle through tissue, the needle should enter the surface of the mucosa at the right angle, to make the smallest possible hole in the mucosal flap (Fig. 9.20). If the needle passes through tissue obliquely, the suture will tear through the surface layers of the flap when the suture knot is tied, which results in greater injury to soft tissue. In addition, if the needle does not

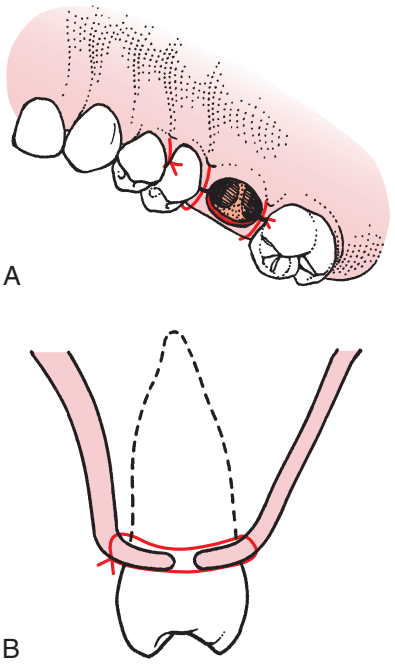


• **Fig. 9.15** (A) Figure-of-eight suture occasionally placed over the top of the socket to aid in hemostasis. (B) This suture is usually performed to help maintain a piece of oxidized cellulose in the tooth socket.



• **Fig. 9.16** (A) The needle holder is held with the thumb and ring finger. (B) The index finger extends along the instrument for stability and control.

• **Fig. 9.17** The shapes and types of needles most commonly used in oral surgery are the three-eighths circle and half-circle cutting needles shown here. *Top*, PS-2. *Middle*, FS-2. *Bottom*, X-1.

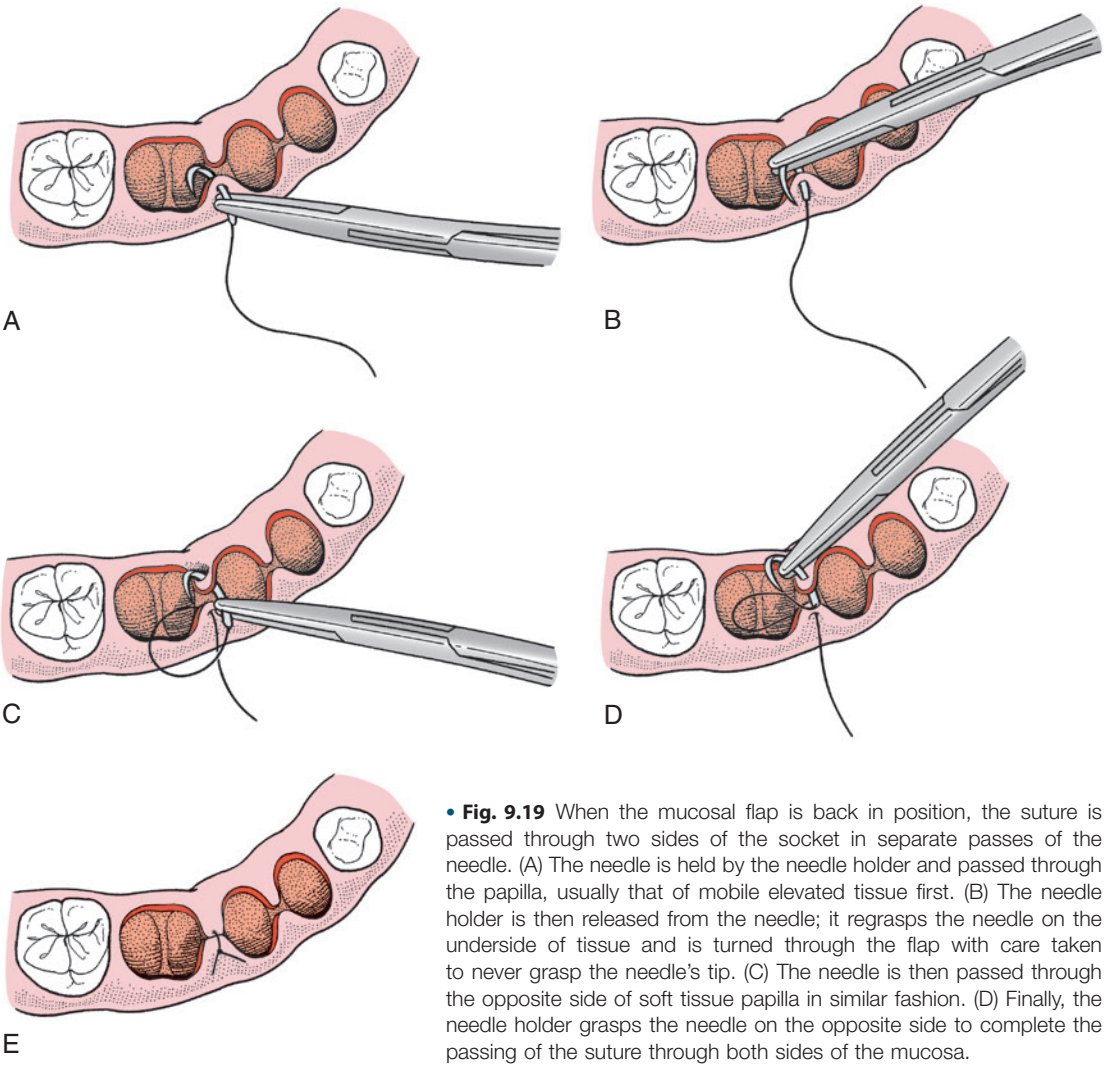


• **Fig. 9.18** (A) The flap held in place with sutures in papillae. (B) Cross-sectional view of suture.

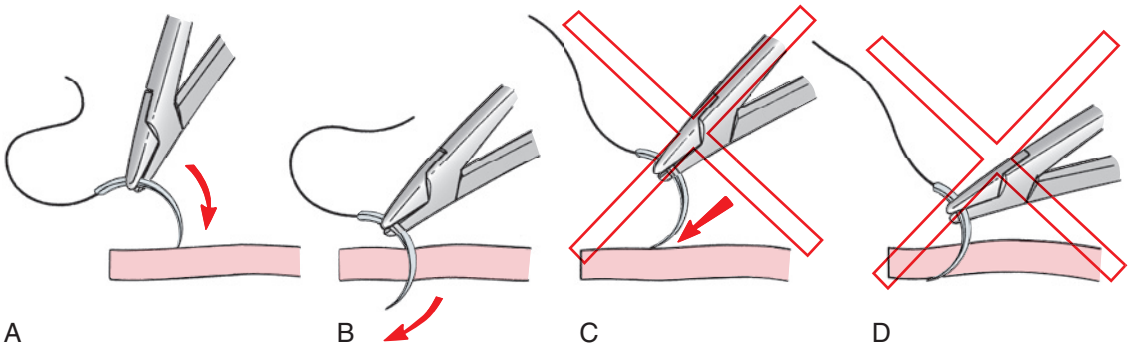
enter and exit a similar amount of tissue along both sides of the incision, the wound edges will not properly align.

When passing the needle through the flap, the surgeon must ensure that an adequate amount of tissue is taken to prevent the needle or suture from pulling through the soft tissue flap. Because the flap being sutured is a mucoperiosteal flap, it should not be tied too tightly. The minimal amount of tissue between the suture and the edge of the flap should be 3 mm. Once the sutures are passed through the mobile flap and the immobile lingual tissue, they are tied with an instrument tie (Fig. 9.21).

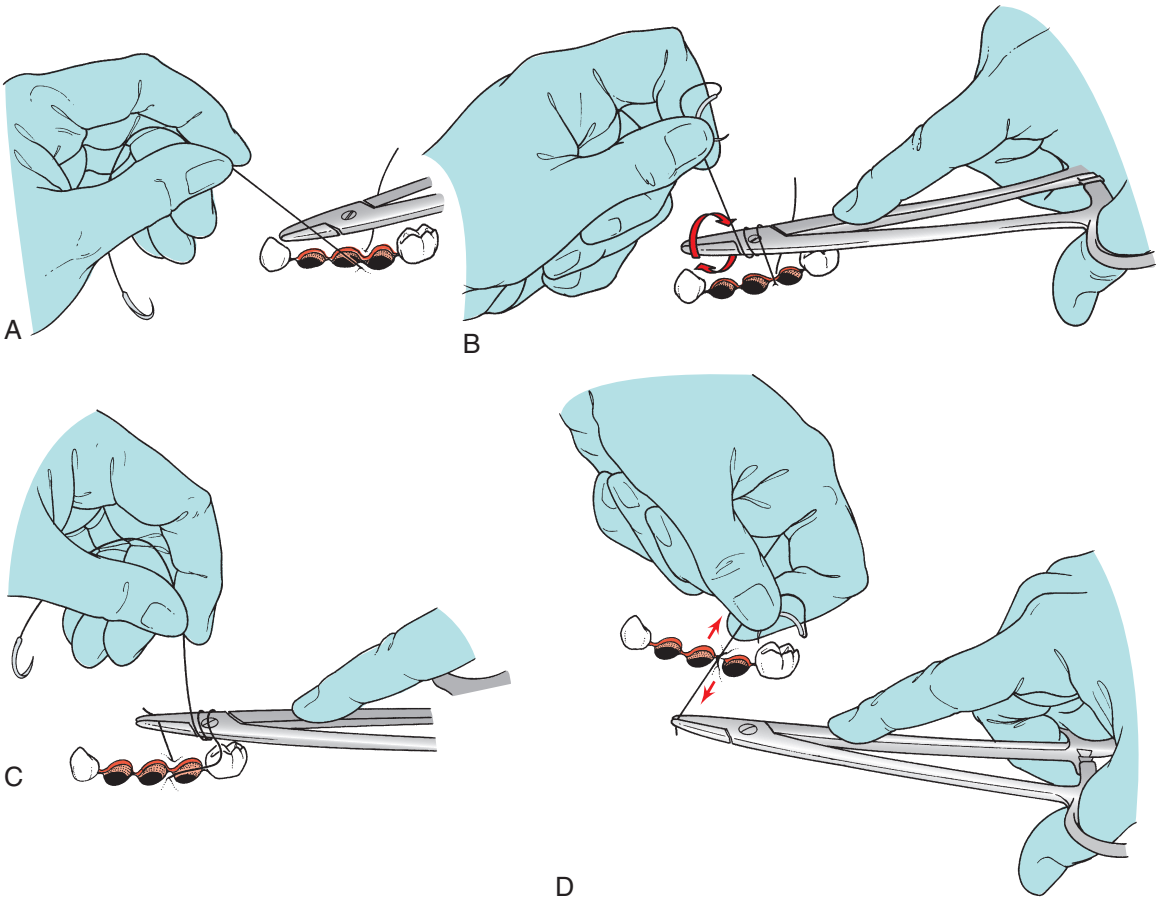
The surgeon must remember that the purpose of the suture is merely to reapproximate the tissue; therefore the suture should not be tied too tightly. Sutures that are too tight cause ischemia of the flap margin and result in tissue necrosis, with eventual tearing of the suture through tissue. Thus sutures that are too tightly tied result in wound dehiscence more frequently compared with sutures that are loosely tied. As a clinical guideline, there should be no blanching or obvious ischemia of the wound edges after a suture is tied. If this occurs, the suture should be removed and replaced. The knot should be positioned so that it does not fall directly over the incision line because this causes additional pressure on the incision. Therefore the knot should be positioned to the side of the incision, usually toward the facial or buccal aspect of the incision.



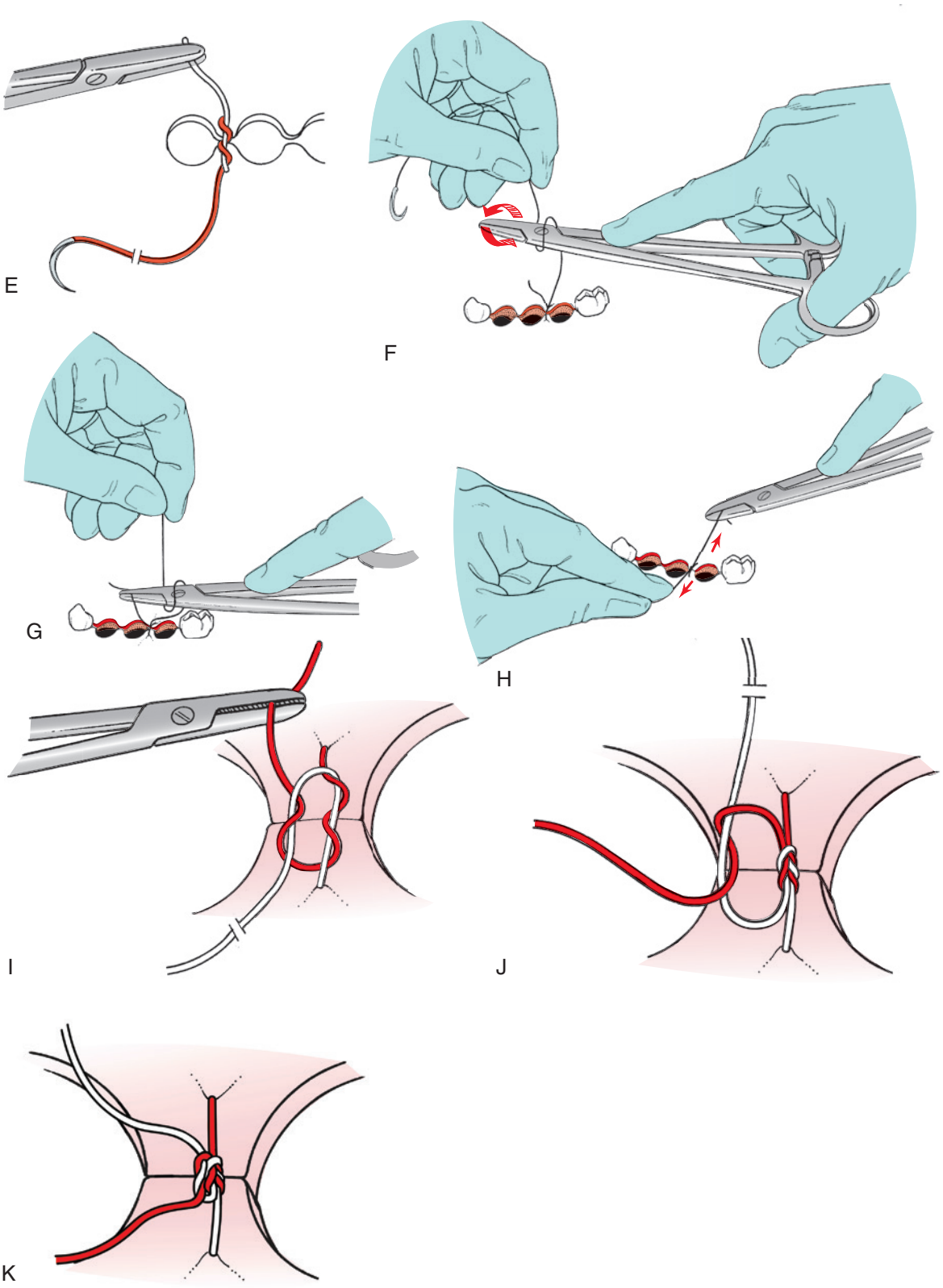
• **Fig. 9.19** When the mucosal flap is back in position, the suture is passed through two sides of the socket in separate passes of the needle. (A) The needle is held by the needle holder and passed through the papilla, usually that of mobile elevated tissue first. (B) The needle holder is then released from the needle; it regrasps the needle on the underside of tissue and is turned through the flap with care taken to never grasp the needle's tip. (C) The needle is then passed through the opposite side of soft tissue papilla in similar fashion. (D) Finally, the needle holder grasps the needle on the opposite side to complete the passing of the suture through both sides of the mucosa.



• **Fig. 9.20** (A) When passing through the soft tissue of mucosa, the needle should enter the surface of tissue at a right angle. (B) The needle holder should be turned so the needle passes easily through tissue at a right angle. (C) If the needle enters soft tissue at an acute angle and is pushed (rather than turned) through tissue, tearing of the mucosa with the needle or with the suture is likely to occur (D).



• **Fig. 9.21** Most intraoral sutures are tied with an instrument tie. (A) The suture is pulled through tissue until the short tail of the suture (approximately 1 to 2 cm long) remains. The needle holder is held horizontally by the right hand in preparation for the knot-tying procedure. (B) The left hand then wraps the long end of the suture around the needle holder twice in the clockwise direction to make two loops of suture around the needle holder. (C) The surgeon then opens the needle holder and grasps the short end of the suture very near its end. (D) The ends of the suture are then pulled to tighten the knot. The needle holder should not pull the suture it is holding at all until the knot is nearly tied to avoid lengthening that portion of the suture. Most intraoral sutures are tied with an instrument tie.



• **Fig. 9.21, cont'd** (E) End of the first step of the surgeon's knot. The double wrap has resulted in a double overhand knot. This increases the friction in the knot and will keep the wound edges together until the second portion of the knot is tied. (F) The needle holder is then released from the short end of the suture and held in the same position as when the knot-tying procedure began. The left hand then makes a single wrap in the counterclockwise direction. (G) The needle holder then grasps the short end of the suture at its end. (H) This portion of the knot is completed by pulling this loop firmly down against the previous portion of the knot. (I) This completes the surgeon's knot. The double loop of the first pass holds tissue together until the second portion of the square knot can be tied. (J) Most surgeons add a third throw to their instrument tie when using a resorbable suture material. The needle holder is repositioned in the original position, and one wrap is placed around the needle holder in the original clockwise direction. The short end of the suture is grasped and tightened down firmly to form the second square knot. (K) The final throw of three knots is tightened firmly. (*Note:* For demonstration purposes, the first knot is left loose here, but in actual knot tying, the first knot is tightened before creating the second knot.) Both ends of the suture are then cut, leaving about 1 cm or less of the suture end with the knot.

Once the knot securing a suture is tied, the surgeon or assistant should use suture scissors to cut the ends of the suture. The person cutting the suture should use the tips of the scissors to do the cutting so that the person can see that nothing beyond the suture is being cut. The length of the ends to leave varies, depending on the circumstances. In most situations in which the oral mucosa is being sutured, the ends of the suture should be left no longer than 1 cm.

If a three-cornered flap is used, the vertical end of the incision must be closed separately. Two sutures usually are required to close the vertical end properly. Before the sutures are inserted, the No. 9 periosteal elevator should be used to slightly elevate the nonflap side of the incision, freeing the margin to facilitate passage of the needle through the tissue (Fig. 9.22). The first suture is placed across the papilla, where the vertical release incision was made. This is an easily identifiable landmark that is most important when repositioning a three-cornered flap. The remainder of the envelope portion of the incision is then closed, after which the vertical component is closed. The slight reflection of the nonflap side of the incision greatly eases the placing of sutures.

Sutures may be configured in several different ways. The routine interrupted suture is the one most commonly used in the oral cavity. This suture goes through one side of the wound, comes up through the other side of the wound, and is tied in a knot at the top. These sutures can be placed quickly, and the tension on each suture can be adjusted individually. If one suture is lost, the remaining sutures stay in position.

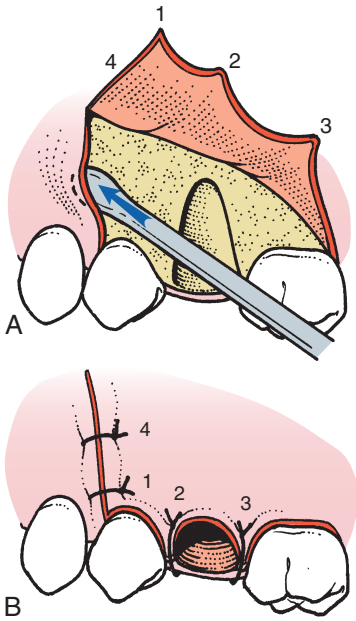
A suture technique that is useful for suturing two adjacent papillae with a single suture is the horizontal mattress suture (Fig. 9.23). A slight variation of that suture is the figure-of-eight suture, which holds the two papilla in position and puts a cross over the top of the socket that may help hold the blood clot or procoagulant materials in position (see Fig. 9.15).

If the incision is long, continuous sutures can be used to efficiently accomplish the closure. When using this technique, a knot does not have to be made for each suture, which makes it quicker to suture a long-span incision and leaves fewer knots to collect debris and to bother the patient's tongue. The continuous simple suture can be locking or nonlocking (Fig. 9.24). The horizontal mattress suture also can be used in a running fashion. A disadvantage of the continuous suture is that if one suture pulls through, the entire suture line becomes loose.

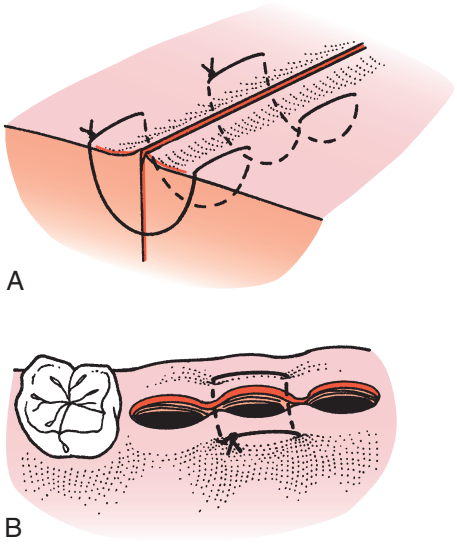
Nonresorbable sutures are left in place for approximately 5 to 7 days. After this time, sutures play no useful role and increase the contamination of the underlying submucosa. The suture is cut with the tips of a sharp, pointed pair of suture scissors and is removed by being pulled toward the incision line (not away from the suture line).

Principles and Techniques for Open Extractions

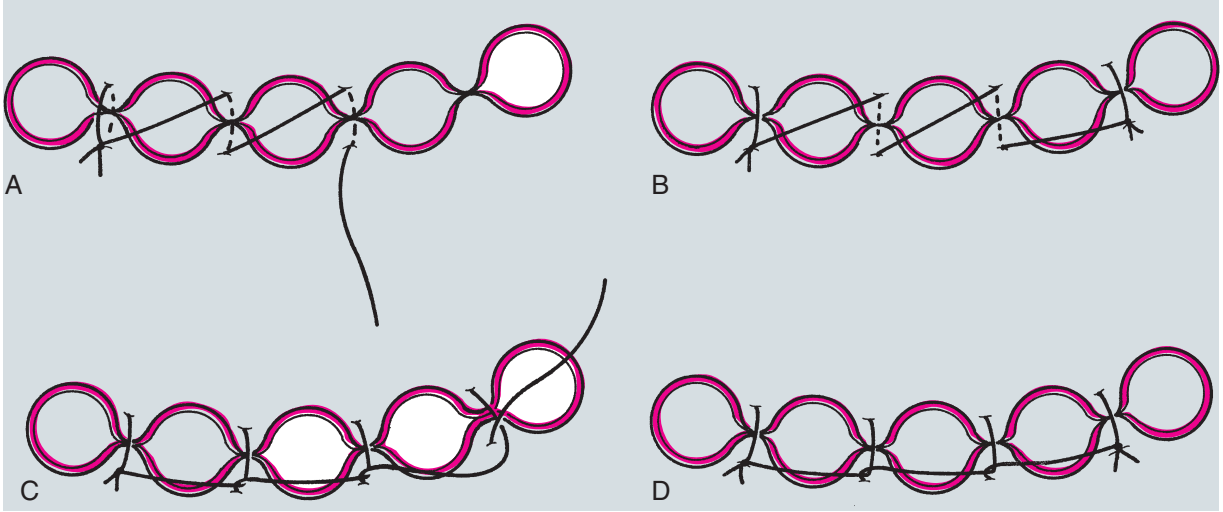
The surgical or open extraction of an erupted tooth using a flap is a technique that should not be reserved for the extreme situation. A prudently used open extraction technique may be more conservative, cause less operative morbidity, and be quicker to perform compared with a closed extraction. Forceps extraction techniques, which require great force, may result in removal not only of the tooth but also of large amounts of adjacent bone and occasionally the floor of the maxillary sinus (Fig. 9.25). The bone loss may be less if a soft tissue flap is reflected and a proper amount of bone is removed; it may also be less if the tooth is sectioned (cut into smaller sections). The morbidity of fragments of bone that may be literally torn from the jaw by the "conservative" closed technique



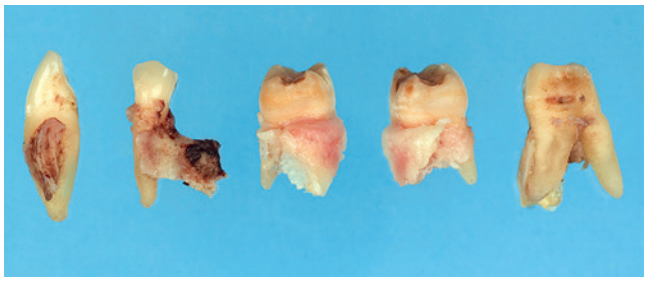
• **Fig. 9.22** (A) To make the suturing of the three-cornered flap easier, a periosteal elevator is used to elevate a small amount of fixed tissue so that the suture can be passed through the entire thickness of the mucoperiosteum. (B) When the three-cornered flap is repositioned, the first suture is placed at the occlusal end of the vertical-releasing incision *(1)*. The papillae are then sutured sequentially *(2, 3)*, and finally, if necessary, the superior aspect of the releasing incision is sutured *(4)*.



• **Fig. 9.23** (A) A horizontal mattress suture is sometimes used to close soft tissue wounds. The use of this suture decreases the number of individual sutures that have to be placed; however, more importantly, this suture compresses the wound together slightly and everts the wound edges. (B) A single horizontal mattress suture can be placed across both papillae of the tooth socket and serves in a similar way as do two individual sutures.



• **Fig. 9.24** When multiple sutures are to be placed, the incision can be closed with running or continuous sutures. (A) The first papilla is closed and the knot tied the usual way. The long end of the suture is held, and the adjacent papilla is sutured without the knot being tied, but just with the suture being pulled firmly through tissue. (B) Succeeding papillae are then sutured until the final one is sutured and the final knot is tied. The final appearance is with the suture going across each empty socket. (C) A continuous locking suture can be made by passing the long end of the suture underneath the loop before it is pulled through tissue. (D) This puts the suture on the deep periosteal and mucosal surfaces directly across the papilla and may aid in more direct apposition of tissues.



• **Fig. 9.25** Forceps extraction of these teeth resulted in removal of bone and the tooth instead of just the tooth.

can greatly exceed the morbidity of a properly done surgical extraction.

Indications for Open Extraction

It is prudent for the surgeon to carefully evaluate each patient and each tooth to be removed for the possibility of an open extraction. Although the decision is to perform a closed extraction in the vast majority of cases, the surgeon must be continually aware that open extraction may be the less traumatic of the two in some situations.

As a general guideline, surgeons should consider performing an elective surgical extraction when they anticipate the possible need for excessive force to extract a tooth. The term *excessive* means that the force will probably result in a fracture of bone, a tooth root, or both. In any case, excessive bone loss, the need for additional surgery to retrieve the root, or both can cause undue tissue damage. The following are examples of situations in which closed extraction may require excessive force.

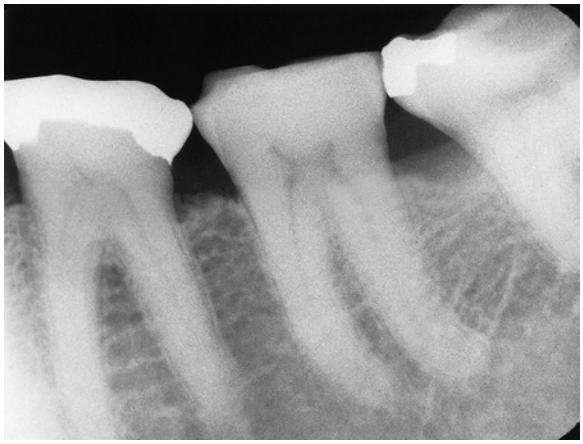
The surgeon should seriously consider performing an open extraction after initial attempts at forceps extraction have failed. Instead of applying greater amounts of force that may be less controlled, the surgeon should instead reflect a soft tissue flap, section the tooth, remove some bone, if needed, and extract the tooth in sections. In these situations, the philosophy of "divide and conquer" results in the most efficient and least traumatic extraction.

If the preoperative assessment reveals that the patient has thick or especially dense bone, particularly of the buccocortical plate, surgical extraction should be considered. The extraction of most teeth depends on the expansion of the buccocortical plate. If this bone is especially thick, then adequate expansion is less likely to occur and fracture of the root is more likely. Young patients have bone that is more elastic and more likely to expand with controlled force, whereas older patients usually have denser, more highly calcified bone that is less likely to provide adequate expansion during luxation of the tooth. Dense bone in the older patient warrants even more caution.

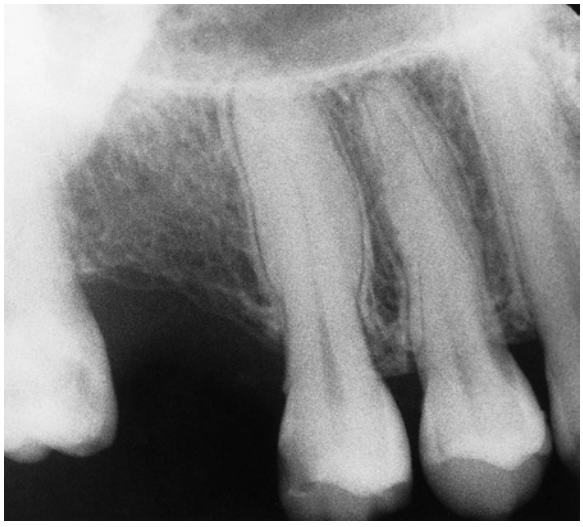
Occasionally, the dentist treats a patient who has very short clinical crowns with evidence of severe attrition. If such attrition is the result of bruxism, it is likely that teeth are surrounded by dense, thick bone with strong periodontal ligament attachments (Fig. 9.26). The surgeon should exercise extreme caution if removal of such teeth is attempted with a closed technique. An open technique usually results in a quicker, more straightforward extraction.

Careful review of the preoperative radiographs may reveal tooth roots that are likely to cause difficulty if the tooth is extracted by the standard forceps technique. One condition commonly seen among older patients is hypercementosis. In this situation, cementum has continued to be deposited on the tooth and has formed a large bulbous root that is difficult to remove through the available tooth socket opening. Great force used to expand the bone may result in fracture of the root or the buccocortical bone (Fig. 9.27).

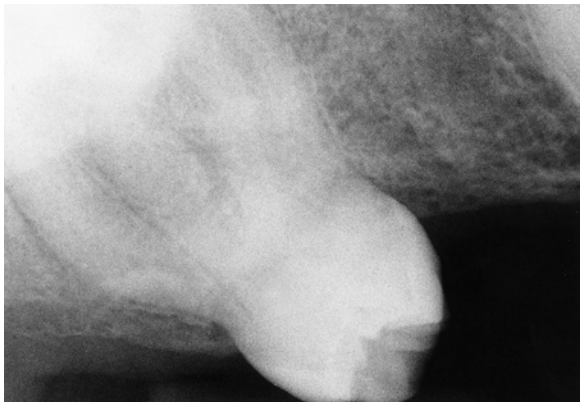
Roots that are widely divergent, especially maxillary first molar roots (Fig. 9.28) or roots that have severe dilaceration or hooks, are also difficult to remove without fracturing one or more of the



• **Fig. 9.26** Teeth that exhibit evidence of bruxism may have denser bone and stronger periodontal ligament attachment, which make them more difficult to extract.



• **Fig. 9.27** Hypercementosis of the root makes forceps delivery difficult.

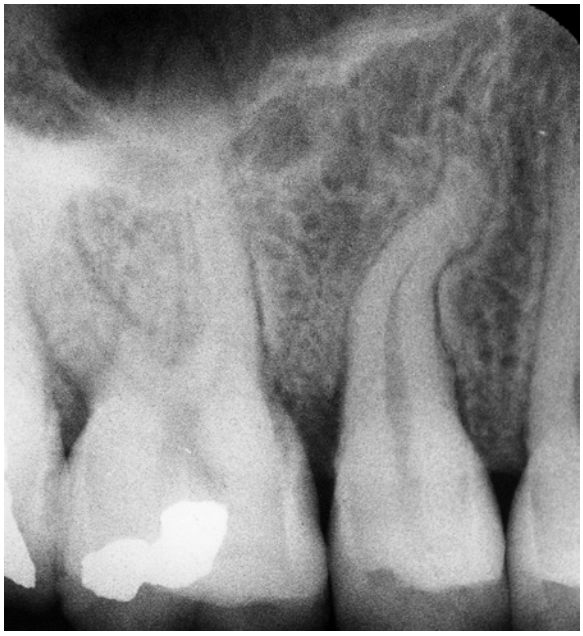


• **Fig. 9.28** Widely divergent roots increase the likelihood of fracture of bone, tooth root, or both.

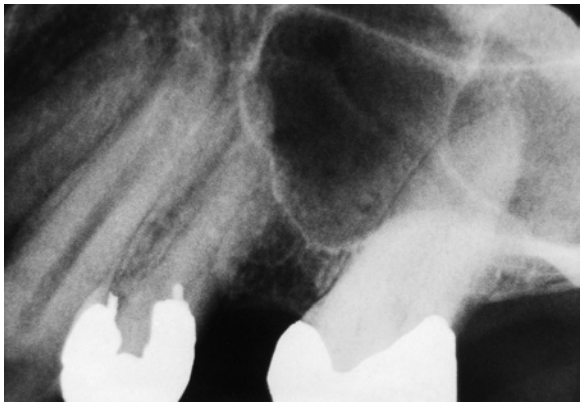
roots (Fig. 9.29). By reflecting a soft tissue flap and dividing the roots prospectively with a burr, a more controlled and planned extraction can be performed with less damage overall.

If the maxillary sinus has pneumatized to include the roots of the maxillary molars, extraction may result in removal of a portion of the sinus floor along with the tooth. If the roots are divergent, then such a situation is even more likely to occur (Fig. 9.30). Surgical extraction is again indicated.

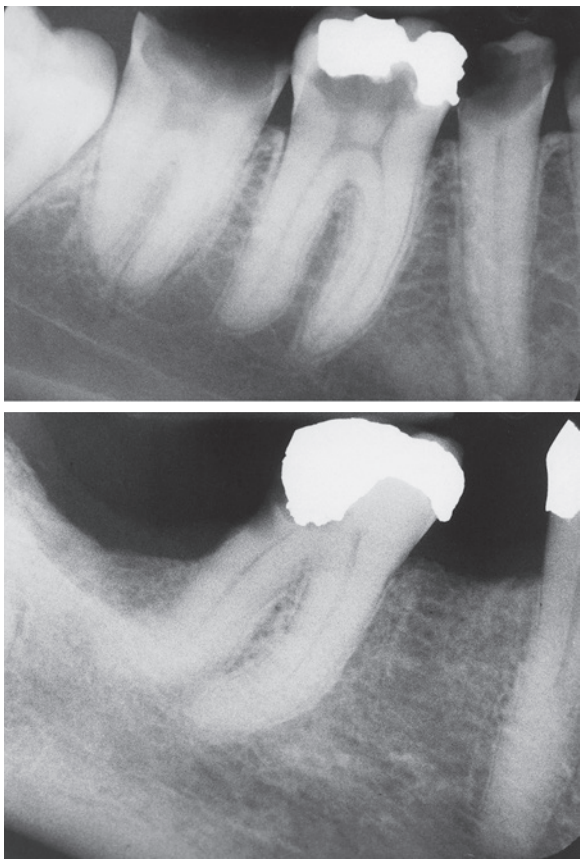
Teeth that have crowns with extensive caries, especially root caries that have large amalgam restorations, or endodontically treated molars are good candidates for open extraction (Fig. 9.31). Although forceps should primarily grasp the tooth root, a portion of the force is applied to the crown. Such pressures can crush and shatter the crowns of teeth with extensive caries, large restorations, or prior endodontic treatment. Open extraction can circumvent the need for extensive force and result in a quicker, less traumatic extraction. Teeth with crowns that have already been lost to caries and that present as retained roots should also be considered for



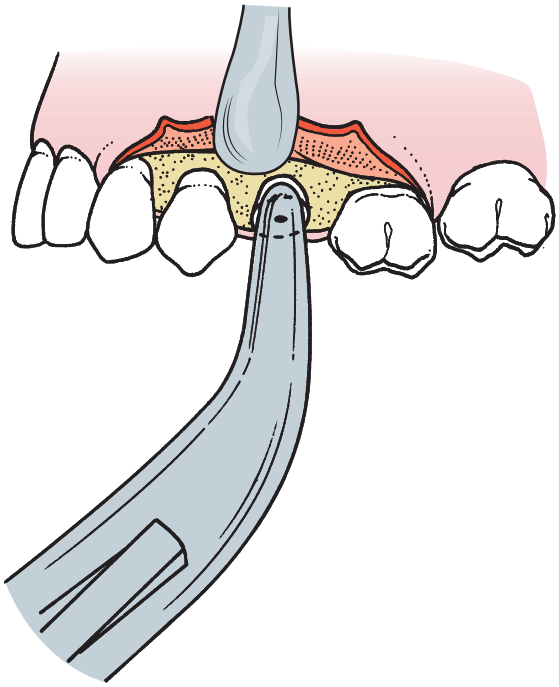
• **Fig. 9.29** Severe dilaceration of roots may result in fracture of the root unless surgical extraction is performed.



• **Fig. 9.30** Maxillary molar teeth "in" the floor of the maxillary sinus increase the chances of fracture of the sinus floor with resulting sinus perforation.



• **Fig. 9.31** Large caries or large restorations may lead to fracture of the crown of the tooth and thus to a more difficult extraction.



• **Fig. 9.32** A small envelope flap can be reflected to expose the fractured root. Under direct visualization, the forceps can be seated more apically into the periodontal ligament space, which eliminates the need for bone removal.

open extraction. If extensive periodontal disease is found around such teeth, it may be possible to deliver them easily with straight elevators or Cryer elevators. However, if bone around the tooth is firm and no periodontal disease exists, the surgeon should consider an open extraction.

Technique for Open Extraction of a Single-Rooted Tooth

The technique for open extraction of a single-rooted tooth is straightforward but requires attention to detail because several decisions must be made during the operation. The technique is essentially the same for single-rooted teeth that have resisted attempts at closed extraction or that have fractured and, therefore, exist only as a root.

The first step is to provide adequate visualization and access by reflecting a sufficiently large mucoperiosteal flap. In most situations, an envelope flap that is extended two teeth anterior and one tooth posterior to the tooth to be removed is sufficient. If a releasing incision is necessary, it should be placed at least one tooth anterior to the extraction site (see Fig. 9.2).

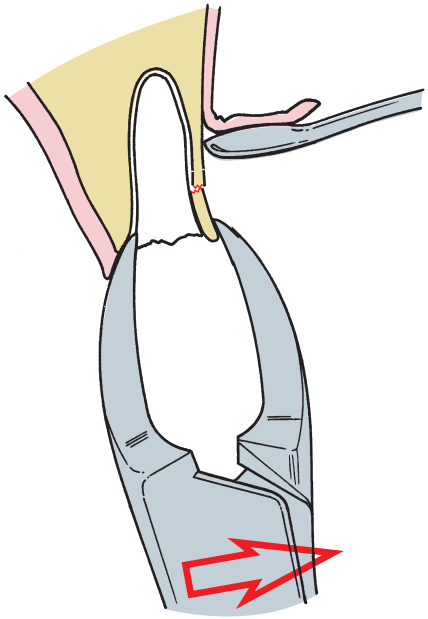
Once an adequate flap has been reflected and is held in its proper position by a periosteal elevator, the surgeon must determine the need for bone removal. Several options are available. First, the surgeon may attempt to reseat the extraction forceps under direct visualization and thus achieve a better mechanical advantage and remove the tooth with no surgical bone removal at all (Fig. 9.32).

The second option is to grasp a bit of buccal bone under the buccal beak of the forceps to obtain a better mechanical advantage and grasp of the tooth root. This may allow the surgeon to luxate the tooth sufficiently to remove it without any additional bone removal (Fig. 9.33). A small amount of buccal bone is pinched off and removed with the tooth.

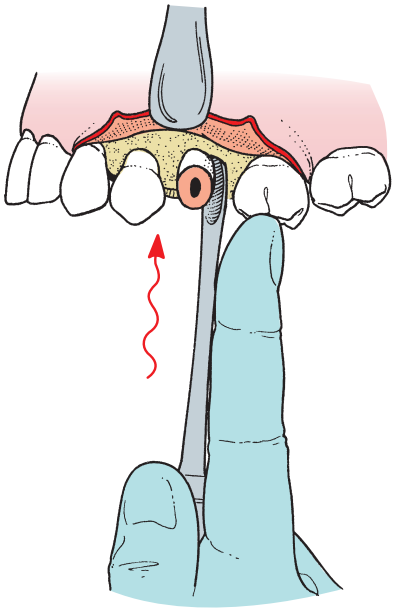
The third option is to use the straight elevator, pushing it toward the apex in the periodontal ligament space of the tooth (Fig. 9.34). The index finger of the surgeon's hand must support the force of the elevator so that the total movement is controlled and no slippage of the elevator occurs. A small to-and-fro motion should be used to help expand the periodontal ligament space, which allows the small straight elevator to enter and proceed apically into the space and act as a wedge to displace the root occlusally. This approach continues with the use of larger straight elevators until the tooth is successfully luxated.

The fourth and final option is to proceed with surgical bone removal over the area of the tooth. Most surgeons prefer to use a burr to remove the bone, along with ample irrigation. The width of buccal bone that is removed is essentially the same width as the tooth in a mesiodistal direction (Fig. 9.35). In a vertical dimension, bone should be removed approximately one-half to two-thirds the length of the tooth root (Fig. 9.36). This amount of bone removal sufficiently reduces the amount of force necessary to displace the tooth and makes removal relatively straightforward. A small straight elevator (Fig. 9.37) or forceps can be used to remove the tooth (Fig. 9.38).

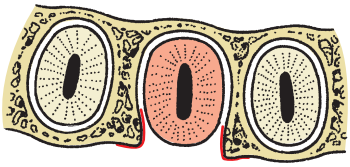
If the tooth is still difficult to extract after the removal of bone, a purchase point (indentation into a tooth into which a pointed elevator can be inserted) can be made in the root with the burr at the most apical portion of the area of bone removal (Fig. 9.39). Care should be taken to limit bone removal to only that needed to remove the root to preserve bone for possible implant placement. The purchase point hole should be about 3 mm in diameter and



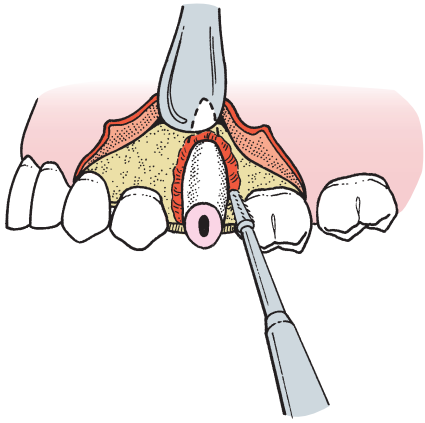
• **Fig. 9.33** If the root is fractured at the level of bone, the buccal beak of the forceps can be used to remove a small portion of bone at the same time that the root is grasped.



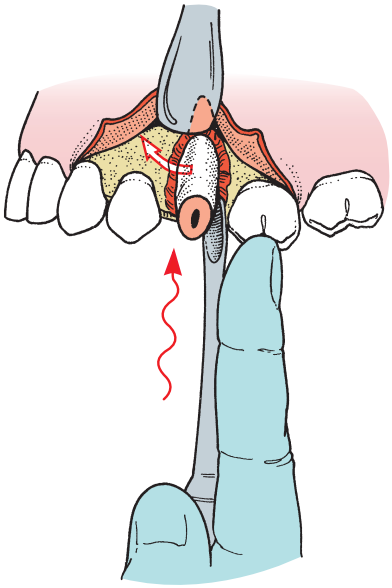
• **Fig. 9.34** The small straight elevator can be used like a shoehorn to luxate the broken root. When the straight elevator is used in this position, the hand must be securely supported on adjacent teeth to prevent inadvertent slippage of the instrument from the tooth and subsequent injury to adjacent tissue.



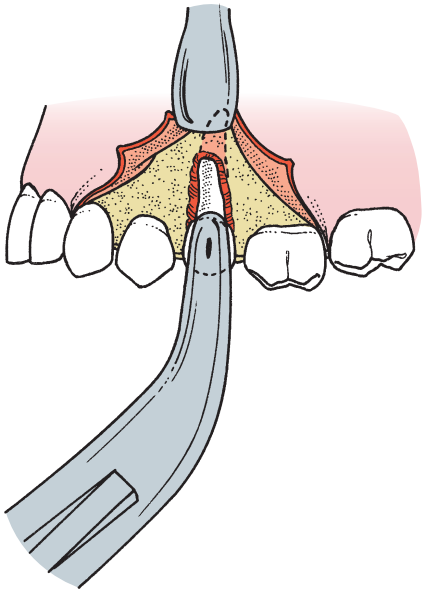
• **Fig. 9.35** When removing bone from the buccal surface of the tooth or tooth root to facilitate removal of that root, the mesiodistal width of bone removal should be approximately the same as the mesiodistal dimension of the tooth root itself. This allows an unimpeded path for removal of the root in the buccal direction.



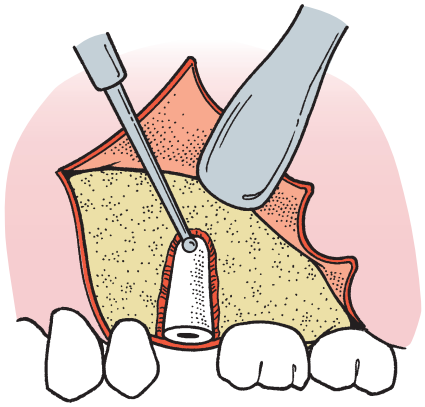
• **Fig. 9.36** Bone is removed with a bone-cutting burr after reflection of the standard envelope flap. Bone should be removed approximately one-half to two-thirds the length of the tooth root.



• **Fig. 9.37** Once the appropriate amount of buccal bone has been removed, the straight elevator can be used down the palatal aspect of the tooth to displace the tooth root in the buccal direction. It must be remembered that when the elevator is used in this direction, the surgeon's hand must be firmly supported on adjacent teeth to prevent slippage of the instrument and injury to the adjacent soft tissue.



• **Fig. 9.38** After bone has been removed and the tooth root luxated with the straight elevator, the forceps can be used to remove the root.

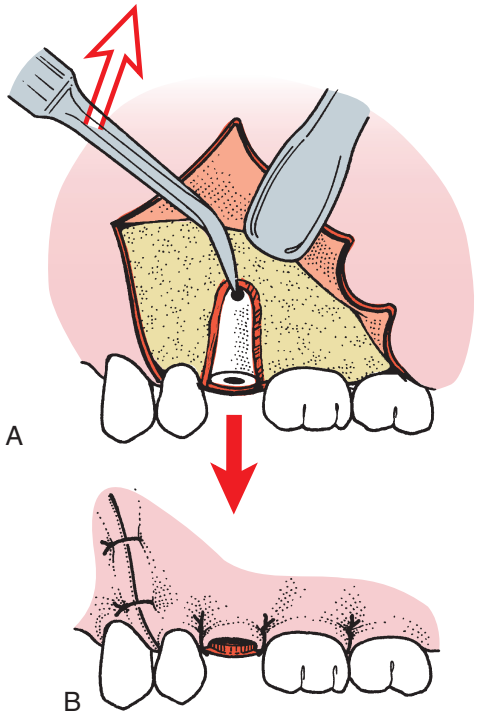


• **Fig. 9.39** If the tooth root is solid in bone, buccal bone can be removed, and a purchase point can be made for the insertion of the elevator.

deep enough to allow the insertion of an instrument. A heavy elevator, such as a Crane pick, can be used to elevate or lever the tooth from its socket (Fig. 9.40A). Soft tissue is repositioned and sutured (Fig. 9.40B).

The bone edges should be checked; if they are sharp, they should be smoothed with a bone file. By replacing the soft tissue flap and gently palpating it with a finger, the clinician can check edge sharpness. Removal of bone with a rongeur is rarely indicated because a rongeur tends to remove too much bone in such circumstances.

Once the tooth is delivered, the entire surgical field should be thoroughly irrigated with copious amounts of sterile saline. Special attention should be directed toward the most inferior portion of the flap (where it joins the bone) because this is a common place for debris to settle, especially in mandibular extractions. If the debris is not removed carefully by curettage or irrigation, it can cause delayed healing or even a small subperiosteal abscess in the ensuing 3 to 4 weeks. The flap is then set in its original position and sutured into place with 3-0 black silk or chromic sutures. If



• **Fig. 9.40** (A) A triangular elevator, such as the Crane pick, is inserted into the purchase point, and the tooth is elevated from its socket. (B) The flap is repositioned and sutured over intact bone.

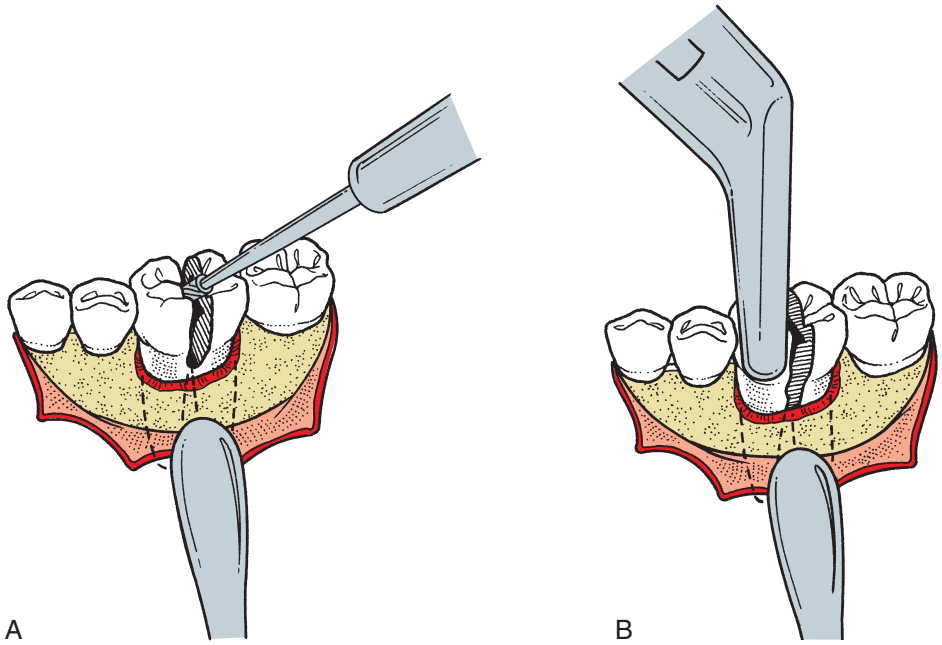
the incision was properly planned and executed, the suture line will be supported by healthy, intact bone.

Technique for Open Extraction of Multirooted Teeth

Once the decision is made to perform an open extraction of a multirooted tooth, such as a mandibular or maxillary molar, the same surgical technique used for the single-rooted tooth is generally used. The major difference is that the tooth may be divided with a burr to convert a multirooted tooth into two or three single-rooted teeth. If the crown of the tooth remains intact, the crown portion is sectioned in such a way as to facilitate removal of roots. However, if the crown portion of the tooth is missing and only the roots remain, the goal is to separate the roots to make them easier to elevate.

Removal of the lower first molar with an intact crown is usually done by sectioning the tooth buccolingually, thereby dividing the tooth into a mesial half (with mesial root and half of the crown) and a distal half. An envelope incision is also made to gain access to the site and protect the soft tissue from the burr. A small amount of crestal bone may be removed. Once the tooth is sectioned, it is luxated with straight elevators to begin the mobilization process. The sectioned tooth is treated as a lower premolar tooth and is removed with a lower universal forceps (Fig. 9.41). The flap is repositioned and sutured.

The surgical technique begins with the reflection of an adequately long envelope flap (Fig. 9.42A–B). Evaluation of the need for sectioning roots and removing bone is made at this stage, as it was with the single-rooted tooth. Occasionally forceps, elevators, or both are positioned with direct visualization to achieve better



• **Fig. 9.41** If the lower molar is difficult to extract, it can be sectioned into single-rooted teeth. (A) The envelope incision is reflected, and a small amount of crestal bone is removed to expose the bifurcation. A drill is then used to section the tooth into mesial and distal halves. (B) Lower universal forceps are used to remove the two crown and root portions separately.

mechanical advantage and to remove the tooth without removing bone.

However, in most situations a small amount of crestal bone should be removed and the tooth should be divided. Tooth sectioning is usually accomplished with a straight handpiece with a straight burr such as the No. 8 round burr or with a fissure burr such as the No. 557 or No. 703 burr (Fig. 9.42C) under copious irrigation.

Once the tooth is sectioned, the small straight elevator is used to luxate and mobilize the sectioned roots (Fig. 9.42D). The straight elevator may be used to deliver the mobilized sectioned tooth (Fig. 9.42E). If the crown of the tooth is sectioned, upper or lower universal forceps are used to remove the individual portions of the sectioned tooth (Fig. 9.42F). If the crown is missing, then straight and triangular elevators are used to elevate the tooth roots from the sockets.

Sometimes a remaining root may be difficult to remove and additional bone removal (as is described for a single-rooted tooth) may be necessary. Occasionally it is necessary to prepare a purchase point with the burr and to use an elevator, such as the Crane pick, to elevate the remaining root.

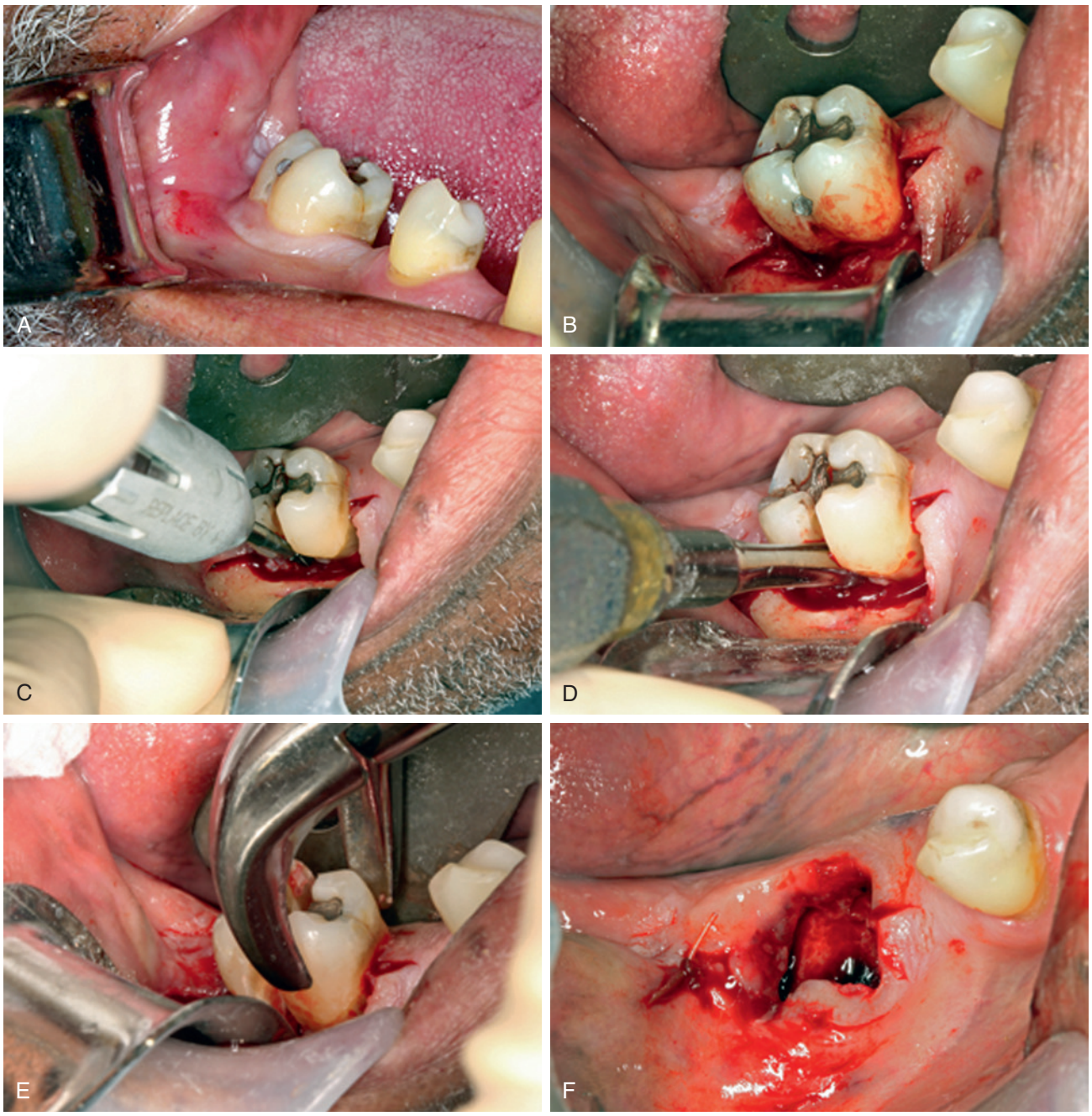
After the tooth and all the root fragments have been removed, the flap is repositioned and the surgical area is palpated for sharp bony edges. If any sharp edges are present, they are smoothed with a bone file. The wound is thoroughly irrigated and debrided of loose fragments of tooth, bone, calculus, and other debris. The flap is repositioned and sutured in the usual fashion.

An alternative method for removing the lower first molar is to reflect the soft tissue flap and remove sufficient buccal bone to expose the bifurcation. Then the burr is used to section the mesial root from the tooth and convert the molar into two single-rooted teeth (Fig. 9.43). The crown with the mesial root intact is extracted with No. 17 lower molar forceps. The remaining mesial root is elevated from the socket with a Cryer elevator. The elevator is inserted into the empty tooth socket and rotated, using the wheel-and-axle principle. The sharp tip of the elevator engages the cementum of the remaining root, which is elevated occlusally from the socket. If the interradicular bone is heavy, the first rotation or two of the Cryer elevator removes bone, which allows the elevator to engage the cementum of the tooth on the second or third rotation.

If the crown of the mandibular molar has been lost, the procedure again begins with the reflection of an envelope flap and removal of a small amount of crestal bone. The burr is used to section the two roots into mesial and distal components (Fig. 9.44A). The small straight elevator is used to mobilize and luxate the mesial root, which is delivered from its socket by insertion of the Cryer elevator into the slot prepared by the dental burr (Fig. 9.44B). The Cryer elevator is rotated in the wheel-and-axle manner, and the mesial root is delivered occlusally from the tooth socket. The opposite member of the paired Cryer instruments is inserted into the empty root socket and rotated through the interradicular bone to engage and deliver the remaining root (Fig. 9.44C).

Extraction of maxillary molars with widely divergent buccal and palatal roots that require excessive force to extract can be done more prudently by dividing the root into several sections. This three-rooted tooth must be divided in a pattern different from that of the two-rooted mandibular molar. If the crown of the tooth is intact, the two buccal roots are sectioned from the tooth and the crown is removed along with the palatal root.

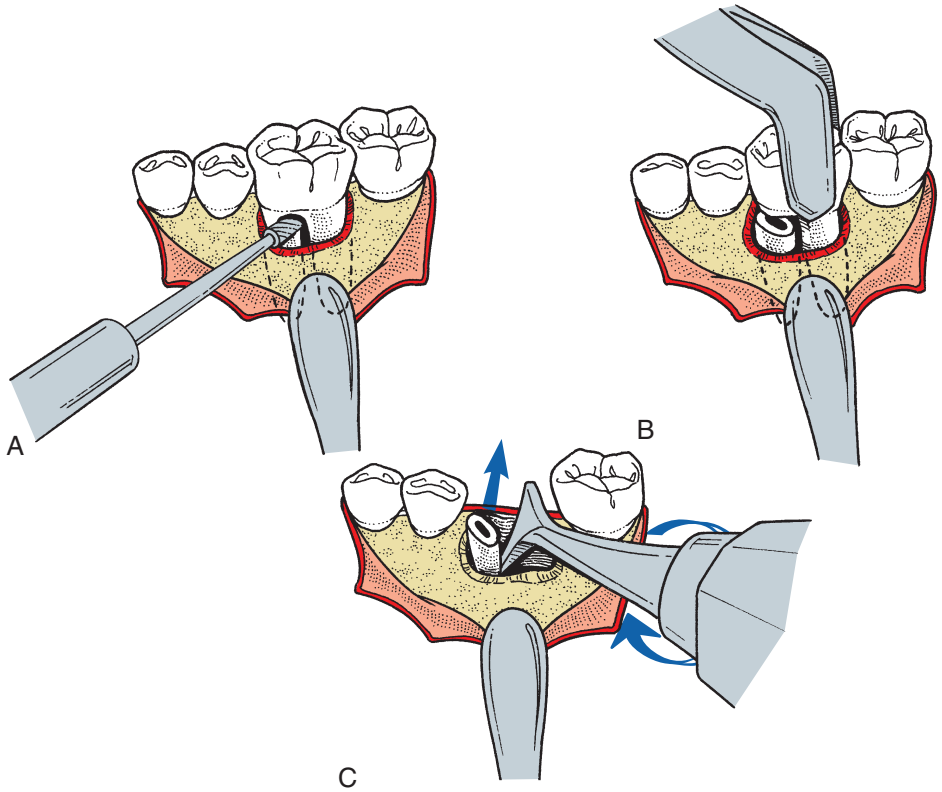
The standard envelope flap is reflected, and a small portion of crestal bone is removed to expose the trifurcation area. The burr is used to section off the mesiobuccal and distobuccal roots (Fig. 9.45A). With gentle but firm bucco-occlusal pressure, the upper molar forceps deliver the crown and palatal root along the long axis of the root (Fig. 9.45B). No palatal force should be delivered



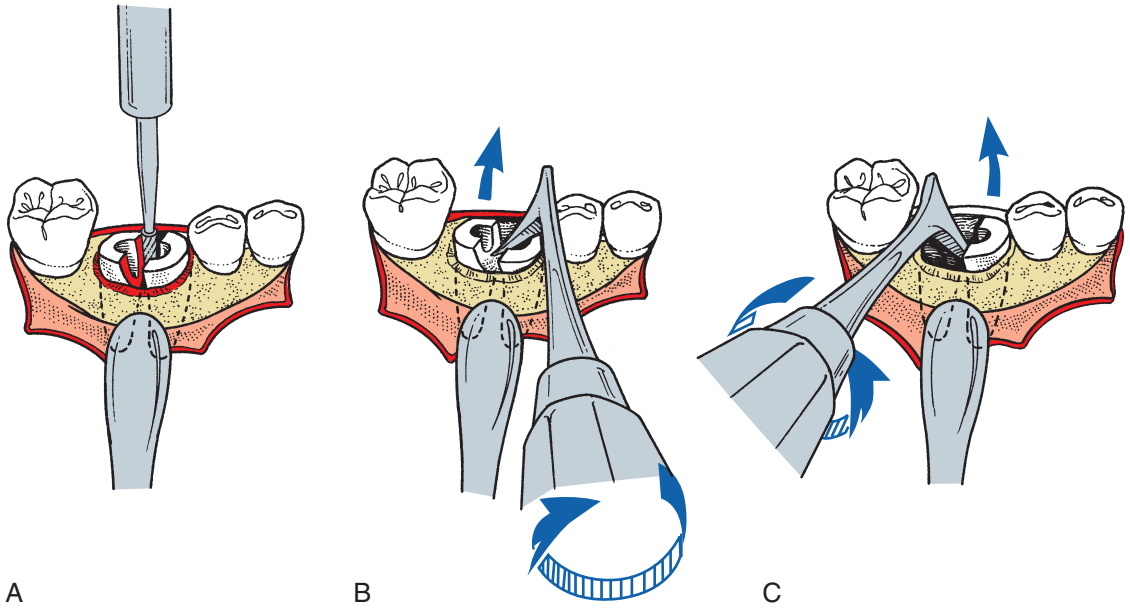
• **Fig. 9.42** (A) This lower molar has roots that make it necessary to section the tooth. (B) The flap is raised to expose bone and allow sectioning. Note the small releasing incisions on the mesial and distal sides of the tooth. (C) The surgical handpiece with fissure burr used to section tooth into mesial and distal parts, allowing each root to independently be removed. (D) The straight elevator is inserted into the burr cut to complete division of the crown. (E) Each root can now be elevated and removed. (F) The completed procedure with chromic suture closing distal release.

with the forceps to the crown portion because this results in fracture of the palatal root. The entire delivery force should be in the buccal direction. A small straight elevator is then used to luxate the buccal roots (Fig. 9.45C), which can then be delivered with a Cryer elevator used in the usual fashion (Fig. 9.45D) or with a straight elevator. If straight elevators are used, the surgeon should remember that the maxillary sinus might be close to these roots, so apically directed forces must be carefully controlled. The force of the straight elevator should be toward the palate, with more limited pressure applied apically.

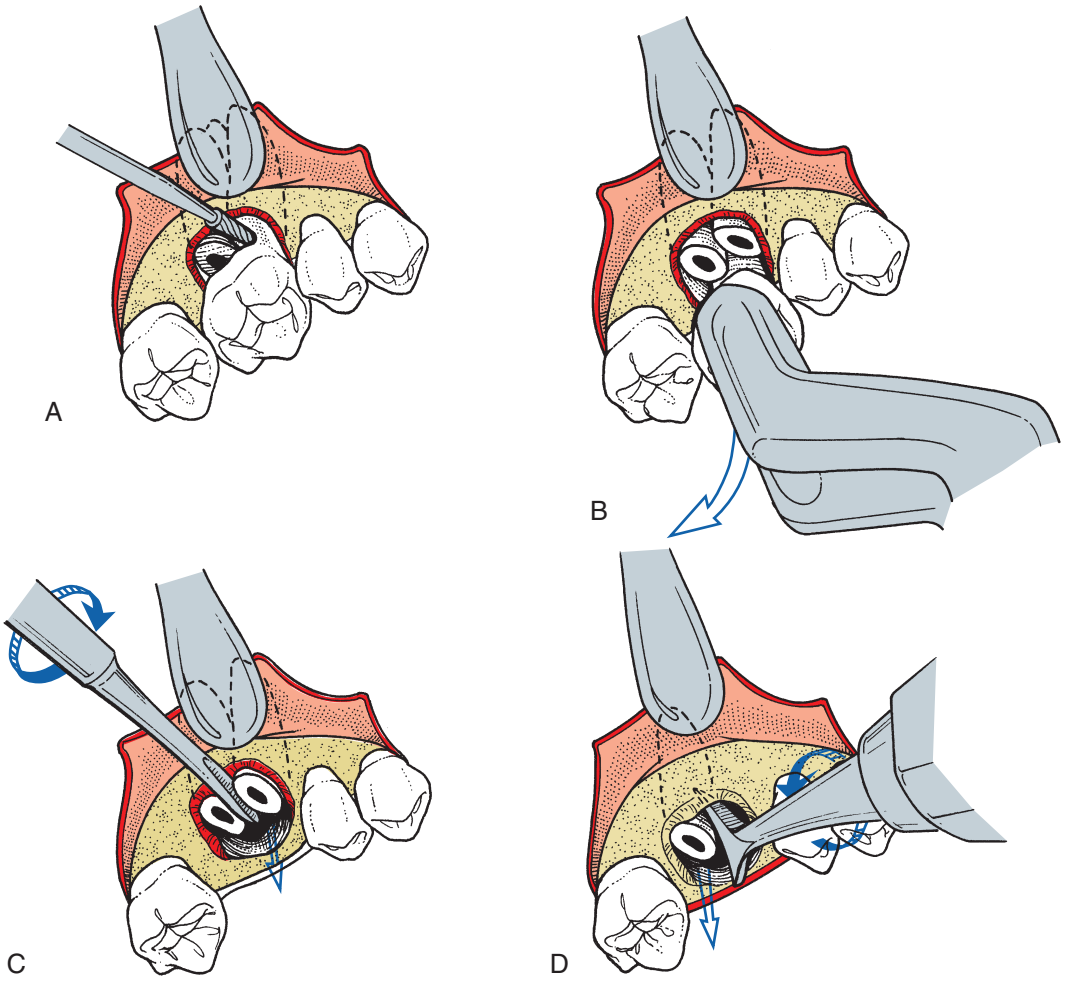
If the crown of the maxillary molar is missing or fractured, the roots should be divided into two buccal roots and a palatal root. The same general approach as before is used. An envelope flap is reflected and retracted with a periosteal elevator. A moderate amount of buccal bone is removed to expose the tooth for sectioning (Fig. 9.46A). The roots are sectioned into two buccal roots and a single palatal root. Next, the roots are luxated with a straight elevator and delivered with Cryer elevators, according to the preference of the surgeon (Fig. 9.46B–C). Occasionally, enough access to the roots exists so that a maxillary root forceps or upper universal



• **Fig. 9.43** (A) An alternative method of sectioning is to use the burr to remove the mesial root from the first molar. (B) The No. 178 forceps are then used to grasp the crown of the tooth and remove the crown and the distal root. (C) The Cryer elevator is then used to remove the mesial root. The point of the Cryer elevator is inserted into the empty socket of the distal root and turned in a wheel-and-axle fashion with the sharp point engaging interseptal bone and root, elevating the mesial root from its socket.



• **Fig. 9.44** (A) When the crown of the lower molar is lost because of fracture or caries, the envelope flap is reflected, and a small amount of crestal bone is removed. A burr is then used to section the tooth into two individual roots. (B) After the small straight elevator has been used to mobilize the roots, the Cryer elevator is used to elevate the distal root. The tip of the elevator is placed into the slot prepared by the burr, and the elevator is turned to deliver the root. (C) The opposite member of the paired Cryer elevators is then used to deliver the remaining tooth root with the same type of rotational movement.



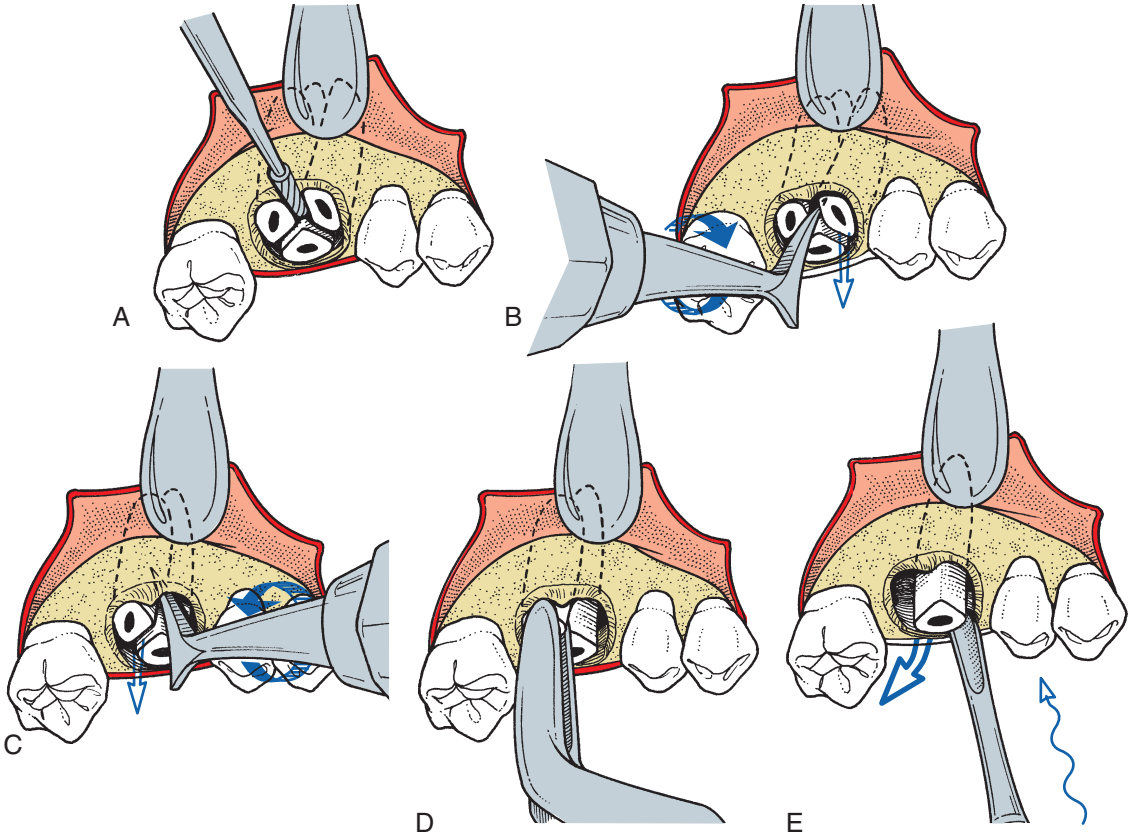
• **Fig. 9.45** (A) When an intact maxillary molar must be divided for judicious removal (as when extreme divergence of roots is found), a small envelope incision is made, and a small amount of crestal bone is removed. This allows the burr to be used to section the buccal roots from the crown portion of the tooth. (B) Upper molar forceps are then used to remove the crown portion of the tooth along with the palatal root. The tooth is delivered in the bucco-occlusal direction, and no palatal pressure is used because it would probably cause a fracture of the palatal root from the crown portion. (C) The straight elevator is then used to mobilize the buccal roots and can occasionally be used to deliver these roots. (D) The Cryer elevator can be used in the usual fashion by placing the tip of the elevator into the empty socket and rotating it to deliver the remaining root.

forceps can be used to deliver the roots independently (see Fig. 9.46D). Finally, the palatal root is delivered after the two buccal roots have been removed. Often, much of the interradicular bone is lost by this time; therefore the small straight elevator can be used efficiently. The elevator is directed down the periodontal ligament space on the palatal aspect with gentle, controlled wiggling motions, which causes displacement of the tooth in the bucco-occlusal direction (Fig. 9.46E).

Removal of Root Fragments and Tips

If fracture of the apical one third (3 to 4 mm) of the root occurs during a closed extraction, an orderly procedure should be used to remove the root tip from the socket. Initial attempts should be made to extract the root fragment by a closed technique, but the surgeon should begin a surgical technique if the closed technique is not immediately successful. Whichever technique is chosen, two requirements for extraction are critically important: (1) excellent light and (2) excellent suction—preferably with a suction tip of small diameter. Removal of a small root tip fragment is difficult unless the surgeon can clearly visualize it. It is also important that an irrigation syringe be available to flush blood and debris from around the root tip so that it can be clearly seen.

The closed technique for root tip retrieval is defined as any technique that does not require reflection of soft tissue flaps and removal of bone. Closed techniques are most useful when the tooth was well luxated and mobile before the root tip fractured. If sufficient luxation occurred before the fracture, the root tip often is mobile and can be removed with the closed technique. However, if the tooth was not well mobilized before the fracture, the closed technique is less likely to be successful. The closed technique is also less likely to be successful if the clinician finds a bulbous hypercementosed root with bony interferences that prevent extraction of the root tip fragment. In addition, severe



• **Fig. 9.46** (A) If the crown of the upper molar has been lost to caries or has been fractured from the roots, a small envelope incision is reflected, and a small amount of crestal bone is removed. The burr is then used to section the three roots into independent portions. (B) After the roots have been luxated with the small straight elevator, the mesiobuccal root is delivered with the Cryer elevator placed into the slot prepared by the burr. (C) Once the mesiobuccal root has been removed, the Cryer elevator is again used to deliver the distal buccal root. The tip of the Cryer elevator is placed into the empty socket of the mesiobuccal root and turned in the usual fashion to deliver the tooth root. (D) Maxillary root forceps occasionally can be used to grasp and deliver the remaining root. The palatal root can then be delivered with the straight or Cryer elevator. If the straight elevator is used, it is placed between the root and the palatal bone and gently rotated to and fro in an effort to displace the palatal root in the bucco-occlusal direction. (E) The small straight elevator can be used to elevate and displace the remaining root of the maxillary third molar in the bucco-occlusal direction with gentle to-and-fro motions.

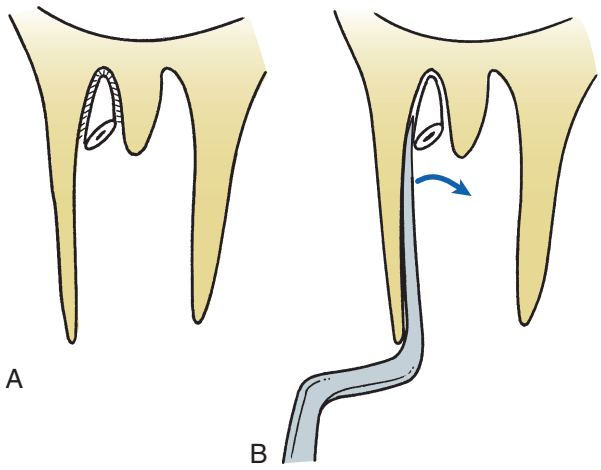
dilaceration of the root end may prevent the use of the closed technique.

Once the fracture has occurred, the patient should be repositioned so that adequate visualization (with proper lighting), irrigation, and suction are achieved. The tooth socket should be irrigated vigorously and suctioned with a small suction tip because the loose tooth fragment occasionally can be irrigated from the socket. Once irrigation and suction are completed, the surgeon should inspect the tooth socket carefully to assess whether the root has been removed from the socket. The extracted tooth should also be examined to see whether and how much of a root remains.

If the irrigation-suction technique is unsuccessful, the next step is to tease the root apex from the socket with a root tip pick. A root tip pick is a delicate instrument and should not be used in the same manner as the Cryer elevator. The root tip pick is inserted into the periodontal ligament space, and the root is teased out of the socket (Fig. 9.47). Neither excessive apical force nor excessive lateral force should be applied to the root tip pick. Excessive apical force could result in displacement of the root tip into other anatomic locations such as the maxillary sinus. Excessive lateral force could result in the bending or fracture of the delicate end of the root tip pick.

The root tip also can be removed with the small straight elevator. This technique is indicated more often for the removal of larger root fragments. The technique is similar to that of the root tip pick because the small straight elevator is wedged into the periodontal ligament space, where it acts like a wedge to deliver the tooth fragment toward the occlusal plane (Fig. 9.48). Excessive apical pressure should be avoided because it may force the root into underlying tissues.

Displacement of root tips into the maxillary sinus can occur in the maxillary premolar and molar areas. When the straight elevator is used to remove small root tips in this fashion, the surgeon's hand must always be supported on an adjacent tooth or a solid bony prominence. This support allows the surgeon to deliver carefully controlled force and to decrease the possibility of displacing tooth fragments or the instrument tip into an unwanted place. The surgeon must be able to visualize the top of the fractured



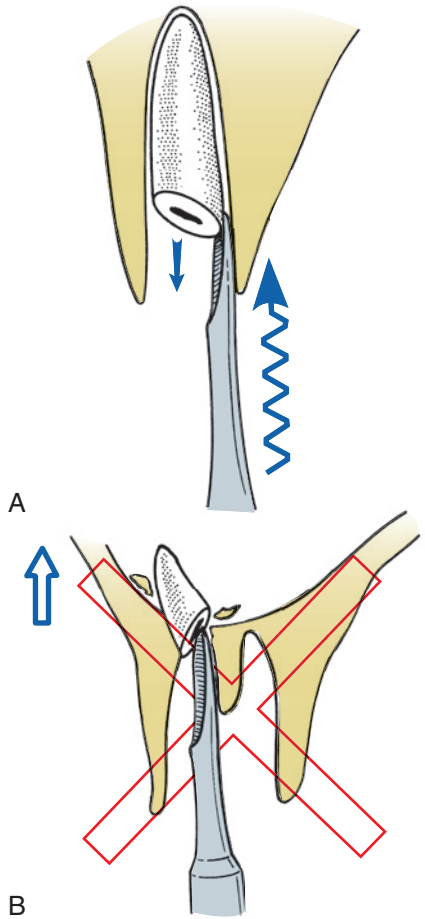
• **Fig. 9.47** (A) When a small (2 to 4 mm) portion of the root apex is fractured from the tooth, the root tip pick can be used to retrieve it. (B) The root tip pick is teased into the periodontal ligament space and is used to gently luxate the root tip from its socket.

root clearly to see the periodontal ligament space. The straight elevator must be inserted into this space and not blindly pushed down into the socket.

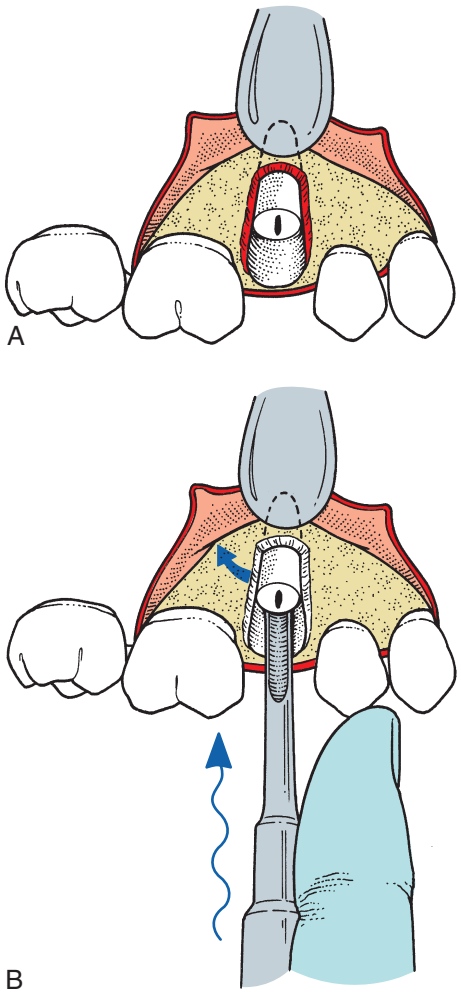
If the closed technique is unsuccessful, the surgeon should switch—without delay—to the open technique. It is important for the surgeon to recognize that a smooth, efficient, properly performed open retrieval of a root fragment is less traumatic than a prolonged, time-consuming, frustrating attempt at closed retrieval.

Two main open techniques are used to remove root tips. The first is simply an extension of the technique described for surgical removal of single-rooted teeth. A soft tissue flap with a releasing incision is reflected and retracted with a periosteal elevator. Bone is removed with a burr to expose the buccal surface of the tooth root. The root is buccally delivered through the opening with a small straight elevator. The wound is irrigated, and the flap is repositioned and sutured (Fig. 9.49).

A modification of the open technique, which has just been described, can be performed to deliver the root fragment without excessive removal of the buccal plate overlying the tooth. This technique is known as the *open-window technique*. A soft tissue flap



• **Fig. 9.48** (A) When a larger portion of the tooth root is left behind after extraction of the tooth, the small straight elevator can sometimes be used as a wedge to displace the tooth in the occlusal direction. It must be remembered that the pressure applied in such a fashion should be in gentle to-and-fro motions; excessive pressure should not be applied. (B) Excessive pressure in the apical direction results in displacement of the tooth root into undesirable places such as the maxillary sinus.



• **Fig. 9.49** (A) If the root cannot be retrieved by closed techniques, the soft tissue flap is reflected, and bone overlying the root is removed with a burr. (B) The small straight elevator is then used to luxate the root buccally by wedging the straight elevator into the palatal periodontal ligament space.

is reflected in the same fashion as for the approach just discussed, and the apical area of the tooth fragment is located. A dental burr is used to remove the bone overlying the apex of the tooth, exposing the root fragment. A root tip pick or small elevator is then inserted into the window, and the tooth is guided out of the socket (Fig. 9.50).

The preferred flap technique is the three-cornered flap because of a need for more extensive exposure of the apical areas. The open-window approach is especially indicated when the buccocrestal bone must be left intact, such as in the removal of maxillary premolars for orthodontic purposes, especially in adults.

Justification for Leaving Root Fragments

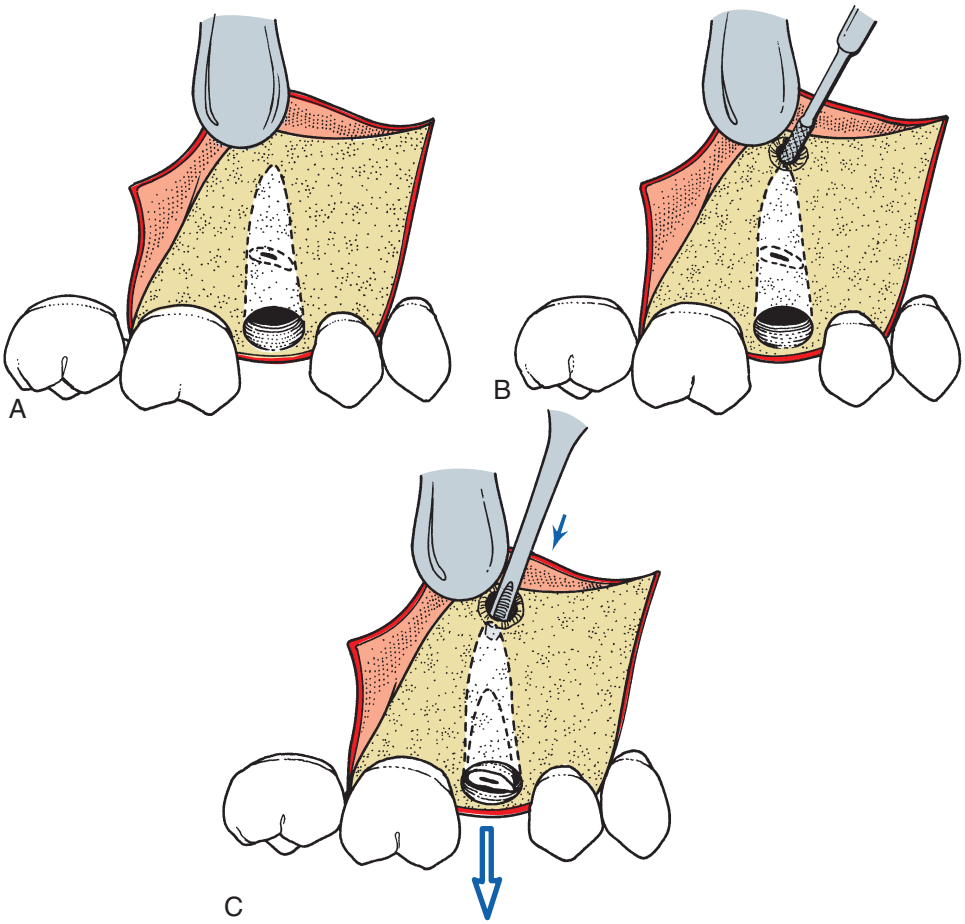
When a root tip has fractured and closed approaches of removal have been unsuccessful and when the open approach may be excessively traumatic, the surgeon may consider leaving a root tip in place. As with any surgical approach, the surgeon must balance the benefits of surgery against the risks of surgery. In some situations, the risks of removing a small root tip may outweigh the benefits.

Three conditions should exist for a tooth root to be left in the alveolar process. First, the root fragment should be small, usually no more than 4 to 5 mm in length. Second, the root must be deeply embedded in bone and not be superficial to prevent subsequent bone resorption from exposing the tooth root and interfering with any prosthesis that will be constructed over the edentulous area. Third, the tooth involved must not be infected, and there must be no radiolucency around the root apex. This lessens the likelihood that subsequent infections will result from leaving the root in position. If these three conditions exist, then consideration can be given to leaving the root.

For the surgeon to leave a small, deeply embedded, noninfected root tip in place, the risk of surgery must be greater than the benefit. This risk is considered to be greater if one of the following three conditions exists: First, the risk is too great if removal of the root will cause excessive destruction of surrounding tissue; that is, if excessive amounts of bone must be removed to retrieve the root. For example, reaching a small palatal root tip of a maxillary first molar may require the removal of large amounts of bone.

Second, the risk is too great if removal of the root endangers important structures, most commonly the inferior alveolar nerve at the mental foramen or along the course of the inferior alveolar canal. If surgical retrieval of a root runs a high risk of permanent or even prolonged temporary anesthesia of the inferior alveolar nerve, the surgeon should seriously consider leaving the root tip in place.

Finally, the risks outweigh the benefits if attempts at recovering the root tip highly risk displacing the root tip into tissue spaces or



• **Fig. 9.50** (A) The open-window approach for retrieving the root is indicated when buccocrestal bone must be maintained. The three-cornered flap is reflected to expose the area overlying the apex of the root fragment being recovered. (B) A burr is used to uncover the apex of the root and to allow sufficient access for the insertion of the straight elevator. (C) The small straight elevator is then used to displace the tooth out of the tooth socket.

into the maxillary sinus. The roots most often displaced into the maxillary sinus are those of the maxillary molars. If the preoperative radiograph shows that the bone is thin over the roots of the teeth and that the separation between the teeth and maxillary sinus is small, the prudent surgeon may choose to leave a small root fragment rather than risk displacing it into the maxillary sinus. Likewise, roots of the mandibular second and third molars can be displaced into the submandibular space during attempts to remove them. During retrieval of any root tip, apical pressure by an elevator may displace teeth into tissue spaces or into the sinus.

If the surgeon elects to leave a root tip in place, a strict protocol should be observed. The patient must be informed that, in the surgeon's judgment, leaving the root in its position will do less harm than the surgery needed to remove it. In addition, radiographic documentation of the presence and position of the root tip must be obtained and retained in the patient's record. The fact that the patient was informed of the decision to leave the root tip in position must be recorded in the patient's chart. In addition, the patient should be recalled for several routine periodic follow-up visits over the ensuing year to track the condition of this root. The patient should be instructed to contact the surgeon immediately if any problems develop in the area of the retained root.

Multiple Extractions

If multiple adjacent teeth are to be extracted at a single sitting, slight modifications of the routine extraction procedure must be made to facilitate a smooth transition from a dentulous to an edentulous state that allows for proper rehabilitation with a fixed or removable prosthesis. This section discusses those modifications.

Treatment Planning

In most situations where multiple teeth are to be removed, preextraction planning with regard to the replacement of the teeth to be removed is necessary. This may be a full or removable partial denture or placement of a single or multiple implants. Before teeth are extracted, the surgeon and the restorative dentist should communicate and make a determination of the need for such items as an interim partial or immediate full dentures. The discussion should also include a consideration of the need for any other type of soft tissue surgery, such as tuberosity reduction or the removal of undercuts or exostoses in critical areas. If dental implants are to be placed at a later time, it may be desirable also to limit bone trimming and socket compression. In some situations, dental implants may be placed when the teeth are removed, which would require the preparation of a surgical guide stent to assist in appropriately aligning the implants.

Extraction Sequencing

The order in which multiple teeth are extracted deserves some discussion. Maxillary teeth should usually be removed first for several reasons. First, an infiltration anesthetic has a more rapid onset and disappears more rapidly. This means that the surgeon can begin the surgical procedure sooner after the injections have been given and that surgery should not be delayed because profound anesthesia is lost more quickly in the maxilla. In addition, maxillary teeth should be removed first because during the extraction process, debris, such as portions of amalgams, fractured crowns, and bone chips may fall into the empty sockets of the lower teeth if the mandibular surgery is performed first. Furthermore, maxillary teeth are removed with a major component of buccal force. Little or no vertical traction force is used in the removal of these teeth, as is commonly required with mandibular teeth. A single minor disadvantage for extracting maxillary teeth first is that if hemorrhage is not controlled in the maxilla before mandibular teeth are undergoing extraction, the hemorrhage may interfere with visualization during mandibular surgery. Hemorrhage is usually not a major problem because hemostasis should be achieved in one area before the surgeon turns his or her attention to another area of surgery, and the surgical assistant should be able to keep the surgical field free of blood with adequate suction.

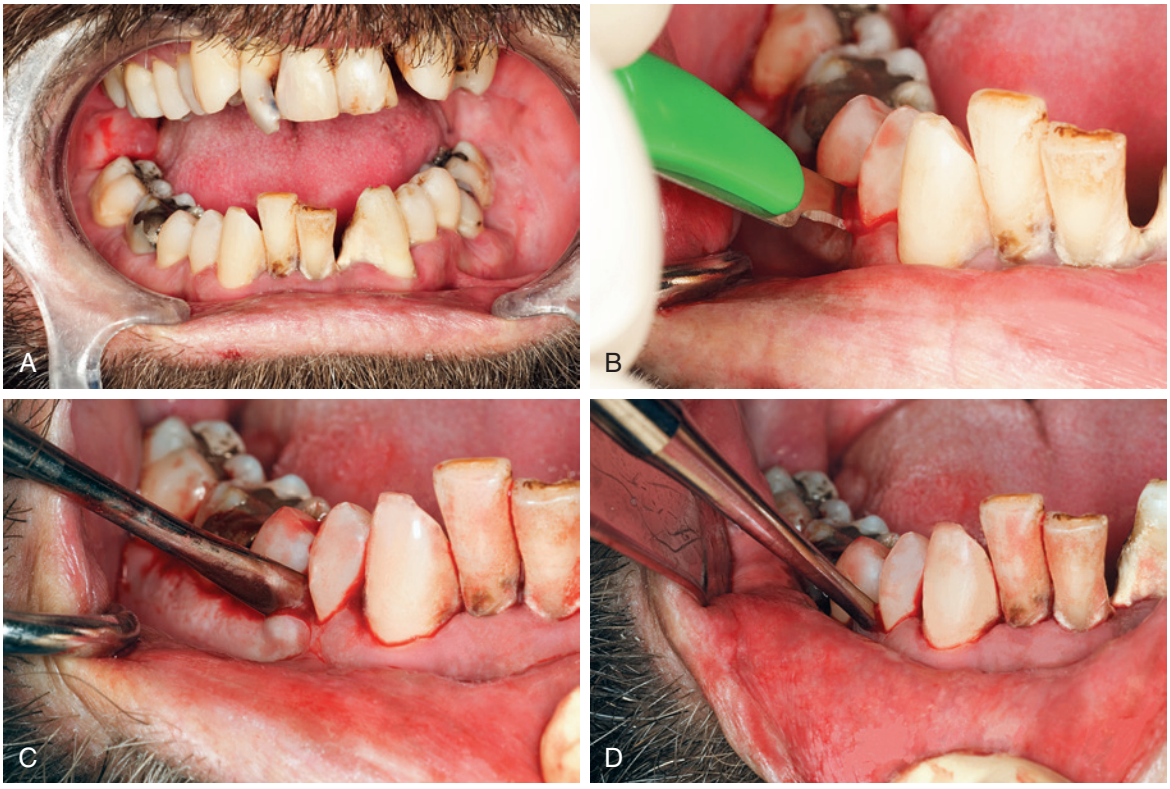
Tooth removal usually begins with extraction of the most posterior teeth first. This allows for the more effective use of dental elevators to luxate and mobilize teeth before forceps are used to extract the tooth. The tooth that is the most difficult to remove—the canine—should be extracted last. Removal of the teeth on either side weakens the bony socket on the mesial and distal sides of these teeth, and their subsequent extraction is made more straightforward.

For example, if teeth in the maxillary and mandibular left quadrants are to be extracted, the following order is recommended: (1) maxillary posterior teeth; (2) maxillary anterior teeth, leaving the canine; (3) maxillary canine; (4) mandibular posterior teeth; (5) mandibular anterior teeth, leaving the canine; and (6) mandibular canine.

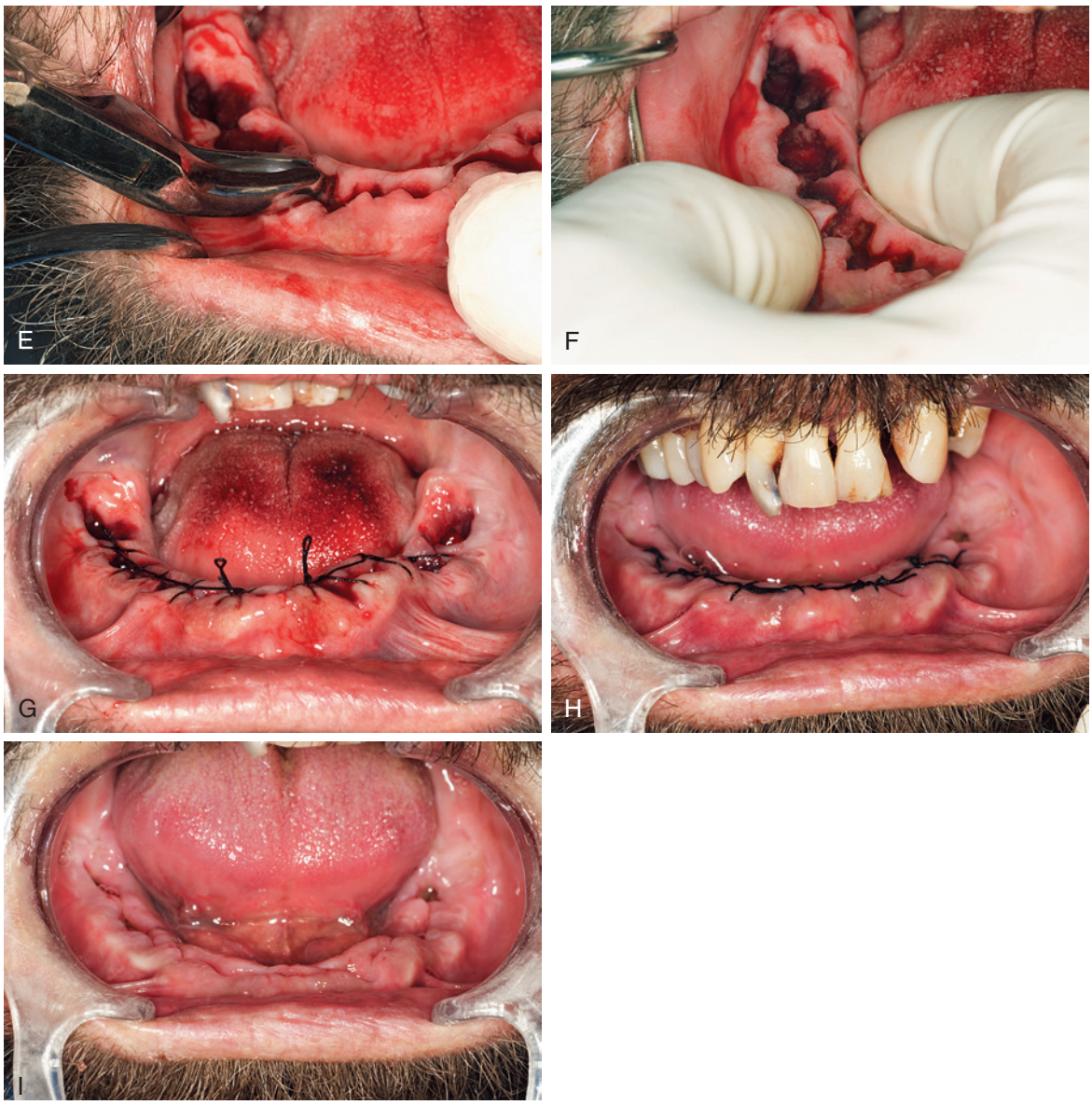
Technique for Multiple Extractions

The surgical procedure for removing multiple adjacent teeth is a slight modification of techniques used to remove individual teeth. The first step in removing a single tooth is to loosen the soft tissue attachment from around the tooth. When performing multiple extractions, the soft tissue reflection is extended slightly to form a small envelope flap to expose the crestal bone only around all the teeth in a quadrant (Fig. 9.51A–C). The teeth in the quadrant are luxated with the straight elevator (see Fig. 9.51D) and then delivered with forceps in the usual fashion. If removing any of the teeth is likely to require excessive force, the surgeon should remove a small amount of buccal bone to prevent fracture and excessive bone loss. It is beneficial to do as much luxation of all teeth in an area to be removed before extracting any of them because the adjacent tooth can be used to anchor against while luxating without worry (since the anchoring tooth is planned for extraction as well).

After the extractions are completed, the buccolingual plates are pressed into their preexisting position with firm pressure unless implants are planned. The soft tissue is repositioned, and the surgeon palpates the ridge to determine whether any areas of sharp bony spicules can be found. If a removable partial or complete denture is planned, undercuts should be identified. If any sharp spicules or undercuts exist, the bone rongeur is used to remove the larger areas of interference, and a bone file is used to smooth any sharp spicules (Fig. 9.51E–F). The area is irrigated thoroughly with sterile saline or sterile water. The soft tissue is inspected for the presence of granulation tissue. If any granulation tissue is present, it should be removed because it may prolong postoperative hemorrhage. Soft tissue is then reapproximated and inspected for now redundant gingiva. If teeth are being removed because of severe periodontitis with bone loss, it is common for the soft tissue flaps to overlap and cause redundant tissue. If this is the situation, the gingiva should be trimmed so that little or no overlap occurs when the



• **Fig. 9.51** (A) This patient's remaining mandibular teeth are to be extracted. The broad zone of attached gingiva is demonstrated in adequate vestibular depth. (B) After adequate anesthesia is achieved, the soft tissue attachment to teeth is incised with the No. 15 blade. The incision is carried around the necks of the teeth and through the interdental papilla. (C) The periosteal elevator is used to reflect labial soft tissue just to the crest of labioalveolar bone. (D) The small straight elevator is used to luxate teeth before forceps are used. The surgeon's opposite hand is reflecting soft tissue and stabilizing the mandible. Teeth adjacent to the mandibular canine are extracted first, which makes extraction of the remaining canine tooth easier to accomplish.



• **Fig. 9.51, cont'd** (E) Rongeur forceps are used to remove only bone that is sharp and protrudes above reapproximated soft tissue. (F) The alveolar plates are compressed firmly together to reestablish the presurgical buccolingual width of the alveolar process. Because an implant may be placed in the future, care should be taken to not overly reduce the alveolar width with compression. Because of mild periodontal disease, excess soft tissue is found, which will be trimmed to prevent redundant tissue on the crest of the ridge. (G) After soft tissue has been trimmed and sharp bony projections removed, tissue is checked one final time for completeness of soft tissue surgery. Tissue is closed with interrupted black silk sutures across the papilla. This approximates soft tissue at the papilla but leaves the tooth socket open. Soft tissue is not mobilized to achieve primary closure because this would tend to reduce the vestibular height. (H–I) The patient returns for suture removal 1 week later. Normal healing has occurred, and sutures are ready for removal. The broad band of attached tissue remains on the ridge, similar to that which existed in the preoperative situation (see A).

soft tissue is apposed. However, if no redundant tissue exists, the surgeon must not try to gain primary closure over the extraction sockets. If this is done, the depth of the vestibule decreases, which may interfere with denture construction and wear. This also puts the wound closure under tension, violating a cardinal rule of wound repair. Finally, the papillae are sutured into position (see Fig. 9.51G). Interrupted or continuous sutures are used, depending on the preference of the surgeon, with removal planned in about a week (Fig. 9.51H–I) if nonresorbable sutures have been used.

In some patients, a more extensive alveoloplasty after multiple extractions is necessary. Chapter 13 has an in-depth discussion of this technique.

10

Principles of Management of Impacted Teeth

JAMES R. HUPP

CHAPTER OUTLINE

An impacted tooth is one that fails to fully erupt into the dental arch within the usual range of expected time. The tooth becomes impacted because abnormal tooth orientation, adjacent teeth, dense overlying bone, excessive soft tissue, or a genetic abnormality prevents eruption. Because impacted teeth do not erupt, they are retained for the patient's lifetime unless surgically removed or exposed because of resorption of overlying tissues. The term *unerupted teeth* includes impacted teeth and teeth that are in the process of developing and erupting.

Teeth most often become impacted because of inadequate dental arch length and space in which to erupt; that is, the total length of the alveolar bone arch is smaller than the total length of the tooth arch. The most common impacted teeth are maxillary and mandibular third molars, followed by maxillary canines and mandibular premolars. The third molars are the most frequently impacted because they are the last teeth to erupt; therefore they are the most likely to have inadequate space for complete eruption.

In the anterior maxilla, the canine is also commonly prevented from erupting by dental crowding. The canine usually erupts after the maxillary lateral incisor and maxillary first premolar. If space is inadequate to allow eruption, the canine becomes impacted or erupts labial to the dental arch. In the mandible, a similar situation affects the mandibular premolars because they erupt after the mandibular first molar and canine. Therefore, if room for eruption is inadequate, one of the premolars, usually the second premolar, remains unerupted and becomes impacted or erupts into a buccal or lingual position in relation to the dental arch.

As a general rule, all impacted teeth should be removed unless removal is contraindicated. Removal of impacted teeth becomes more difficult with advancing age of the patient. The dentist should typically not recommend that impacted teeth be left in place until they cause difficulty. If the impacted teeth are left in place until problems arise, the patient may experience an increased incidence of local tissue morbidity, loss of, or damage to, adjacent teeth and bone, and potential injury to adjacent vital structures. In addition, if the removal of impacted teeth is deferred until problems arise later in life, surgery is more likely to be complicated and hazardous because the patient may have compromising systemic diseases, the surrounding bone becomes denser, and more fully formed roots may grow near structures such as the inferior alveolar nerve or the maxillary sinus.

This chapter discusses the management of impacted teeth. This is not a thorough or in-depth discussion of the technical aspects

of surgical impaction removal. Instead, the goal is to provide the information necessary for proper treatment planning and management and a basis for predicting the difficulty of surgery.

Indications for Removal of Impacted Teeth

The average age for completion of normal eruption of the third molar is 20 years, although eruption may continue in some patients until age 25 years. During normal development, the lower third molar begins in a horizontal angulation, and as the tooth develops and the jaw grows, the angulation changes from horizontal to mesioangular to vertical. Failure of rotation from the mesioangular to the vertical direction is the most common cause of lower third molars becoming impacted. The second major factor is that the mesiodistal dimension of teeth versus the length of the jaw is such that inadequate room exists in the alveolar process anterior to the anterior border of the mandibular ramus to allow the tooth to erupt into position.

As noted before, some third molars continue to erupt after age 20 years, particularly in males, coming into final position by age 25 years. Multiple factors are associated with continued eruption. When late eruption occurs, the unerupted tooth is usually covered with only soft tissue or slightly with bone. These teeth are almost always in a vertical position and are relatively superficially positioned with respect to the occlusal plane of the adjacent second molar, and the completion of root development is late.

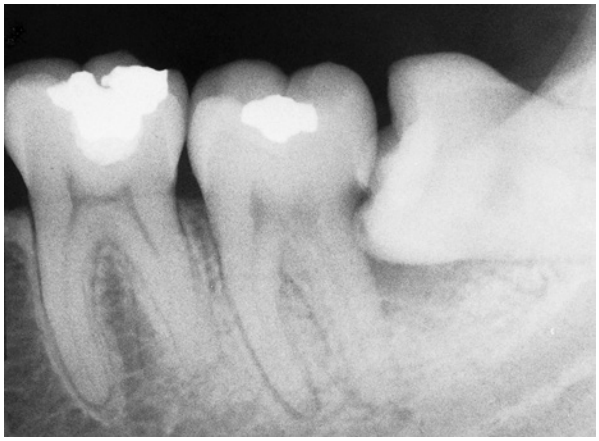
Finally, and perhaps most importantly, sufficient space needs to exist between the anterior border of the ramus and the second molar to allow eruption. This causative factor of lower third molar impaction is shown most graphically by the finding that many of these teeth do erupt, although typically tipped mesially, if the adjacent second molar is lost while the third molar is developing. Likewise, if the lower third molar does not erupt after age 20 years, it is most likely covered with bone. In addition, the tooth is likely a mesioangular impaction and is located lower in the alveolar process near the cervical level of the adjacent second molar. Therefore the dentist can use these parameters to predict whether a tooth will erupt into the arch or remain impacted.

Early removal reduces postoperative morbidity and allows for the best healing. Younger patients tolerate the procedure better, recovering more quickly and with less interference to their daily lives. Periodontal healing is better in younger patients because of better and more complete regeneration of the periodontal tissues on the distal aspect of the second molar. Also, recovery is better in these patients if the nerve is injured. The procedure is more straightforward to perform in younger patients because bone is less dense and root formation is incomplete. The ideal time for removal of impacted third molars is when the roots of teeth are one-third formed and before they are two-thirds formed. This usually occurs during the mid-to-late teenage years, between the ages of 16 and 20.

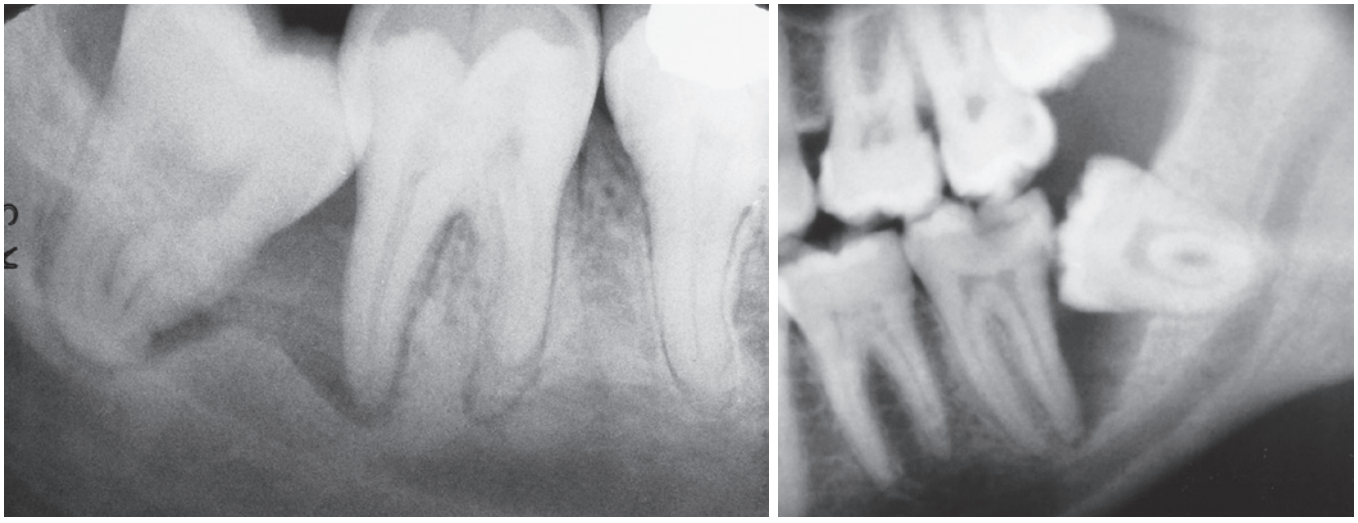
If impacted teeth are left in the alveolar process, it is highly probable that one or more of several problems will result, as discussed below.

Prevention of Periodontal Disease

Erupted teeth adjacent to impacted teeth are predisposed to periodontal disease (Figs. 10.1 and 10.2). The mere presence of an impacted mandibular third molar decreases the amount of bone on the distal aspect of an adjacent second molar. Because the most difficult tooth surface to keep clean is the distal aspect of the last



• **Fig. 10.1** Radiograph of a mandibular third molar impacted against a second molar with bone loss resulting from the presence of a third molar.



• **Fig. 10.2** Radiographs showing variations of a mandibular third molar impacted against a second molar with severe bone loss resulting from periodontal disease and a third molar.

tooth in the arch, patients commonly have gingival inflammation with apical migration of the gingival attachment on the distal aspect of the second molar. With even minor gingivitis, the causative bacteria gain access to a large portion of the root surface, which results in the early formation of periodontitis. Patients with impacted mandibular third molars often have deep periodontal pockets on the distal aspect of the second molars, even though they have normal sulcular depth in the remainder of the mouth.

The accelerated periodontal problems resulting from an impacted third molar are especially serious in the maxilla. As a periodontal pocket expands apically, it comes to involve the distal furcation of the maxillary second molar. This occurs relatively early, which makes advancement of the periodontal disease more rapid and severe. In addition, treatment of the localized periodontal disease around the maxillary second molar is more difficult because of the distal furcation involvement.

By removing the impacted third molars early, periodontal disease can be prevented, and the likelihood of bony healing and optimal bone fill into the area previously occupied by the crown of the third molar is increased.

Prevention of Dental Caries

When a third molar is impacted or partially impacted, the bacteria and other factors that cause dental caries are commonly exposed to the distal aspect of the second molar as well as to the crown of the impacted third molar. Even in situations in which no obvious communication between the mouth and the impacted third molar is visible, there may be enough communication to allow for caries initiation (Figs. 10.3 to 10.5).

Prevention of Pericoronitis

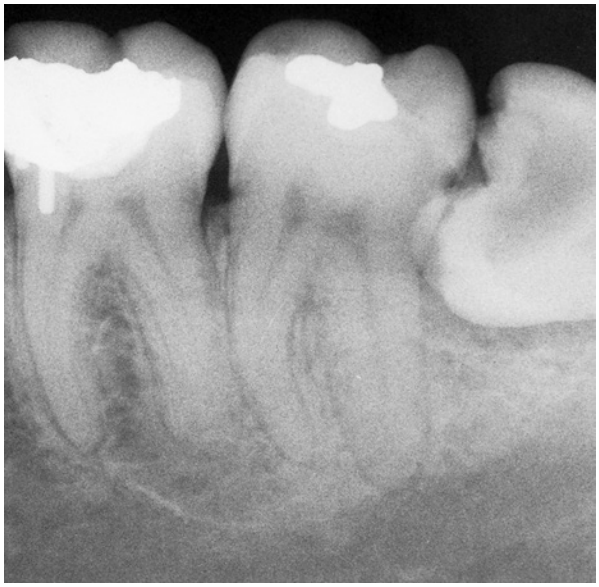
When a tooth is partially impacted with a large amount of soft tissue over the axial and occlusal surfaces, the patient frequently has one or more episodes of pericoronitis. Pericoronitis is an infection of the soft tissue around the crown of a partially impacted tooth and is usually caused by normal oral flora. In most patients, bacteria and host defenses maintain a delicate balance, but even normal host defenses cannot eliminate the bacteria (Fig. 10.6).

If host defenses are compromised (e.g., during minor illnesses such as influenza or an upper respiratory infection or because of immune-compromising drugs), infection can occur. Thus, although the impacted tooth has been present for some time without infection, if the patient experiences even a mild, transient decrease in host defenses, pericoronitis commonly results even if the patient does not have any immunologic problems.

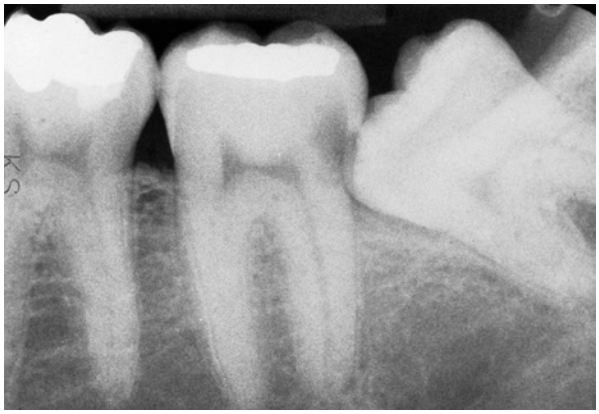
Pericoronitis can also arise following repeated trauma from a maxillary third molar. The soft tissue that covers the occlusal surface of the partially erupted mandibular third molar (known as the *operculum*) can be traumatized and become swollen. Often the maxillary third molar further traumatizes the already swollen operculum, which causes a further increase in swelling that is now traumatized more easily. This spiraling cycle of trauma and swelling is often interrupted only by removal of the maxillary third molar.

Another common cause of pericoronitis is entrapment of food under the operculum. During eating, food debris may become lodged into the pocket between the operculum and the impacted tooth. Because this pocket cannot be cleaned, bacteria colonize it, which results in pericoronitis.

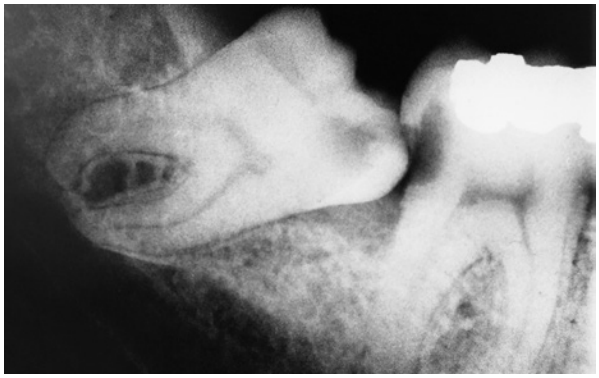
Streptococci and a large variety of anaerobic bacteria (the usual bacteria that inhabit the gingival sulcus) are the usual cause of pericoronitis. Pericoronitis can be treated initially by mechanically debriding the large periodontal pocket that exists under the operculum by using hydrogen peroxide as an irrigating solution.



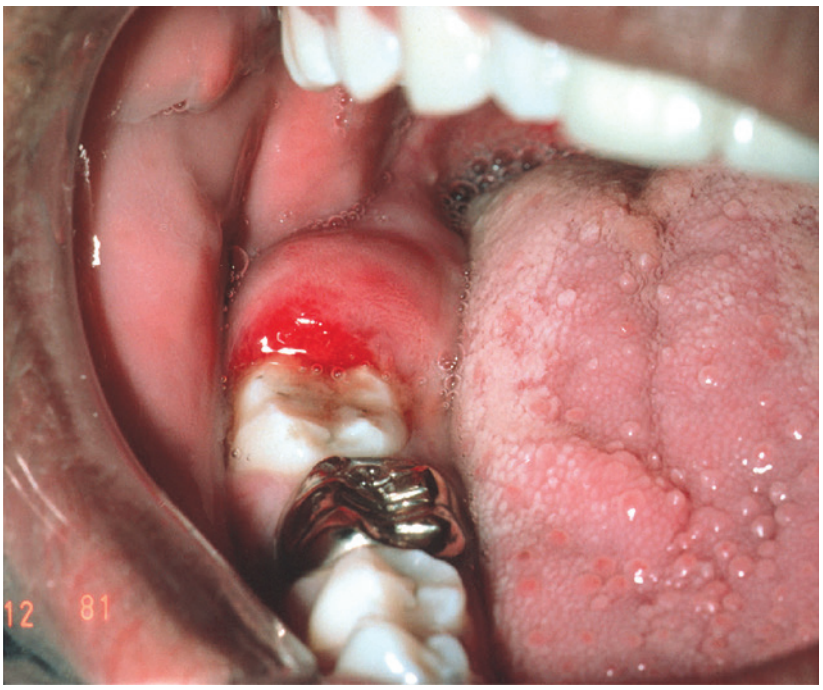
• **Fig. 10.4** Radiograph of caries in a mandibular impacted molar.



• **Fig. 10.3** Radiograph of caries in a mandibular second molar resulting from the presence of an impacted third molar.



• **Fig. 10.5** Radiograph of caries in an impacted third molar and a second molar.



• **Fig. 10.6** Pericoronitis in the area of impacted tooth #32 exhibiting classic signs of inflammation with erythema and swelling. If opposing tooth #1 is erupted, it commonly impinges on this area of swelling when teeth are brought into occlusion, causing even more pain and swelling.

Hydrogen peroxide not only mechanically removes bacteria with its foaming action, it also reduces the number of anaerobic bacteria by releasing oxygen into the usually anaerobic environment of the pocket. Other irrigants, such as chlorhexidine or iodophors, can also reduce the bacterial counts of the pocket. Even saline solutions, if delivered regularly with pressure via a syringe, can reduce bacterial numbers and flush away food debris.

Pericoronitis can present as a mild infection or as a severe infection that requires hospitalization of the patient. Just as the severity of the infection varies, the treatment and management of this problem vary from mild to aggressive.

In its mildest form, pericoronitis presents with localized tissue swelling and soreness. For patients with a mild infection, irrigation and curettage by the dentist and home irrigations by the patient usually suffice.

If the infection is slightly more severe with a large amount of local soft tissue swelling being traumatized by a maxillary third molar, the dentist should consider immediately extracting the maxillary third molar in addition to local irrigation.

For patients who have (in addition to local swelling and pain) mild facial swelling, mild trismus resulting from inflammation extending into the muscles of mastication, or a low-grade fever, the dentist should consider administering a systemic antibiotic along with irrigation delivered under pressure and extraction. The antibiotic of choice is penicillin or, in the case of penicillin allergy, clindamycin.

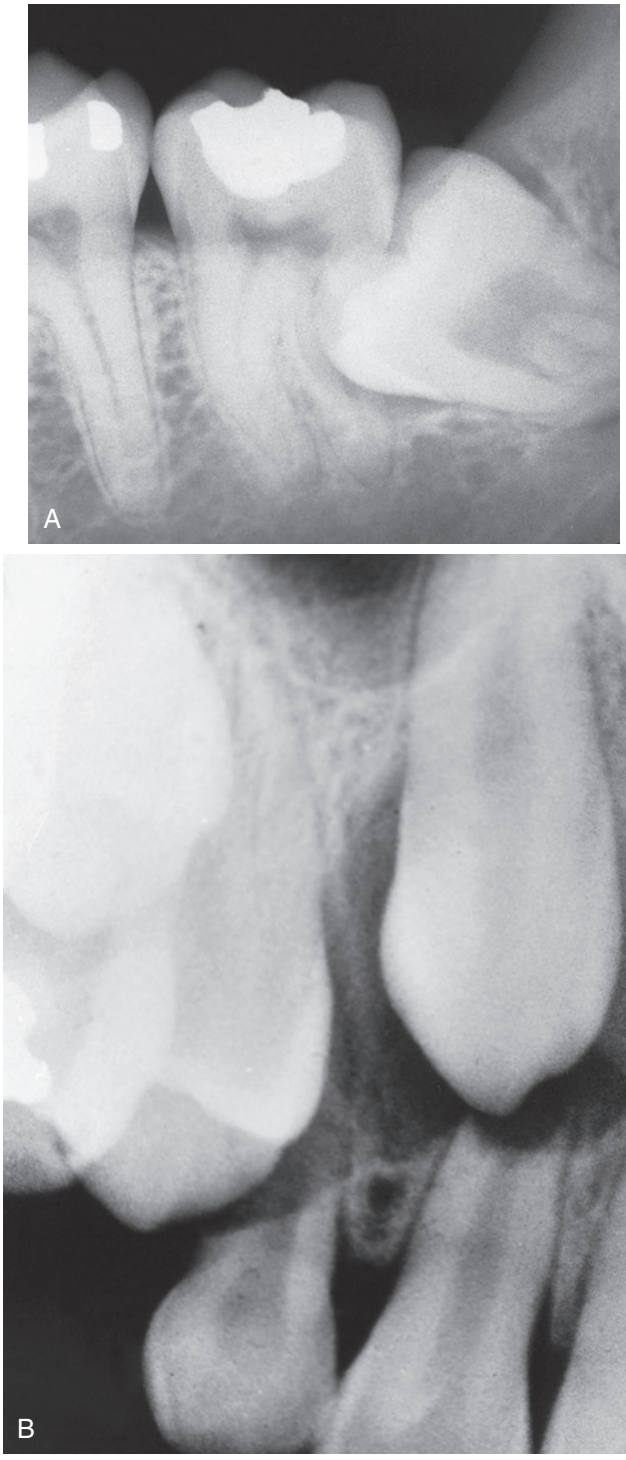
Pericoronitis can lead to serious fascial space infections. Because the infection begins in the posterior mouth, it can spread rapidly into the fascial spaces of the mandibular ramus and the lateral neck. If a patient has trismus (with an inability to open the mouth >20 mm), a temperature of greater than 101°F, facial swelling, pain, and malaise, the patient should be referred to an oral-maxillofacial surgeon, who is likely to admit the patient to the hospital for parenteral antibiotic administration, careful monitoring, and surgical extraction.

Patients who have had one episode of pericoronitis, although managed successfully by these methods, are highly likely to continue to have episodes of pericoronitis unless the offending mandibular third molar is removed. The patient should be informed that the tooth should be removed at the earliest possible time to prevent recurrent infections. However, the mandibular third molar should not be removed until the signs and symptoms of pericoronitis have completely resolved. The incidence of postoperative complications, specifically dry socket and postoperative infection, increases if the tooth is removed during the time of active soft tissue infection. More bleeding and slower healing also occur when a tooth is removed in the presence of pericoronitis.

Prevention of pericoronitis can be achieved by removing the impacted third molars before they penetrate the oral mucosa and are visible. Although excision of surrounding soft tissue, or operculectomy, has been advocated as a method for preventing pericoronitis without removal of the impacted tooth, it is painful and usually ineffective. The soft tissue excess tends to recur because it drapes over the impacted tooth and causes regrowth of the operculum. The gingival pocket on the distal aspect also remains deep after operculectomy. The overwhelming majority of cases of pericoronitis can be prevented only by extraction of the tooth.

Prevention of Root Resorption

Occasionally an impacted tooth causes sufficient pressure on the root of an adjacent tooth to cause external root resorption (Fig. 10.7). Although the process by which root resorption occurs is not well understood, it appears to be similar to the resorption process primary teeth undergo during the eruptive process of the succedaneous teeth. Removal of the impacted tooth may result in salvage of the adjacent tooth by cemental repair. Endodontic therapy may be required to save these teeth.



• **Fig. 10.7** (A) Root resorption of a second molar as result of an impacted third molar. (B) Root resorption of maxillary lateral incisors as a result of an impacted canine.

Impacted Teeth Under a Dental Prosthesis

When a patient has an edentulous area restored, there are several reasons for removing impacted teeth in the area before the prosthetic appliance is constructed. After teeth are extracted, the alveolar process slowly undergoes resorption. This is particularly true with tissue-borne prostheses. Thus the impacted tooth becomes closer to the surface of the bone, giving the appearance of erupting. The denture may compress the soft tissue onto the impacted tooth, which is no longer covered with bone; the result is ulceration of the overlying soft tissue and the initiation of an odontogenic infection (Fig. 10.8).

Impacted teeth should be removed before a prosthesis is constructed because if the impacted teeth must be removed after construction, the alveolar ridge may be so altered by the extraction that the prosthesis becomes less functional (Fig. 10.9). In addition, if removal of impacted teeth in edentulous areas is achieved before the prosthesis is made, the patient is probably in good physical condition. If ulceration with infection occurs while waiting until the overlying bone has resorbed, it does not produce a favorable situation for extraction. If extraction is postponed, the patient will be older and more likely to be in poorer health.

Furthermore, the mandible may have become atrophic, which increases the likelihood of fracture during tooth removal (Fig. 10.10). Also, if implants are planned near the position of impacted teeth, removal is warranted to eliminate the risk of interference with the implantation procedure.

Prevention of Odontogenic Cysts and Tumors

When impacted teeth are completely within the alveolar process, the associated follicular sac is also frequently retained. Although the dental follicle maintains its original size in most patients, it may undergo cystic degeneration and become a dentigerous cyst. If the patient is closely monitored, the dentist can diagnose the cyst before it reaches large proportions (Fig. 10.11). However, unmonitored cysts can reach enormous sizes (Fig. 10.12). As a general guideline, if the follicular space around the crown of the tooth is greater than 3 mm, the preoperative diagnosis of a dentigerous cyst is reasonable.

In the same way that odontogenic cysts can occur around impacted teeth, odontogenic tumors can arise from the epithelium contained within the dental follicle. The most common odontogenic tumor to occur in this region is the ameloblastoma. Usually, ameloblastomas in this area must be treated aggressively by excision of the overlying soft tissue and of at least a portion of the mandible. Occasionally, other odontogenic tumors may occur in conjunction with impacted teeth (Fig. 10.13).

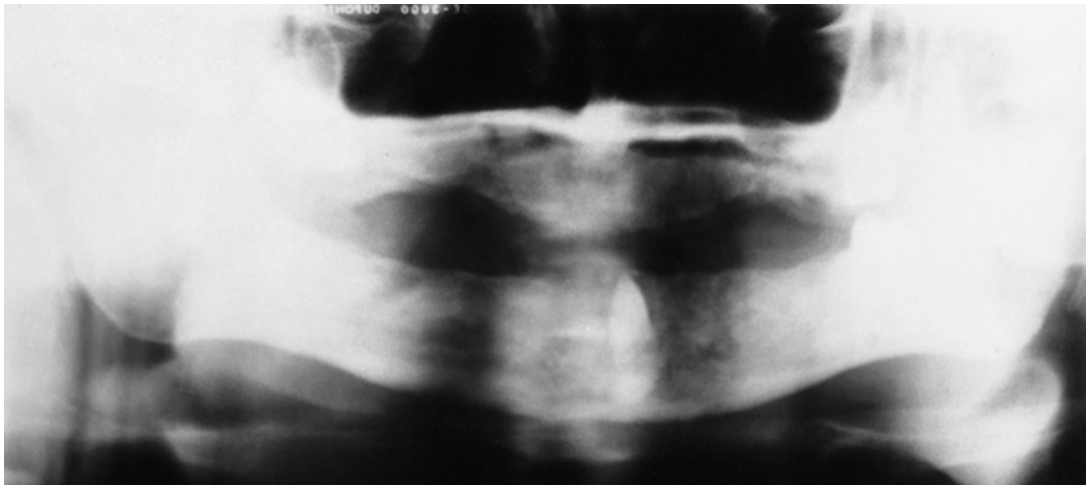
Although the overall incidence of odontogenic cysts and tumors around impacted teeth is not high, the overwhelming majority of pathologic conditions of the mandibular third molar are associated with unerupted teeth.

Treatment of Pain of Unexplained Origin

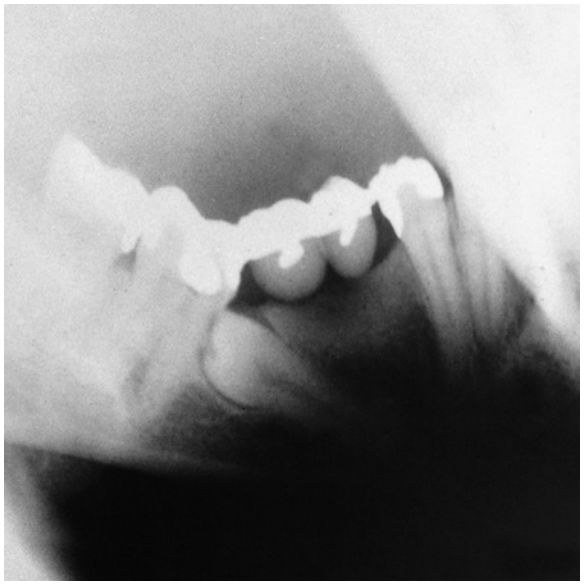
Occasionally, patients come to the dentist complaining of pain in the retromolar region of the mandible, but the reason for the pain may not be obvious. If conditions such as myofascial pain dysfunction syndrome and other facial pain disorders are excluded, and if the patient has an unerupted tooth, removal of the tooth sometimes results in resolution of the pain. In addition, delaying third molar removal to a later age may increase the chances of temporomandibular disorders.

Prevention of Jaw Fractures

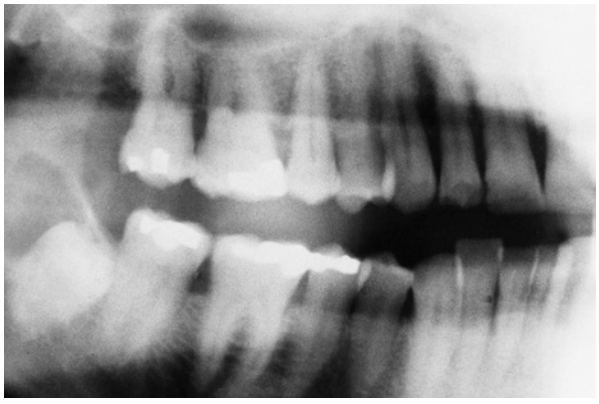
An impacted third molar in the mandible occupies space that is usually filled with bone. This weakens the mandible and renders the jaw more susceptible to fracture at the site of the impacted tooth (Fig. 10.14). If the jaw fractures through the area of an



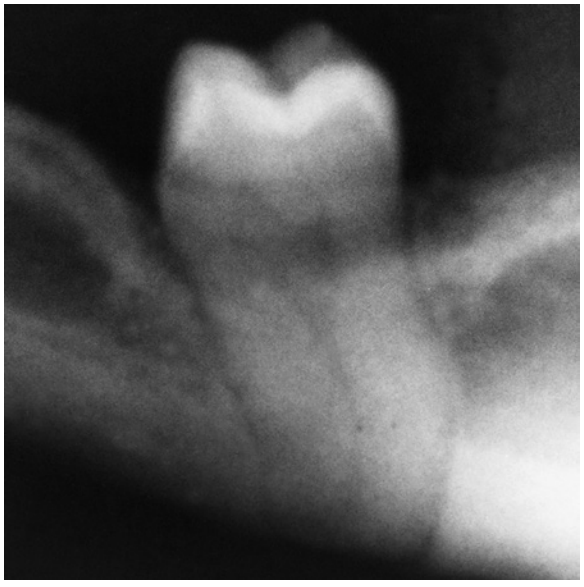
• **Fig. 10.8** Impacted canine retained under a denture. The tooth is now at the surface and is causing infection.



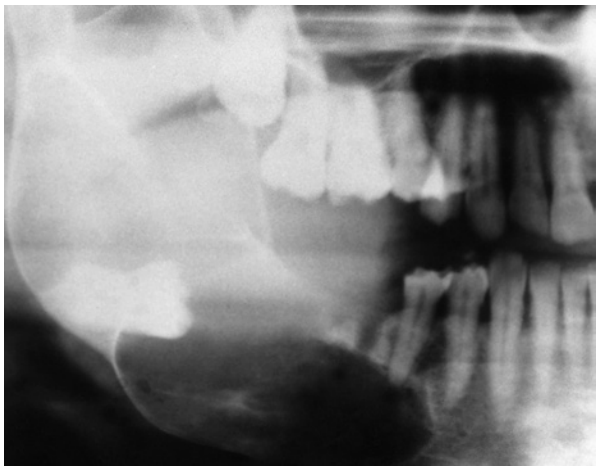
• **Fig. 10.9** Impacted tooth under a fixed bridge. The tooth must be removed and therefore may jeopardize the bridge.



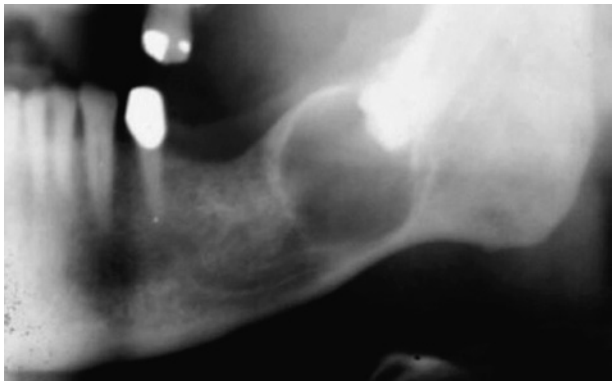
• **Fig. 10.11** Small dentigerous cyst arising around an impacted tooth.



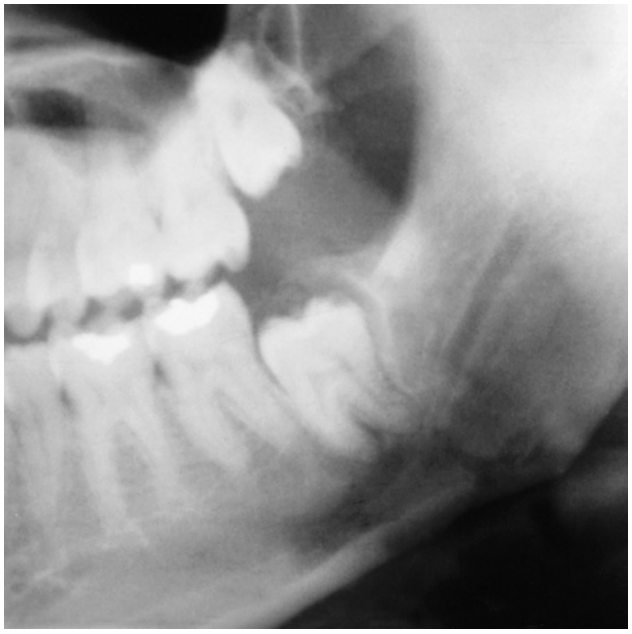
• **Fig. 10.10** Impaction in an atrophic mandible, which may result in jaw fracture during extraction.



• **Fig. 10.12** Large dentigerous cyst that extends from the coronoid process to the mental foramen. The cyst has displaced the impacted third molar to the inferior border of the mandible.



• **Fig. 10.13** Ameloblastoma associated with the crown of an impacted third molar. (Courtesy Dr. Frances Gordy.)



• **Fig. 10.14** Fracture of a mandible, which occurred through the location of an impacted third molar.

impacted third molar, the impacted third molar is frequently removed before the fracture is reduced, and fixation is applied (see Chapter 24).

Facilitation of Orthodontic Treatment

When patients require retraction of first and second molars by orthodontic techniques, the presence of impacted third molars may interfere with the treatment. Therefore it is recommended that impacted third molars be removed before orthodontic therapy is begun.

Some orthodontic approaches to a malocclusion might benefit from the placement of retromolar implants to provide distal anchorage. When this is planned, removal of impacted lower third molars is necessary.

Optimal Periodontal Healing

As noted before, one of the most important indications for removal of impacted third molars is to preserve the periodontal health of the adjacent second molar. A great deal of attention has been given to the two primary parameters of periodontal health after third molar surgery: (1) bone height and (2) periodontal attachment level on the distal aspect of the second molar.

Recent studies have provided information on which to base the likelihood of optimal periodontal tissue healing. Two most important factors that have been shown are (1) the extent of the preoperative infrabony defect on the distal aspect of the second molar and (2) the patient's age at the time of surgery. If a large amount of distal bone is missing because of the presence of the impacted tooth and its associated follicle, it is less likely that the infrabony pocket can be decreased. Likewise, if the patient is older, the likelihood of optimal bony healing is decreased. Patients whose third molars are removed before age 25 years are more likely to have better bone healing than those whose impacted teeth are removed after age 25 years. In the younger patient, not only is the initial periodontal healing better, but also the long-term continued regeneration of the periodontium is clearly better.

As mentioned previously, unerupted teeth may continue to erupt until age 25 years. Because the terminal portion of the eruption process occurs slowly, the chance of developing pericoronitis increases and so does the amount of contact between the third molar and the second molar. Both of these factors decrease the possibility for optimal periodontal healing. However, it should be noted that the asymptomatic completely bony impacted third molar in a patient older than age 30 years should probably be left in place unless some specific pathologic condition develops. Removal of such asymptomatic completely impacted third molars in older patients clearly results in pocket depths and alveolar bone loss, which are greater than if the tooth were left in place.

Contraindications for Removal of Impacted Teeth

All impacted teeth should be removed unless specific contraindications justify leaving them in position. When the potential benefits outweigh the potential complications and risks, the procedure should be performed. Similarly, when the risks are greater than the potential benefits, the procedure should be deferred.

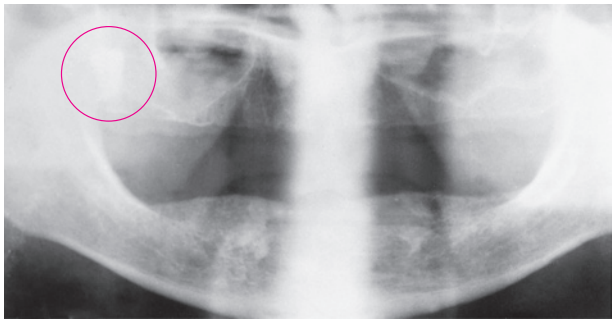
Contraindications for the removal of impacted teeth primarily involve the patient's physical status.

Extremes of Age

The third molar tooth bud can be radiographically visualized by age 6 years. Some surgeons think that removal of the tooth bud at age 7 to 9 years can be accomplished with minimal surgical morbidity and therefore should be performed at this age. However, most surgeons believe that it is not possible to accurately predict if the forming third molar will be impacted. The consensus is that very early removal of third molars should be deferred until an accurate diagnosis of impaction can be made.

The most common contraindication for the removal of impacted teeth is advanced age. As a patient ages, the bone becomes highly calcified and, therefore, less flexible and less likely to bend under the forces of tooth extraction. The result is that more bone must be surgically removed to elevate the tooth from its socket.

Similarly, as patients age, they respond less favorably and with more postoperative sequelae. An 18-year-old patient may have 1 or 2 days of discomfort and swelling after the removal of an impacted tooth, whereas a similar procedure may result in a 4- or 5-day recovery period for a 50-year-old patient.



• **Fig. 10.15** Impacted maxillary right third molar in a 63-year-old patient. This molar should not be extracted because it is deeply embedded and no signs of disease are present.

Finally, if a tooth has been retained in the alveolar process for many years without periodontal disease, caries, or cystic degeneration, it is unlikely that these unfavorable sequelae will occur. Therefore, in an older patient (usually >35 years) with an impacted tooth that shows no signs of disease and that has a radiographically detectable layer of overlying bone, the tooth should not be removed (Fig. 10.15). The dentist caring for the patient should check the impacted tooth radiographically every 1 or 2 years to ensure that no adverse sequelae have occurred.

If the impacted tooth shows signs of cystic formation or periodontal disease involving the adjacent tooth or the impacted tooth, if it is a single impacted tooth underneath a prosthesis with thin overlying bone, or if it becomes symptomatic as the result of infection, the tooth should be removed.

Compromised Medical Status

A compromised medical status may contraindicate the removal of an impacted tooth. Frequently, compromised medical status and advancing age go hand in hand. If the impacted tooth is asymptomatic, its surgical removal must be viewed as elective. If the patient's cardiovascular or respiratory function or host defenses for combating infection are seriously compromised, or if the patient has a serious acquired or congenital coagulopathy, the surgeon should consider leaving the tooth in the alveolar process. However, if the tooth becomes symptomatic, the surgeon should consider working with the patient's physician to plan removal of the tooth with minimal operative and postoperative medical sequelae.

Probable Excessive Damage to Adjacent Structures

If the impacted tooth lies in an area in which its removal may seriously jeopardize adjacent nerves, teeth, or previously constructed bridges, it may be prudent to leave the tooth in place. When the dentist makes the decision not to remove a tooth, the reasons must be weighed against potential future complications. In the case of younger patients who may suffer the sequelae of impacted teeth, it may be wise to remove the tooth while taking special measures to prevent damage to adjacent structures. However, in the case of the older patient with no signs of impending complications and for whom the probability of such complications is low, the impacted tooth should not be removed. A classic example of such a case is the older patient with a potentially severe periodontal defect on the distal aspect of the second molar but in whom removal of the third molar would almost surely result in the loss of the second molar. In this situation the impacted tooth should not be removed.

Treatment Planning

The preceding discussion of indications and contraindications for the removal of impacted third molars has been designed to point out that there are various risks and benefits in removing impacted teeth in patients. Patients who have one or more pathologic symptoms or problems should have their impacted teeth removed. Most of the symptomatic, pathologic problems that result from impacted third molars occur because of partially erupted teeth and occur less commonly with complete bony impaction.

However, what should be done with impacted teeth before they cause symptoms or problems is less clear. In making a decision as to whether an impacted third molar should be removed, one must consider a variety of factors. First, the available room in the arch into which the tooth can erupt must be considered. If adequate room exists, the clinician may choose to defer removal of the tooth until eruption is complete. Second, the status of the impacted tooth and the age of the patient should be considered. It is critical to remember that the average age of complete eruption is 20 years but that eruption may continue to occur up to age 25 years. Occasionally, a tooth that appears to be a mesioangular impaction at age 17 years may eventually become more vertical and erupt into the mouth. Also, if the patient's second molar is seriously diseased and is likely to require removal, it may be wise to leave the third molar in place; if the second molar is removed, the stair molar can often be guided into good occlusion. If insufficient room exists to accommodate the tooth and a soft tissue operculum exists over the posterior aspect, then pathologic sequelae are likely to occur.

Although there have been some attempts at making very early predictions of whether a tooth is going to be impacted, these efforts have not yet resulted in a reliable predictive model. However, by the time the patient reaches age 18 years, the dentist can reasonably predict whether there will be adequate room for tooth eruption with sufficient clearance of the anterior ramus to prevent soft tissue operculum formation. At this time, if surgical removal is chosen, soft tissue and bone tissue healing will occur at its maximal level. At age 18 or 19 years, if the diagnosis for inadequate room for functional eruption can be made, then the asymptomatic third molar can be removed, and the long-term periodontal health of the second molar will be optimized.

Classification Systems for Mandibular Third Molar Impactions

Removal of impacted teeth can be relatively straightforward or extremely difficult, even for the experienced surgeon. To determine the degree of difficulty preoperatively, the surgeon should methodically examine the clinical circumstances. The primary factor determining the difficulty of the removal is accessibility. Accessibility is determined by adjacent teeth or other structures impairing access or the extraction delivery pathway. This includes assessing the ease of exposing the tooth, preparing a pathway for its delivery, and preparing a purchase point. With careful classification of the impacted teeth using a variety of systems, the surgeon can approach the proposed surgery in a methodical fashion and predict whether any extraordinary surgical approaches will be necessary or if the patient will encounter certain postoperative problems.

The majority of classification schemes are based on an analysis of a radiograph. The panoramic radiograph is the imaging of choice for planning removal of impacted third molars. In some

circumstances, a well-positioned periapical radiograph is adequate as long as all parts of the impacted tooth are visible along with important adjacent anatomy. When the roots of a lower third molar appear very close to, or superimpose over, the inferior alveolar canal on a panoramic radiograph, a cone-beam computed tomography (CT) scan may be useful. This imaging technique can accurately show the relationship of the roots to the canal.

For each patient, the surgeon should carefully analyze the factors discussed in this section. By considering all of these factors, the dentist can assess the difficulty of the surgery and elect to extract the impacted teeth that are within his or her skill level. However, for the patient's well-being and the dentist's peace of mind, the patient should be referred to a specialist if a tooth presents a difficult surgical situation or if the dentist cannot offer optimal intraoperative pain and anxiety control.

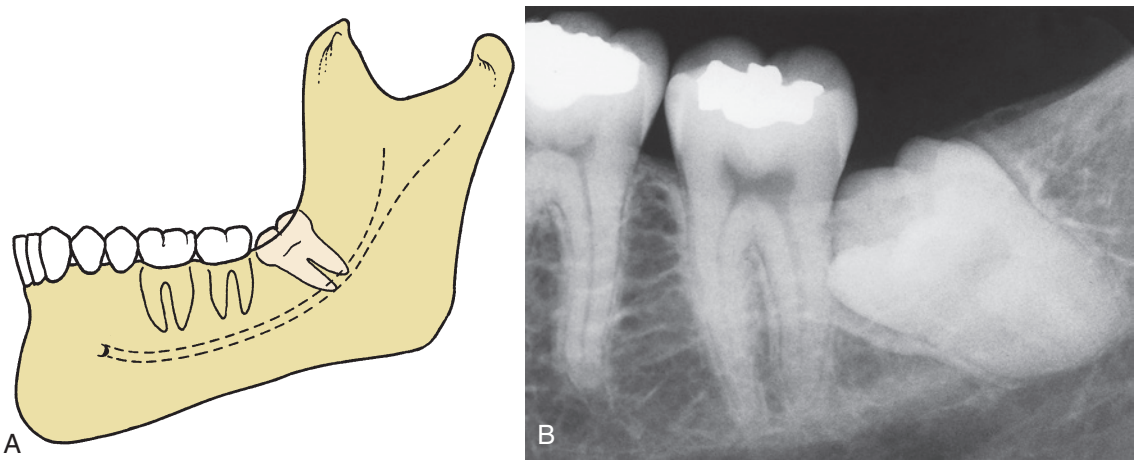
Angulation

The most commonly used classification system with respect to treatment planning uses a determination of the angulation of the long axis of the impacted third molar with respect to the long axis of the adjacent second molar. Teeth at certain inclinations have ready-made pathways for removal, whereas pathways for teeth of other inclinations require the removal of substantial amounts of bone and/or tooth division. This classification system provides an initial useful evaluation of the difficulty of extractions but is not sufficient by itself to fully define the difficulty of molar removal.

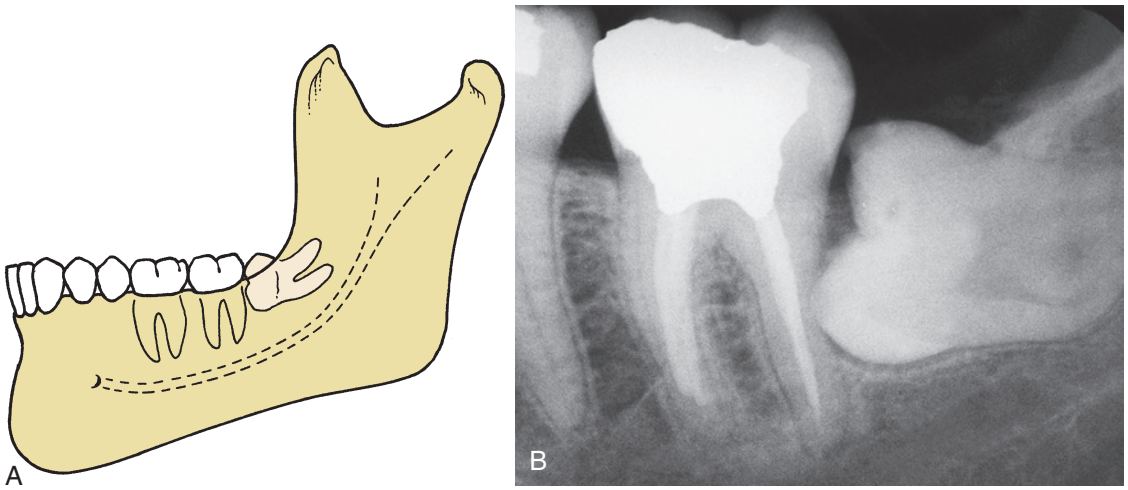
The impaction generally acknowledged as the least difficult impaction to remove is the mesioangular impaction, particularly when only partially impacted (Fig. 10.16). The crown of the mesioangular-impacted tooth is tilted toward the second molar in a mesial direction. This type of impaction is the most commonly seen, making up approximately 43% of all impacted lower third molars.

When the long axis of the third molar is perpendicular to the second molar, the impacted tooth is considered horizontal (Fig. 10.17). This type of impaction is usually considered more difficult to remove compared with mesioangular impaction. Horizontal impactions occur less frequently, being seen in approximately 3% of all mandibular impactions.

In vertical impaction, the long axis of the impacted tooth runs parallel to the long axis of the second molar. This impaction occurs



• **Fig. 10.16** (A) Mesioangular impaction—the most common and easiest impaction to remove. (B) Mesioangular impaction is usually in proximity to the second molar.



• **Fig. 10.17** (A) Horizontal impaction—an uncommon and more difficult to remove impaction than a mesioangular impaction. (B) The occlusal surface of the horizontal impacted third molar is usually immediately adjacent to the root of the second molar, which often produces early severe periodontal disease.

with the second greatest frequency, accounting for approximately 38% of all lower third molar impactions, and is considered third in ease of removal (Fig. 10.18).

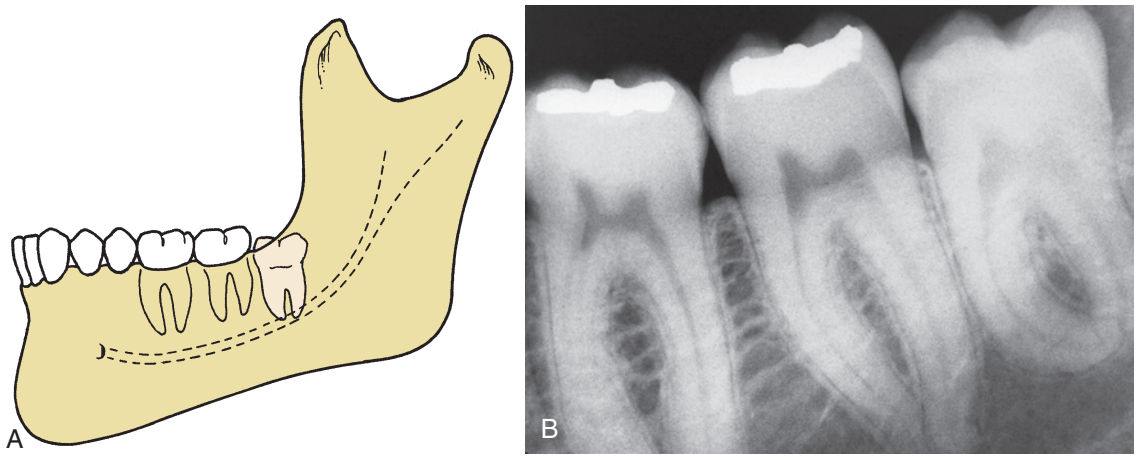
Finally, distoangular impaction involves the tooth with the most difficult angulation for removal (Fig. 10.19). In distoangular impaction the long axis of the third molar is distally or posteriorly angled away from the second molar. This impaction is the most difficult to remove because the tooth has a withdrawal pathway that runs into the mandibular ramus, and its removal requires significant surgical intervention. Distoangular impactions occur uncommonly and account for only approximately 6% of all impacted third molars. Erupted third molars may also be in a distoangular position. When this occurs, these teeth are much more difficult to remove compared with other erupted teeth. The reason is that the third molar's mesial root is very close to the root of the second molar.

In addition to the relationship between the angulation of the long axes of the second and third molars, teeth also can be angled in buccal, lingual, or palatal directions. When approaching lower third molars, the possible presence of a high-riding lingual nerve still makes a buccal approach appropriate, even when the tooth is inclined toward the lingual aspect.

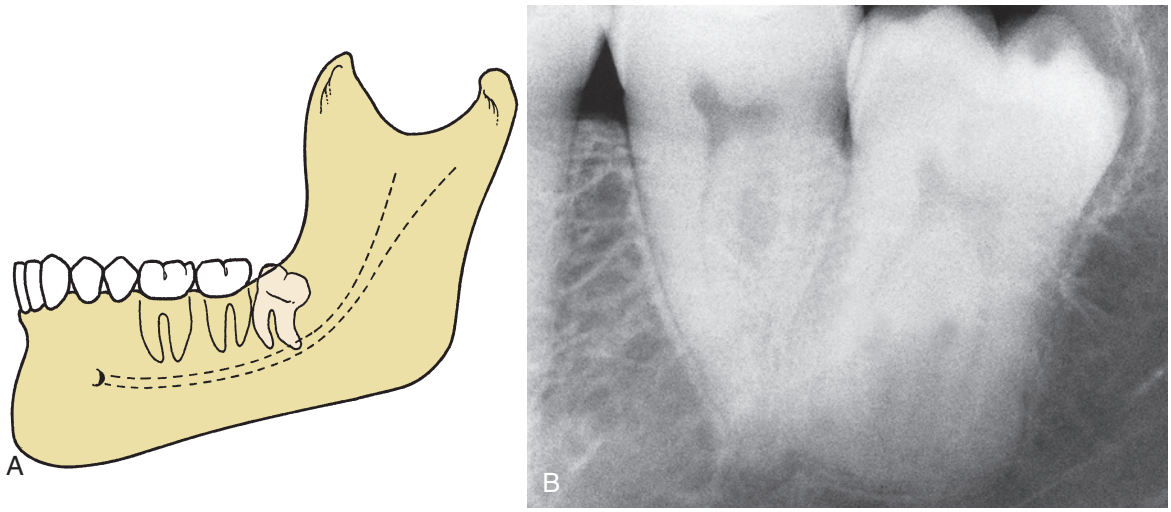
Rarely, a transverse impaction occurs; that is, the tooth erupting in an absolutely horizontal position in the buccolingual direction. The occlusal surface of the tooth can face the buccal or lingual direction. To determine buccal or lingual version accurately, the dentist must take a perpendicular occlusal radiograph or obtain a cone-beam CT scan. However, this determination is usually not necessary because the surgeon can make this identification early in the operation, and the buccal or lingual position of the tooth does not greatly influence the approach to the surgery.

Relationship to Anterior Border of Ramus

Another method for classifying impacted mandibular third molars is based on the amount of impacted tooth that is covered with the bone of the mandibular ascending ramus. This classification is known as the *Pell and Gregory classification*, also referred to as *Pell and Gregory classes 1, 2,* and *3*. For this classification, it is important that the surgeon carefully examine the relationship



• **Fig. 10.18** (A) Vertical impaction—the second most common impaction and the second most difficult to remove. (B) Vertical impaction is frequently covered on its posterior aspect with bone of the anterior ramus of the mandible.



• **Fig. 10.19** (A) Distoangular impaction—an uncommon and the most difficult of the four types of impactions to remove. (B) The occlusal surface of distoangular impaction is usually embedded in the ramus of the mandible and requires significant bone removal for extraction.

between the tooth and the anterior part of the ramus. If the mesiodistal diameter of the crown is completely anterior to the anterior border of the mandibular ramus, it is in a class 1 relationship. If the tooth is angled in a vertical direction, the chances for the tooth to erupt into a normal position are good, provided the root formation is incomplete (Fig. 10.20).

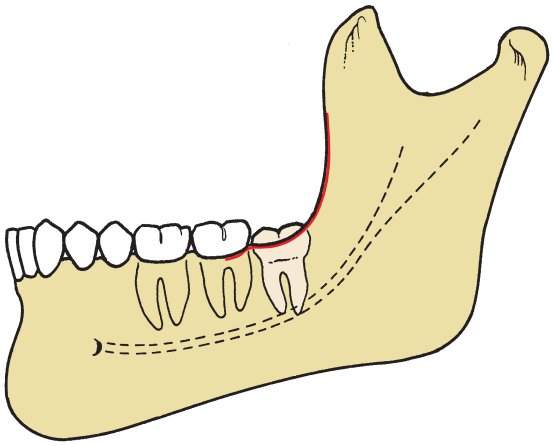
If the tooth is positioned posteriorly so that approximately one half is covered by the ramus, the relationship of the tooth with the ramus is class 2. In the class 2 situation, the tooth cannot erupt completely free from bone over the crown and the distal aspect because a small shelf of bone overlies the distal portion of the tooth (Fig. 10.21). A class 3 relationship between the tooth and ramus occurs when the tooth is located completely within the mandibular ramus (Fig. 10.22). Obviously the class 1 relationship provides the greatest accessibility to the impacted tooth; therefore such a tooth is the most straightforward to remove. The class 3 relationship provides the least accessibility and thus presents the greatest difficulty.

Relationship to the Occlusal Plane

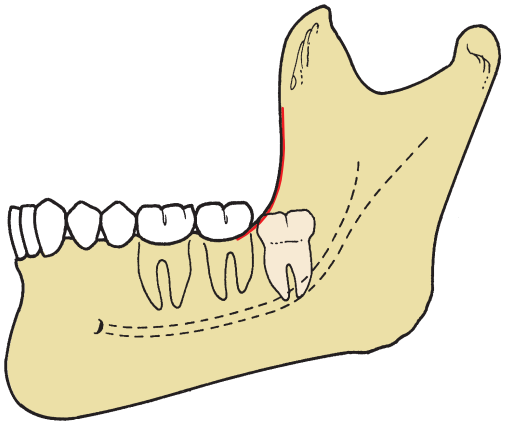
The depth of the impacted tooth compared with the height of the adjacent second molar provides the next classification system for determining the difficulty of impaction removal. This classification system was also suggested by Pell and Gregory and is called the *Pell and Gregory A, B,* and *C classification*. In this classification the degree of difficulty is measured by the thickness of overlying bone; that is, the degree of difficulty increases as the depth of the impacted tooth increases. As the tooth becomes less accessible and it becomes more difficult to section the tooth and to prepare purchase points, the overall difficulty of the operation substantially increases.

A class A impaction is one in which the occlusal surface of the impacted tooth is level or nearly level with the occlusal plane of the second molar (Fig. 10.23). A class B impaction involves an impacted tooth with an occlusal surface between the occlusal plane and the cervical line of the second molar (Fig. 10.24). Finally, the class C impaction is one in which the occlusal surface of the impacted tooth is below the cervical line of the second molar (Fig. 10.25).

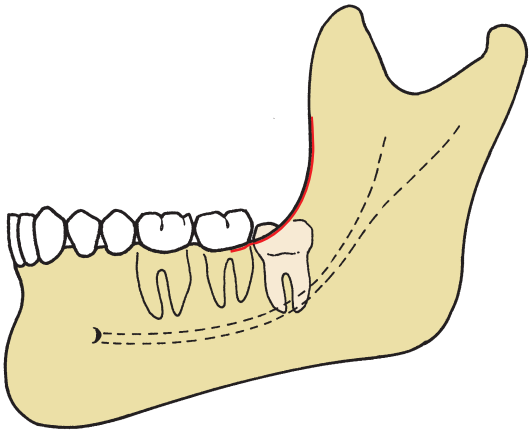
The three classification systems discussed above can be used together to determine the difficulty of an extraction. For example, a mesioangular impaction with a class 1 ramus and a class A depth is usually straightforward to remove (Fig. 10.26). However, as the ramus relationship changes to a class 2 and the depth of the impaction increases to a class B, the degree of difficulty becomes



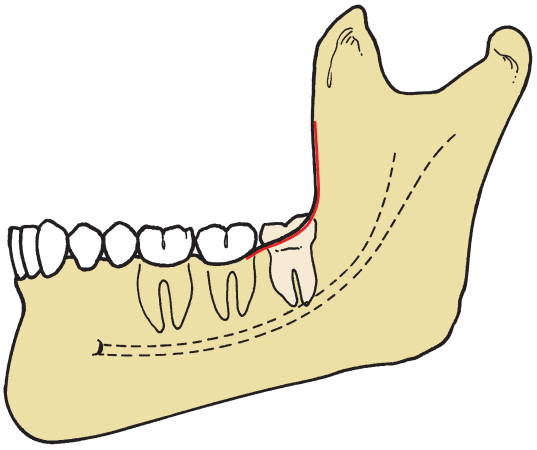
• **Fig. 10.20** Pell and Gregory class 1 impaction. The mandibular third molar has sufficient anteroposterior room (i.e., anterior-to-anterior border of ramus) to erupt.



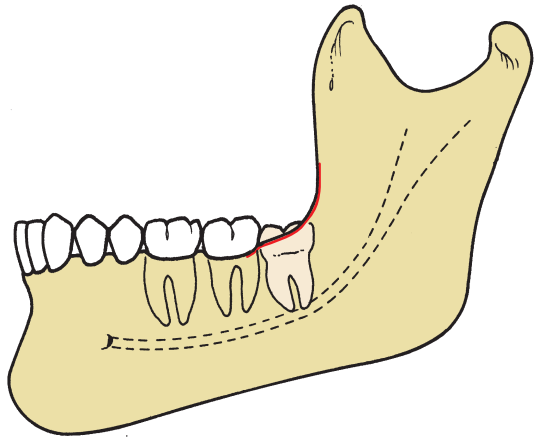
• **Fig. 10.22** Pell and Gregory class 3 impaction. The impacted third molar is completely embedded in the bone of the ramus of the mandible.



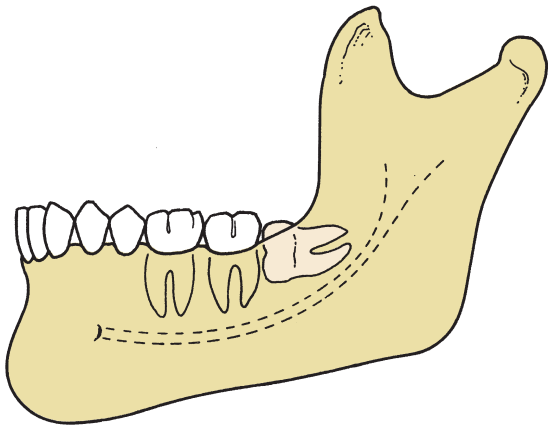
• **Fig. 10.21** Pell and Gregory class 2 impaction. Approximately half is covered by the anterior portion of the ramus of the mandible.



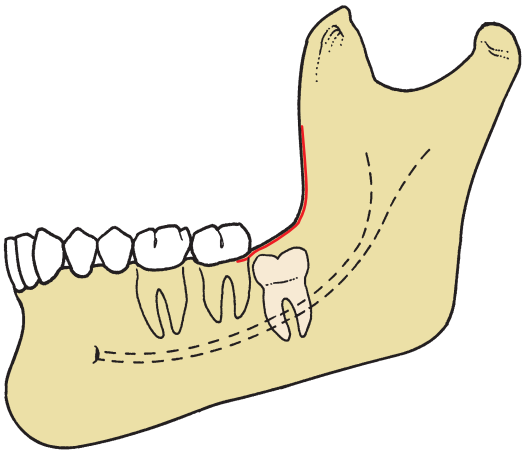
• **Fig. 10.23** Pell and Gregory class A impaction. The occlusal plane of the impacted tooth is at the same level as the occlusal plane of the second molar.



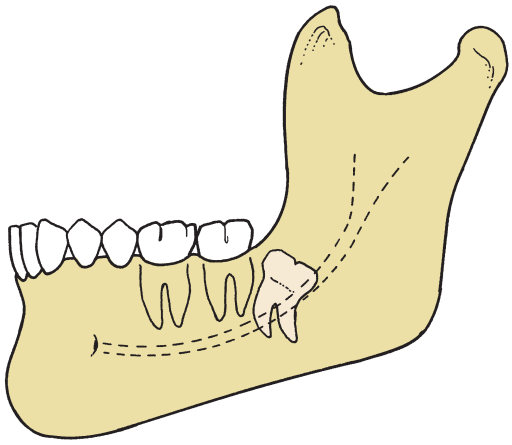
• **Fig. 10.24** Pell and Gregory class B impaction. The occlusal plane of the impacted tooth is between the occlusal plane and the cervical line of the second molar.



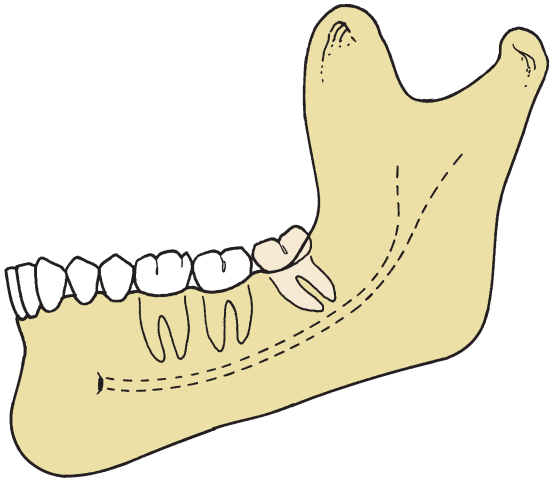
• **Fig. 10.27** Horizontal impaction with class 2 ramus relationship and class B depth makes it moderately difficult to extract.



• **Fig. 10.25** Pell and Gregory class C impaction. The impacted tooth is below the cervical line of the second molar.



• **Fig. 10.28** Impaction with a distoangular class 3 ramus relationship and class C depth makes the tooth extremely difficult to remove safely.



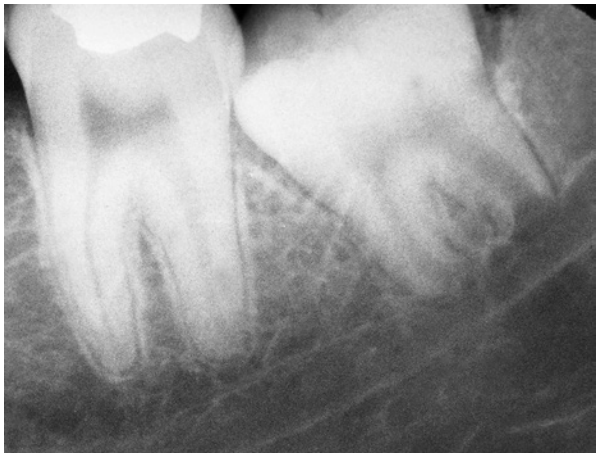
• **Fig. 10.26** Mesioangular impaction with class 1 ramus relationship and class A depth. All three classifications make this the easiest type of impaction to remove.

much greater. A horizontal impaction with a class 2 ramus relationship and a class B depth is a moderately difficult extraction and one that most experienced general practitioners do not want to attempt (Fig. 10.27). Finally, the most difficult of all impactions is a distoangular impaction with a class 3 ramus relationship at a class C depth. Even specialists view removing this tooth as a surgical challenge (Fig. 10.28).

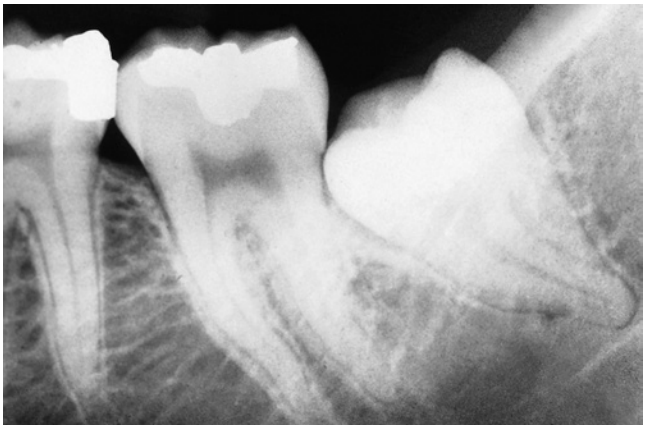
Root Morphology

Just as the root morphology of the erupted tooth has a strong influence on the degree of difficulty of a closed extraction, root morphology plays a major role in determining the degree of difficulty of the removal of an impacted tooth. Several factors must be considered when assessing the morphologic array of the root.

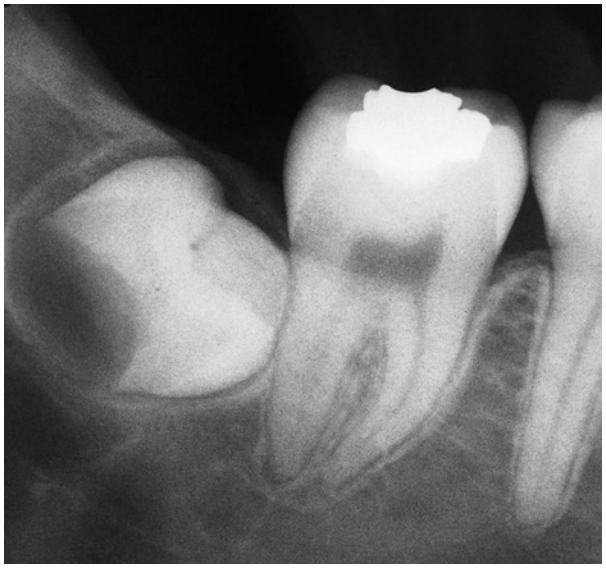
The first consideration is the length of the root. As previously discussed, the optimal time for the removal of an impacted tooth is when the root is one-third to two-thirds formed. When this is the case, the ends of the roots are blunt (Fig. 10.29). If the tooth is not removed during the formative stage and the entire length



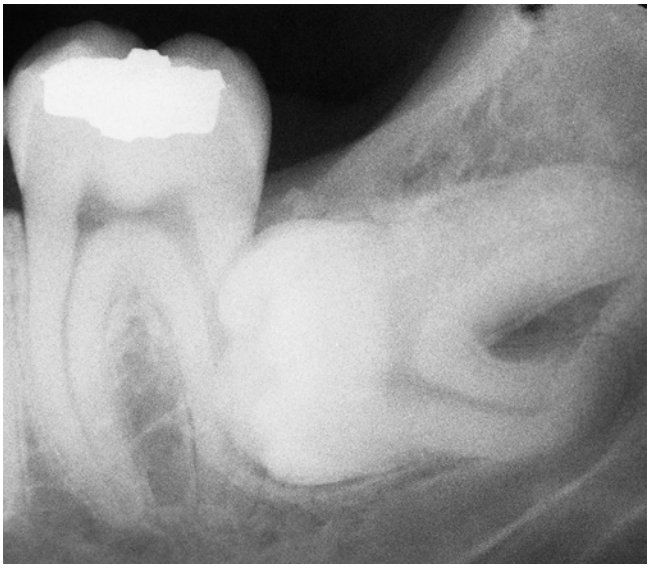
• **Fig. 10.29** Roots that are two-thirds formed, which are less difficult to remove than if fully formed.



• **Fig. 10.31** Fused roots with a conical shape.



• **Fig. 10.30** Lack of root development. If extraction is attempted, the crown will often roll around in the socket, making it difficult to remove.



• **Fig. 10.32** Divergent roots with severe curvature. Such roots are more difficult to remove.

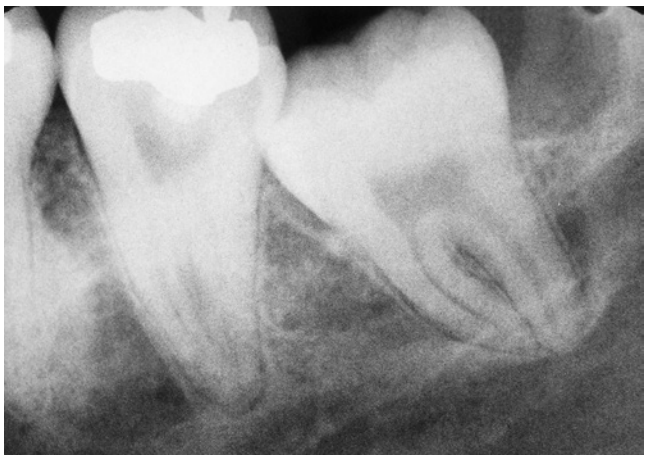
of the root develops, the possibility increases for distorted root morphology, leading to fracture of the root tips during extraction or to the root tips impeding root delivery. If the root development is limited (i.e., less than one-third complete), the tooth is often more difficult to remove because it tends to roll in its socket like a marble, which prevents routine elevation (Fig. 10.30). The next factor to be assessed is whether the roots are fused into a single, conical root (Fig. 10.31) or whether they are separate and distinct roots. The fused, conical roots are more straightforward to remove than are widely separated roots (Fig. 10.32).

The curvature of the tooth roots also plays a role in the difficulty of the extraction. Severely curved or dilacerated roots are more difficult to remove than are straight or slightly curved roots (see Fig. 10.32). The surgeon should carefully examine the apical area of impacted teeth on the radiograph to assess the presence of small, abnormal, and sharply hooked roots that will probably fracture if the surgeon does not give them special consideration. Even with extra focus during surgery, hooked roots are a challenge to remove.

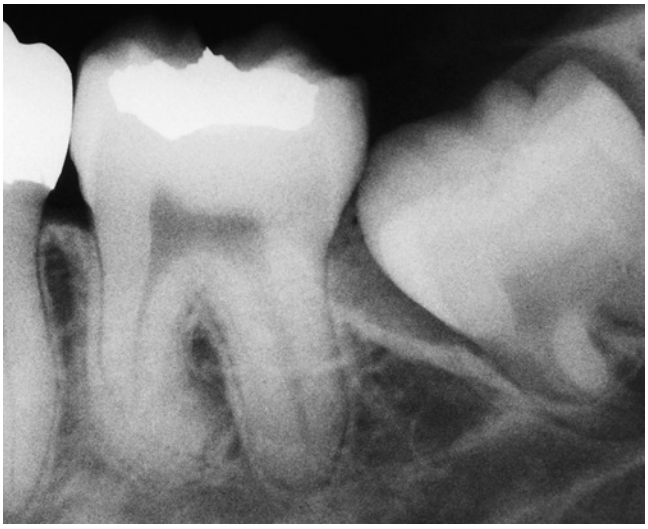
The direction of the tooth root curvature is also important to examine preoperatively. During removal of a mesioangular impaction, roots that are curved gently in the distal direction (following along the pathway of extraction) can be removed without the force that can fracture them. However, if the roots of a mesioangular impaction are straight or curved mesially, the roots commonly fracture if the tooth is not sectioned before being delivered.

The total width of the roots in the mesiodistal direction should be compared with the width of the tooth at the cervical line. If the tooth root width is greater, the extraction will be more difficult. More bone must be removed, or the tooth should be sectioned before extraction.

Finally, the surgeon should assess the periodontal ligament space. Although the periodontal ligament space is of normal dimensions in most patients, sometimes it is wider or narrower. The wider the periodontal ligament space, typically the more straightforward the tooth is to remove (Fig. 10.33). However, older patients, especially those older than 40 years, tend to have a much narrower periodontal ligament space that increases the difficulty of the extraction.



• **Fig. 10.33** Wide periodontal ligament space. The widened space makes the extraction process less difficult.



• **Fig. 10.34** Large follicular sac. When the space of the sac is large, the amount of bone removal required is decreased.

Size of the Follicular Sac

The size of the follicle around the impacted tooth can help determine the difficulty of the extraction. If the follicular sac is wide (almost cystic in size), much less bone must be removed, which makes the tooth more straightforward to extract (Fig. 10.34). (Young patients are more likely to have large follicles, which is another factor that makes extractions less complex in younger patients.) However, if the follicular space around the crown of the tooth is narrow or nonexistent, the surgeon must create space around the crown, increasing the difficulty of the procedure and the time required to remove the tooth.

Density of Surrounding Bone

The density of bone surrounding the tooth plays a role in determining the difficulty of the extraction. Although some clues can be seen on the radiographs, variations in radiographic density and angulation render bone density interpretations based on radiographs unreliable. Bone density is best determined by the patient's age. Patients who are 25 years old or younger have bone densities favorable for tooth removal. The bone is less dense, is more likely to be pliable, and expands and bends somewhat, which allows the socket to be expanded by elevators or by luxation forces applied to the tooth itself. In addition, the less dense bone is more straightforward to cut with a dental burr and can be removed more rapidly compared with denser bone.

Conversely, patients who are older than 25 years have much denser bone with decreased flexibility and ability to expand. In these patients the surgeon must remove all interfering bone because it is not possible to expand the bony socket. In addition, as the bone increases in density, it becomes more difficult to remove with a dental burr, and the bone removal process takes longer. Also, excessive force is more likely to fracture very dense bone compared with less dense bone of a similar cross-section.

Gender also plays a role in bone density; males, particularly larger ones, in general have greater bone density than females.

Contact With Mandibular Second Molar

If space exists between the second molar and the impacted third molar, the extraction will be more straightforward to approach because damage to the second molar is less likely. However, if the tooth is a distoangular or horizontal impaction, it is frequently in direct contact with the adjacent second molar. To remove the third molar safely without injuring the second molar, the surgeon must be cautious with pressure from elevators and with the burr when removing bone. If the second molar has caries or a large restoration or has been endodontically treated, the surgeon must take special care not to fracture the restoration or a portion of the carious crown. The patient should be forewarned of this possibility (see Fig. 10.17B).

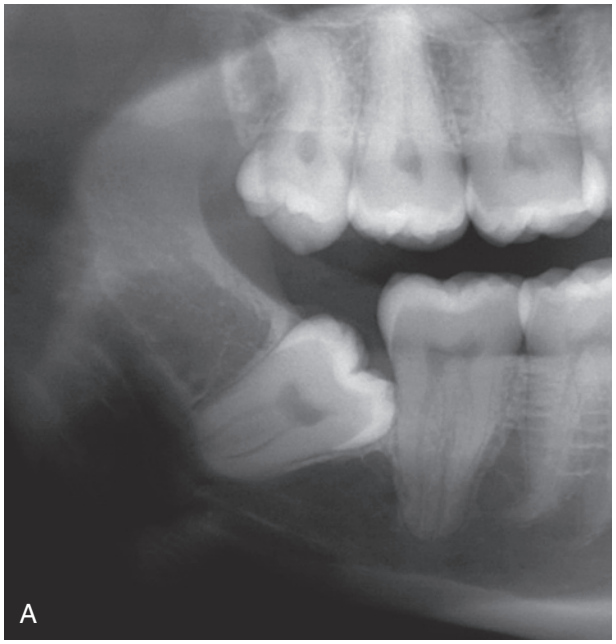
Relationship to Inferior Alveolar Nerve

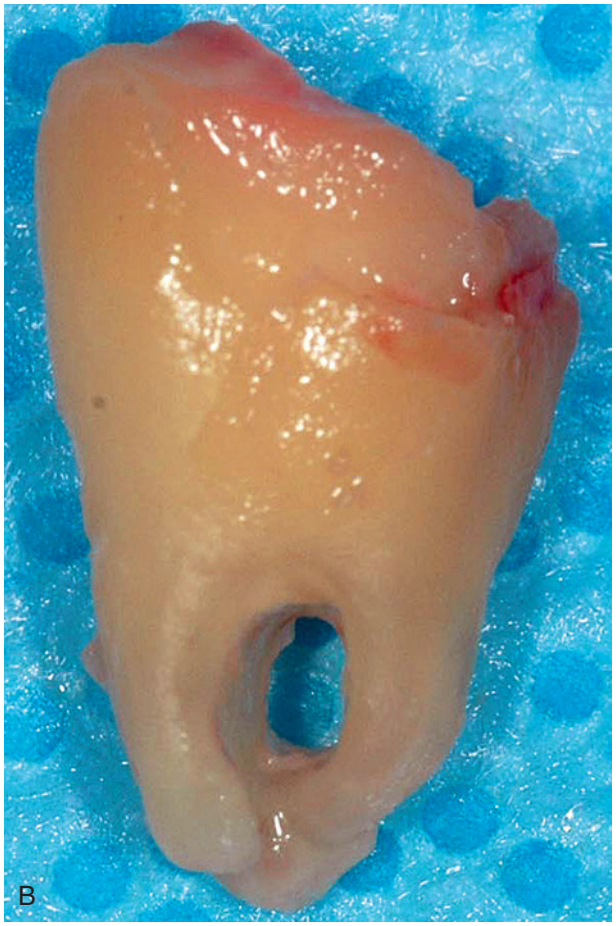
Impacted mandibular third molars frequently have roots that are superimposed on the inferior alveolar canal on radiographs. Although the canal is usually on the buccal aspect of the tooth, it is still in proximity to the roots. Therefore one of the potential sequelae of impacted third molar removal is damage to the inferior alveolar nerve. This commonly results in some altered sensation (paresthesia or anesthesia) of the lower lip and chin on the injured side. Although this altered sensation is usually brief (lasting only a few days), it may extend for weeks or months; on rare occasions it can be permanent. The duration depends on the extent of nerve damage. If the root ends of the tooth appear to be close to the inferior alveolar canal on a radiograph, the surgeon must take special care to avoid injuring the nerve (Fig. 10.35), which greatly increases the difficulty of the procedure. The availability of cone-beam CT scans makes preoperative assessment of the root and canal relationship much easier to view, which helps guide surgical decisions.

Nature of Overlying Tissue

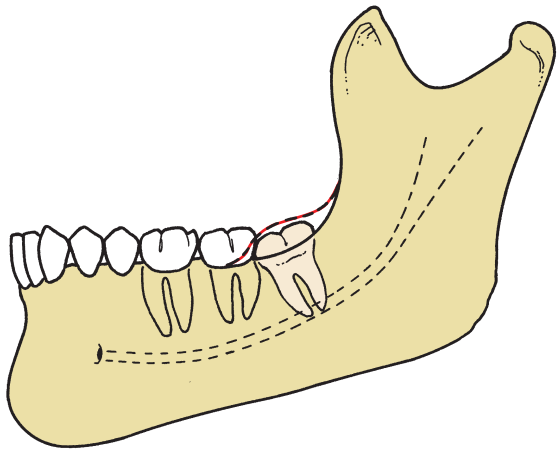
The preceding systems classify factors that make third molar extraction more straightforward or more difficult. The classification system discussed below does not fit into these categories. However, this classification is the system used by most dental insurance companies and is the one by which the surgeon charges for the services.

The dental insurance companies separate types of third molar impactions into three categories: (1) soft tissue, (2) partial bony, and (3) full bony. An impaction is defined as soft tissue impaction

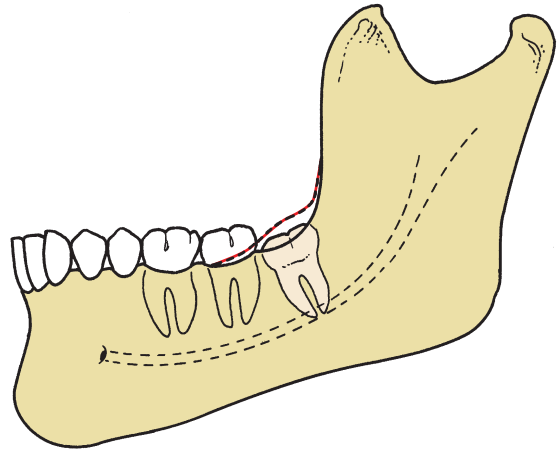




• **Fig. 10.35** (A) Radiographic view of the mandibular third molar that suggests proximity to the inferior alveolar nerve. (B) Hole through the root of the third molar seen in the radiograph after removal. During removal, the inferior alveolar neurovascular bundle was severed. (Courtesy Dr. Edward Ellis III.)



• **Fig. 10.36** Soft tissue impaction in which the crown of the tooth is covered by soft tissue only and can be removed without bone removal.

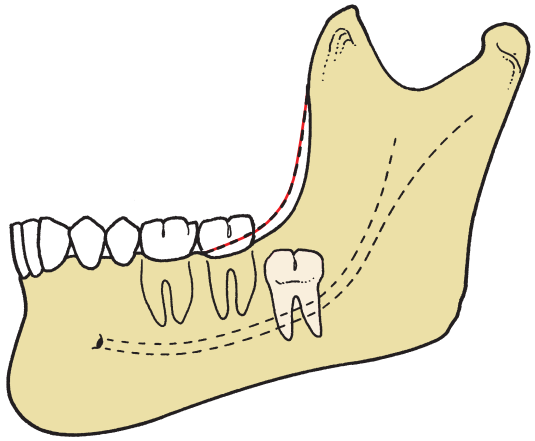


• **Fig. 10.37** Partial bony impaction in which part of the tooth—usually a posterior aspect—is covered with bone and requires bone removal or tooth sectioning for extraction.

when the height of the contour of the tooth is above the level of alveolar bone and the superficial portion of the tooth is covered only by soft tissue (Fig. 10.36). To remove soft tissue impaction, the surgeon must incise the soft tissue and reflect a soft tissue flap to obtain access to the tooth to elevate it from its socket. The soft tissue impaction is usually the most straightforward of the three extractions but can be complex, depending on factors discussed in the preceding sections.

The partial bony impaction occurs when the superficial portion of the tooth is covered by soft tissue, but at least a portion of the height of the contour of the tooth is below the level of the surrounding alveolar bone (Fig. 10.37). To remove the tooth, the surgeon must incise the soft tissue, reflect a soft tissue flap, and remove the bone above the height of the contour. The surgeon may need to divide the tooth in addition to removing bone. A partial bony impacted tooth is commonly more difficult to remove than a full bony impacted third molar.

The complete bony impaction is an impacted tooth that is completely encased in bone, so the tooth is not visible when the surgeon reflects the soft tissue flap (Fig. 10.38). To remove the tooth, extensive amounts of bone must be removed, and the tooth almost always requires sectioning.



• **Fig. 10.38** Complete bony impaction in which the tooth is completely covered with bone and requires extensive removal of bone for extraction.

• BOX 10.1 Factors That Make Impaction Surgery Less Difficult

1. Mesioangular position
2. Pell and Gregory class 1 ramus
3. Pell and Gregory class A depth
4. Roots one-third to two-thirds formed[a]
5. Fused conical roots
6. Wide periodontal ligament[a]
7. Large follicle[a]
8. Elastic bone[a]
9. Separated from second molar
10. Separated from inferior alveolar nerve[a]
11. Soft tissue impaction

[a]*Present in the young patient.*

• BOX 10.2 Factors That Make Impaction Surgery More Difficult

1. Distoangular position
2. Pell and Gregory class 2 or 3 ramus
3. Pell and Gregory class B or C depth
4. Long, thin roots[a]
5. Divergent, curved roots
6. Narrow periodontal ligament
7. Thin follicle[a]
8. Dense, inelastic bone[a]
9. Contact with second molar
10. Close to inferior alveolar canal
11. Complete bony impaction[a]

[a]*Present in older patients.*

Although this classification is extensively used, it frequently has no relationship to the difficulty of the extraction or to the likelihood of complications (Boxes 10.1 and 10.2). The parameters of angulation, ramus relationship, root morphology, and patient age are more relevant to treatment planning than the system used by third-party dental insurers. The surgeon must use all of the information available to determine the difficulty of the proposed surgery.

Classification Systems for Maxillary Third Molar Impactions

The classification systems for the maxillary impacted third molar are essentially the same as for the impacted mandibular third molar. However, several distinctions and additions must be made to more accurately assess the difficulty of removal during the treatment planning phase of the procedure.

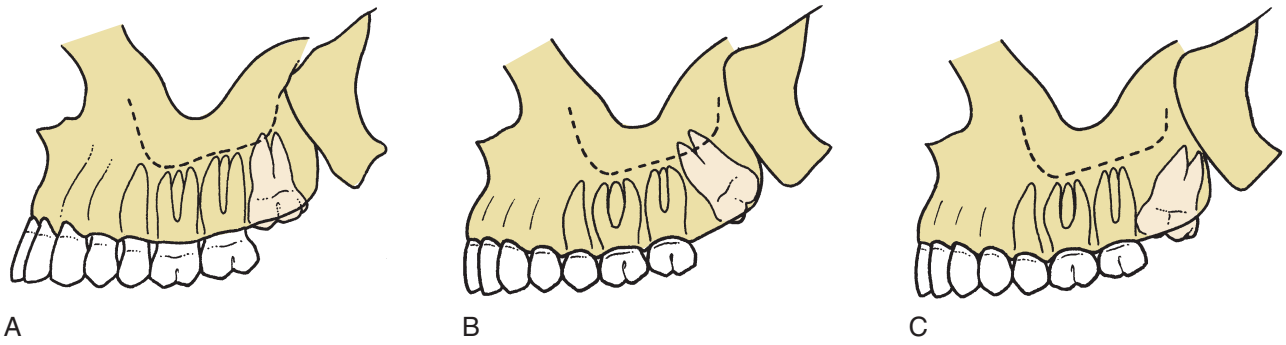
Concerning angulation, the three types of maxillary third molars are (1) vertical impaction (Fig. 10.39A), (2) distoangular impaction (Fig. 10.39B), and (3) mesioangular impaction (Fig. 10.39C). Vertical impaction occurs approximately 63% of the time, distoangular impaction approximately 25% of the time, and mesioangular impaction approximately 12% of the time. Rarely, other positions such as a transverse, inverted, or horizontal are encountered; these unusual positions account for less than 1% of impacted maxillary third molars.

The same angulations in mandibular third molar extractions cause opposite degrees of difficulty for maxillary third molar extractions. Vertical and distoangular impactions are the less complex to remove, whereas mesioangular impactions are the most difficult (exactly the opposite of impacted mandibular third molars). Mesioangular impactions are more difficult to remove because the bone that overlies the impaction and requires removal or expansion is on the posterior aspect of the tooth and is much thicker than in vertical or distoangular impaction. In addition, access to the mesioangularly positioned tooth is more difficult if an erupted second molar is in place.

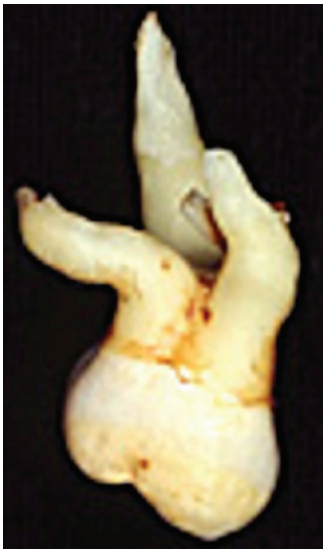
The position of the maxillary third molar in a buccopalatal direction is also important for determining the difficulty of the removal. Most maxillary third molars are angled toward the buccal aspect of the alveolar process; this makes the overlying bone in that area thin and therefore straightforward to remove or expand. Occasionally the impacted maxillary third molar is positioned toward the palatal aspect of the alveolar process. This makes the tooth much more difficult to extract because greater amounts of bone must be removed to gain access to the underlying tooth, and an approach from the palatal aspect risks injury to nerves and vessels of the palatine foramina. A combination of radiographic assessment and clinical digital palpation of the tuberosity area can usually help determine whether the maxillary third molar is in the buccopalatal position. If the tooth is positioned toward the buccal aspect, a palpable bulge is found in the area; if the tooth is palatally positioned, a bony deficit is found in that region. If a more palatal position is determined by clinical examination, the surgeon must anticipate a longer, more involved procedure.

The most common factor that causes difficulty with maxillary third molar removal is a thin, nonfused root with erratic curvature (Fig. 10.40). The majority of maxillary third molars have fused roots that are conical. However, the surgeon should carefully examine the preoperative radiograph to ensure that an unusual root pattern is not present. The surgeon should also check the periodontal ligament because the wider the ligament space, the less difficult the tooth is to remove. In addition, similar to mandibular third molars, the periodontal ligament space tends to narrow as the patient ages.

The follicle surrounding the crown of the impacted tooth also has an influence on the difficulty of the extraction. If the follicular



• **Fig. 10.39** (A) Vertical impaction of a maxillary third molar. This angle accounts for 63% of impactions. (B) Distoangular impaction of a maxillary third molar. This angle accounts for 25% of impactions. (C) Mesioangular impaction of a maxillary third molar. This angle accounts for 12% of impactions.



• **Fig. 10.40** The maxillary third molar has the most erratic and variable root formation of all teeth.

space is broad, the tooth will be more readily removed than if the follicular space is thin or nonexistent.

Bone density is also an important factor in maxillary impaction removal and is closely related to the age of the patient. The younger the patient, the more elastic and expandable the bone is surrounding the impacted third molar.

The relationship to the adjacent second molar tooth also influences the difficulty of the extraction. Extraction may require that additional bone be removed to displace the tooth tucked under the height of the contour of the closely adjacent second molar. In addition, because the use of elevators is common in the removal of maxillary third molars, the surgeon must be aware of the existence of large restorations or caries in the adjacent second molar. Injudicious use of elevators can result in the fracture of restorations or brittle crowns of teeth.

The type of impaction, with respect to overlying tissue, also must be considered for maxillary third molars. The insurance industry classification system used for maxillary teeth is the same as the system that is used for mandibular teeth: soft tissue impaction, partial bony impaction, and complete bony impaction. The definitions of these types of impactions are precisely the same as those used for mandibular third molars.

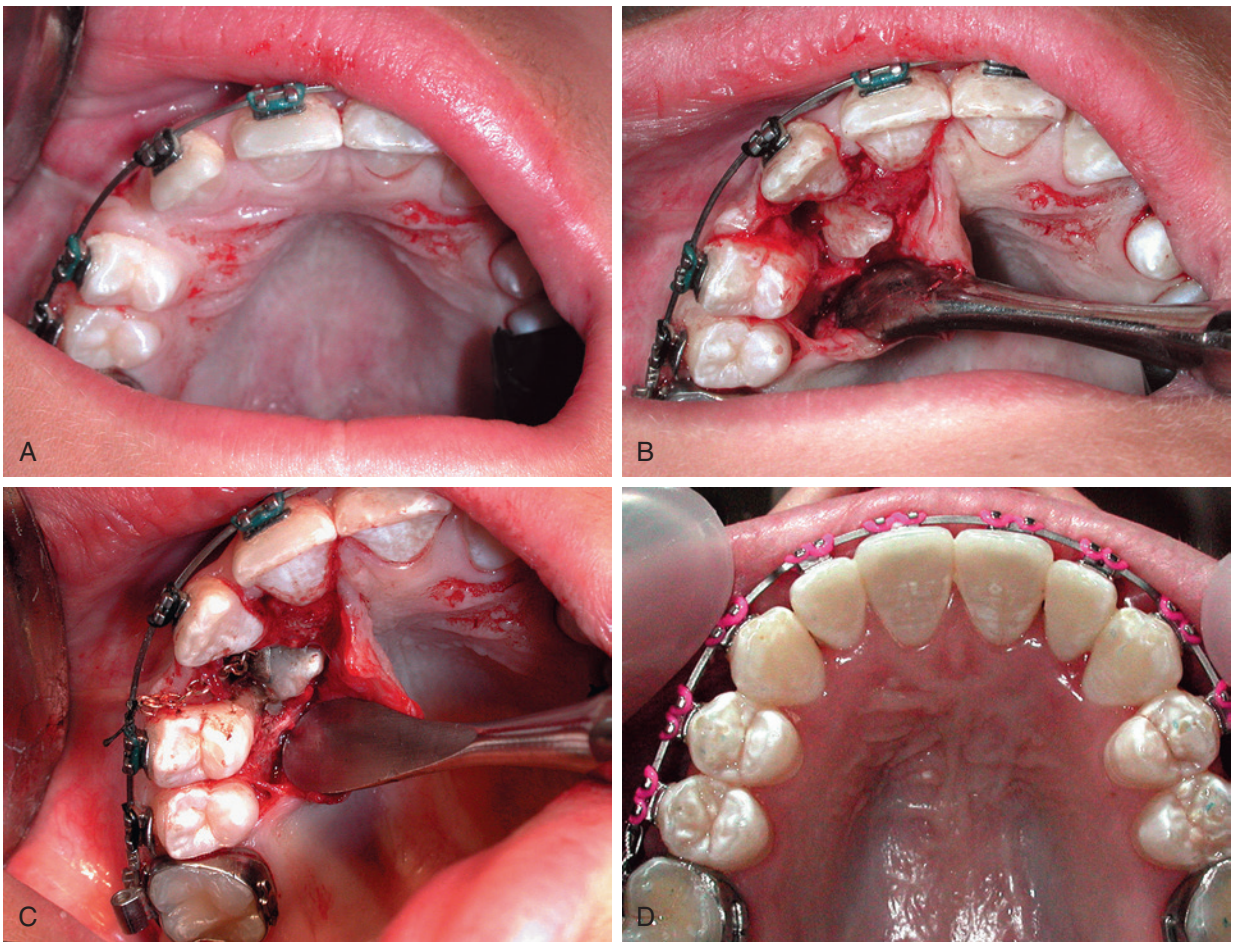
Two additional factors influence the difficulty of maxillary third molar removal but do not exist for mandibular third molars. Both factors are related to the structure and position of the maxillary sinus. First, the maxillary sinus is commonly in intimate contact with the roots of molars; and, frequently, the maxillary third molar actually forms a portion of the posterior sinus wall. If this is the case, removal of the maxillary third molar may result in maxillary sinus complications such as sinusitis or an oroantral fistula. The presence of the maxillary sinus does not necessarily make the removal of the impacted tooth more difficult, but it increases the likelihood of postoperative complications.

Second, in maxillary third molar removal, the tuberosity of the posterior maxilla can be fractured. This is true even when the third molar is erupted or if an erupted second molar is the most distal remaining tooth. Such fractures are possible, especially when dense and nonelastic bone exists, as in older patients. In addition, a large maxillary sinus makes the surrounding alveolar bone thin and more susceptible to fracture when excessive force is applied. A root morphology that has divergent roots requires greater force to remove and increases the likelihood of bone fracture. In addition, mesioangular impactions increase the possibility of fractures (see Fig. 10.39C). In these situations, the overlying tuberosity is heavier, but the surrounding bone is usually thinner. When the surgeon prepares a purchase point at the mesiocervical line, fracture of the tuberosity becomes a greater risk if (1) the bone is nonelastic (as in older patients), (2) the tooth is multirooted with large bulbous roots (as in older patients), (3) the maxillary sinus is large and greatly pneumatized to include the roots of the impacted third molar, or (4) the surgeon uses excessive force to elevate the tooth. Management of the fractured tuberosity is discussed in Chapter 25.

Removal of Other Impacted Teeth

After mandibular and maxillary third molars, the next most commonly impacted tooth is the maxillary canine.

If the dentist decides that the tooth needs to be removed rather than orthodontically repositioned, it must be determined whether the tooth is positioned labially, toward the palate, or in the middle of the alveolar process. If the tooth is on the labial aspect, a soft tissue flap can be reflected to allow removal of the overlying bone and the tooth. However, if the tooth is on the palatal aspect or in the intermediate buccolingual position, it is much more difficult to remove. Therefore, when assessing the impacted maxillary canine for removal, the surgeon's most important assessment is of the



• **Fig. 10.41** (A) Labially positioned impacted maxillary canine. The tooth should be uncovered with an apically positioned flap procedure to preserve the attached gingiva. (B) The mucoperiosteal flap is outlined, allowing for repositioning of the keratinized mucosa over the exposed tooth. When the flap is reflected, the thin overlying bone is removed. (C) The tissue is retracted and bracket bonded to the tooth with an attached gold chain. The flap is apically sutured to the tooth. (D) After 6 months the exposed tooth is in the desired position with the broad zone of the attached gingiva. (Courtesy Dr. Myron Tucker.)

buccolingual position of the tooth. A cone-beam CT is the best way to make this assessment.

Similar considerations are necessary for other impactions such as those of mandibular premolars and supernumerary teeth. The supernumerary tooth in the midline of the maxilla, called a *mesiodens*, is almost always found on the palate and should be approached from the palatal direction for removal.

When a buried canine is positioned in such a way that orthodontic manipulation can assist the proper positioning, the tooth can be exposed and bracketed. A flap is created to allow the soft tissue to be repositioned apically should this be required for maximum keratinized tissue management. The overlying bone tissue is then removed with burrs as is necessary. Once the area is debrided, the surface of the tooth is prepared by the usual standard procedures of etching and application of primer. The bracket is then luted onto the surface of the tooth. A wire can be used to connect the bracket to the orthodontic appliance or, more commonly, a gold chain is attached from the orthodontic bracket to the orthodontic arch wire. The gold chain provides a greater degree of flexibility, and the incidence of breakage of the chain is much less likely than breakage of a wire. Soft tissue is then sutured in such a way as to provide the maximum coverage of the exposed tissue with keratinized tissue. As the tooth is pulled into place with orthodontic appliances, soft tissue surrounding the newly positioned tooth should have adequate keratinized tissue, and the tooth should be in an ideal position.

If the tooth is positioned toward the palatal aspect, it may be repositioned or removed. If the tooth is repositioned, it is surgically exposed and guided into position orthodontically. In this procedure the overlying soft tissue is excised; flaps are not needed to gain attached tissue. Because the bone in the palate is thicker, a burr is usually necessary to remove the overlying bone. The exposed tooth then is managed in the same manner as is the labially positioned tooth (Fig. 10.41).

Surgical Procedure

The principles and steps for removing impacted teeth are the same as for other surgical extractions. Five basic steps make up the technique. (1) The first step is to have adequate exposure of the area of the impacted tooth. This means that the reflected soft tissue flap must have adequate dimensions to allow retraction of the soft tissue to safely perform the necessary surgery without seriously damaging the flap. (2) The second step is to assess the need for

bone removal and to remove a sufficient amount of bone to expose the tooth for any needed sectioning and delivery. (3) The third step, if needed, is to divide the tooth with a burr to allow the tooth to be extracted without removing unnecessarily large amounts of bone. Purchase points may also be placed at this step. (4) In the fourth step, the sectioned or unsectioned tooth is delivered from the alveolar process with the appropriate elevators. (5) Finally, in the fifth step, bone in areas of elevation is smoothed with a bone file, the wound is thoroughly irrigated with a sterile solution, and the flap is reapproximated with sutures. The following discussion elaborates on these steps for the removal of impacted third molars.

Although the surgical approach to the removal of impacted teeth is similar to other surgical tooth extractions, it is important to keep in mind several distinct differences. For instance, the typical surgical extraction of a tooth or tooth root requires the removal of a relatively small amount of bone. However, when an impacted tooth (especially a mandibular third molar) is extracted, the amount of bone that must be removed to deliver the tooth can be substantially greater. This bone is also much denser than it is for typical surgical extractions, and its removal requires better instrumentation and a higher degree of surgical precision.

Impacted teeth frequently require sectioning, whereas other types of tooth extractions do not. Although erupted maxillary and mandibular molars are occasionally divided for removal, it is not a routine step in the extraction of these teeth. However, in a substantial majority of patients with impacted mandibular third molars, the surgeon is required to divide the tooth. Therefore the surgeon must have the necessary equipment for such sectioning and the necessary skills and experience for dividing the tooth along the proper planes.

Unlike most other types of surgical tooth extractions, for an impacted tooth removal, the surgeon must be able to balance the degree of bone removal and sectioning. Essentially, all impacted teeth can be removed without sectioning if a large amount of bone is removed. However, the removal of excessive amounts of bone unnecessarily prolongs the healing period and may result in a weakened jaw. Therefore the surgeon should remove most bony impacted mandibular third molars only after sectioning them. However, removal of a small amount of bone with multiple divisions of the tooth may cause the tooth sectioning process to take an excessively long time, thus unnecessarily prolonging the operation. The surgeon must remove an adequate amount of bone and section the tooth into a reasonable number of pieces, both to hasten healing and to minimize the time of the surgical procedure.

Step 1: Reflecting Adequate Flaps for Accessibility

The ease of removing an impacted tooth depends on its accessibility. To gain access to the area and to visualize the overlying bone that must be removed, the surgeon must reflect an adequate mucoperiosteal flap. The reflection must be of a dimension adequate to allow the placement and stabilization of retractors and instruments for the removal of bone.

In most situations, the envelope flap is the preferred technique. The envelope flap is quicker to suture and heals better than the three-cornered flap (envelope flap with a releasing incision). However, if the surgeon requires greater access to the more apical areas of the tooth, which might stretch and tear the envelope flap, the surgeon should consider using a three-cornered flap.

The preferred incision for the removal of an impacted mandibular third molar is an envelope incision that extends from the mesial papilla of the mandibular first molar, around the necks of the teeth, to the distobuccal line angle of the second molar, and then posteriorly to and laterally up the anterior border of the mandibular ramus (Fig. 10.42A).

The incision must not continue posteriorly in a straight line because the mandible diverges laterally in the third molar area. An incision that extends straight posteriorly falls off the bone and into the sublingual space and may damage the lingual nerve, which is close to the mandible in the area of the third molar. If this nerve is traumatized, the patient will probably have lingual nerve anesthesia, which is extremely disturbing to patients. The incision must always be kept over bone; therefore the surgeon should carefully palpate the retromolar area before beginning the incision.

The flap is reflected laterally to expose the external oblique ridge with a periosteal elevator (Fig. 10.42B). The surgeon should not reflect more than a few millimeters beyond the external oblique ridge because this results in increased morbidity and an increased number of complications after surgery. The retractor is placed on the buccal shelf, just lateral to the external oblique ridge, and it is stabilized by applying pressure toward the bone. This results in a retractor that is stable and does not continually traumatize soft tissue. The Austin and the Minnesota retractors are the most commonly used for flap retraction when removing mandibular third molars.

If the impacted third molar is deeply embedded in bone and requires more extensive bone removal, an oblique, vertical releasing incision may be useful (Fig. 10.42C–D). The flap created by this incision can be reflected farther apically without risk of tearing the tissue.

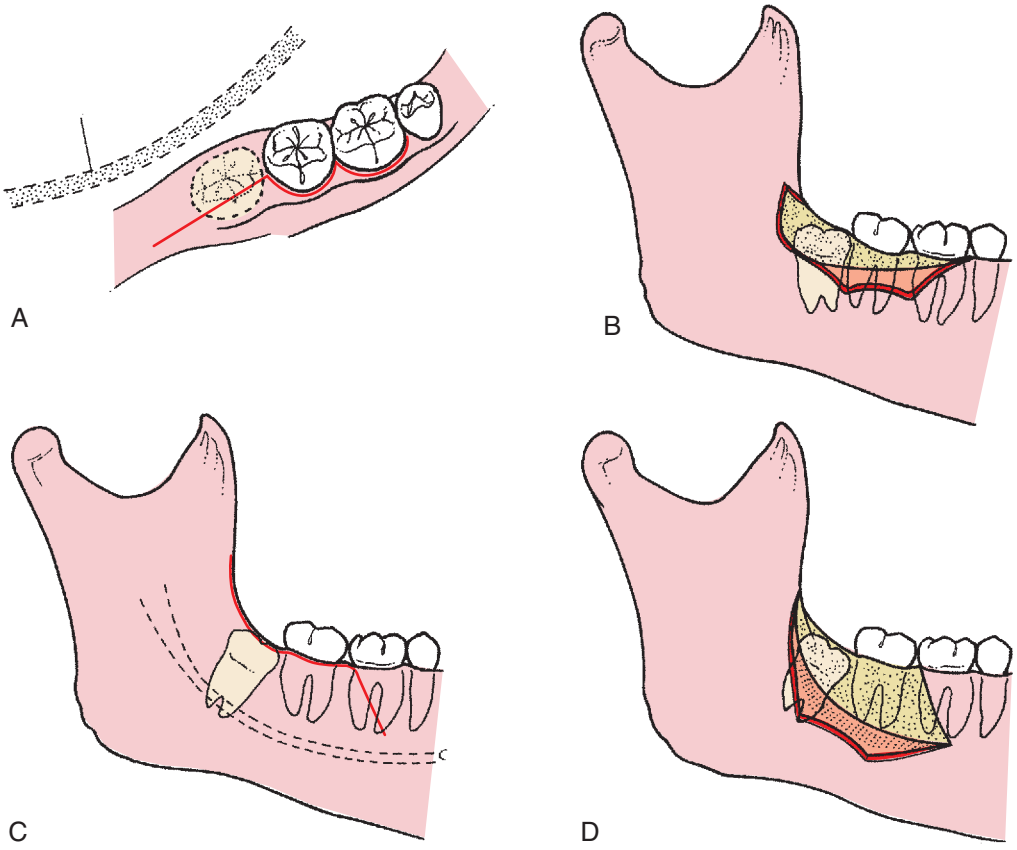
The recommended incision for the maxillary third molar is also an envelope incision. The incision extends posteriorly over the tuberosity from the distal aspect of the second molar and anteriorly to the mesial aspect of the first molar (Fig. 10.43A–B). In situations in which greater access is required (e.g., in a deeply embedded impaction), a release incision extending from the mesial aspect of the second molar can be used (Fig. 10.43C–D).

In the removal of third molars, it is vital that the flap be large enough for adequate access and visibility of the surgical site. The flap must have a broad base if a releasing incision is used. The incision must be made with a smooth stroke of the scalpel, which is kept in contact with bone throughout the entire incision so that the mucosa and periosteum are completely incised. This allows a full-thickness mucoperiosteal flap to be reflected. The incision should be designed so it can be closed over solid bone (rather than over a bony defect). This is achieved by extending the incision at least one tooth anterior to the surgical site when a vertical-releasing incision is used. The incision should avoid vital anatomic structures. Only a single releasing incision should be used.

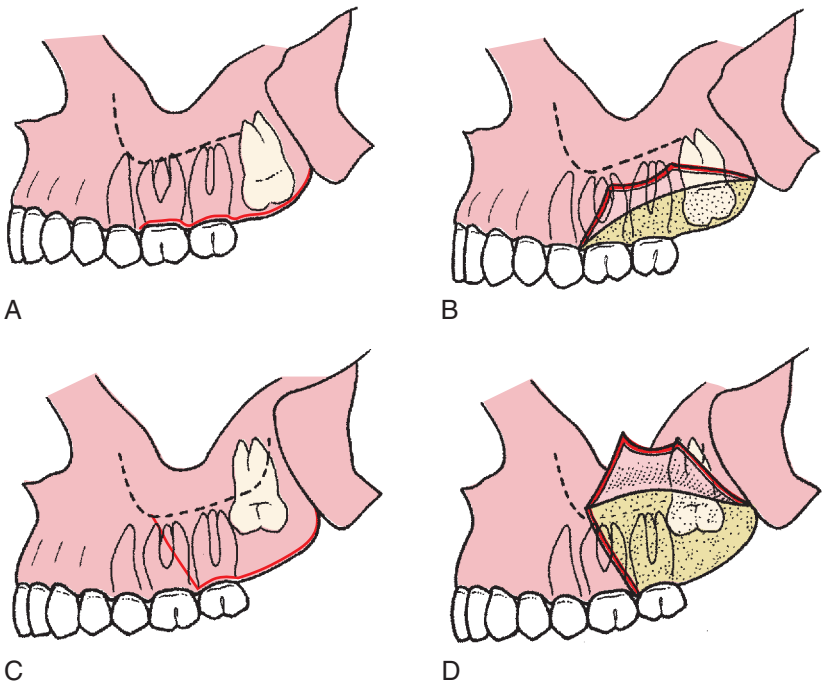
Step 2: Removal of Overlying Bone

Once the soft tissue is elevated and retracted so that the surgical field can be visualized, the surgeon must make a judgment concerning the amount of bone to be removed. In some situations the tooth can be sectioned with a burr and delivered without bone removal. However, in most cases, some bone removal is required.

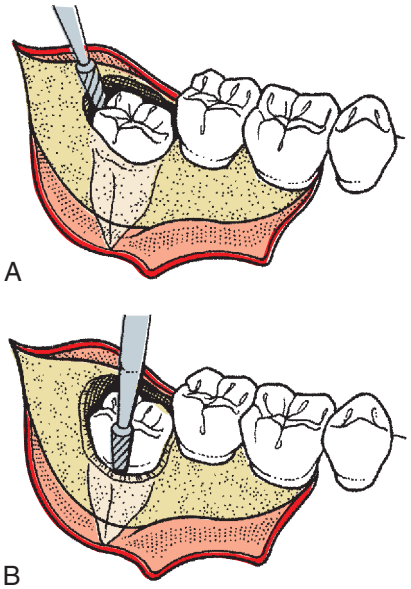
The bone on the occlusal aspect and on the buccal and distal aspects, down to the cervical line of the impacted tooth, should be removed initially. The amount of bone that must be removed varies with the depth of the impaction, the morphology of the roots, and the angulation of the tooth. Bone should not be removed



• **Fig. 10.42** (A) The envelope incision is most commonly used to reflect soft tissue for removal of the impacted third molar. Posterior extension of the incision should laterally diverge to avoid injury to the lingual nerve. (B) The envelope incision is laterally reflected to expose bone overlying the impacted tooth. (C) When a three-cornered flap is made, a releasing incision is made at the mesial aspect of the second molar. (D) When the soft tissue flap is reflected by means of a releasing incision, greater visibility is possible, especially at the apical aspect of the surgical field.



• **Fig. 10.43** (A) The envelope flap is the most commonly used flap for the removal of maxillary impacted teeth. (B) When soft tissue is reflected, the bone overlying the third molar is easily visualized. (C) If the tooth is deeply impacted, a releasing incision into the vestibule can be used to gain greater access. (D) When the three-cornered flap is reflected, the more apical portions become more visible.



• **Fig. 10.44** (A) After soft tissue has been reflected, bone overlying the occlusal surface of the tooth is removed with a fissure burr. (B) The bone on the buccodistal aspect of the impacted tooth is then removed with a burr.

from the lingual aspect of the mandible because of the likelihood of damaging the lingual nerve and because it is unnecessary.

The burrs that are used to remove the bone overlying the impacted tooth vary with surgeons' preferences. A large round burr, such as a No. 8, is desirable because it is an end-cutting burr and can be used effectively for drilling with a pushing motion. The tip of a fissure burr, such as a No. 703, does not cut well, but the edge rapidly removes bone and quickly sections teeth when used in a lateral direction. Note that a dental handpiece such as that used for restorative dentistry should never be used to remove bone around third molars or to section them.

The typical bone removal for the extraction of an impacted mandibular tooth is illustrated in Fig. 10.44. Bone on the occlusal aspect of the tooth is removed first to expose the crown of the tooth. Then, cortical bone on the buccal aspect of the tooth is removed down to the cervical line. Next, the burr can be used to remove bone between the tooth and cortical bone in the cancellous area of bone with a maneuver called *ditching*. This provides access for elevators to gain purchase points and a pathway for delivery of the tooth. No bone is removed from the lingual aspect so as to protect the lingual nerve from injury.

For maxillary teeth, bone removal is usually unnecessary, but when it is, bone is removed primarily on the buccal aspect of the tooth, down to the cervical line to expose the entire clinical crown. Usually, bone removal can be accomplished with a periosteal elevator, rather than a burr. Additional bone usually must be removed on the mesial aspect of the tooth to allow an elevator an adequate purchase area to deliver the tooth.

Step 3: Sectioning the Tooth

Once sufficient amounts of bone have been removed from around the impacted tooth, the surgeon should assess the need to section the tooth. Sectioning allows portions of the tooth to be removed separately with elevators through the opening provided by bone removal.

The direction in which the impacted tooth should be divided depends primarily on the angulation of the impacted tooth and any root curvature. Although minor modifications are necessary for teeth with divergent roots or for teeth that are more or less deeply impacted, the most important determinant is the angulation of the tooth.

Tooth sectioning is performed with a burr, and the tooth is sectioned three fourths of the way toward the lingual aspect. The burr should not be used to section the tooth completely through in the lingual direction because this is more likely to injure the lingual nerve. A straight elevator is inserted into the slot made by the burr and is rotated to split the tooth.

The mesioangular mandibular impaction is usually the least difficult impaction to remove of the four basic angulation types. After sufficient bone has been removed, the distal half of the crown is sectioned off at the buccal groove to just below the cervical line on the distal aspect. This portion is removed. The remainder of the tooth is removed with a No. 301 elevator placed at the mesial aspect of the cervical line. A mesioangular impaction also can be removed by preparing a purchase point in the tooth with the drill and by using a Crane pick elevator to elevate the tooth from the socket (Fig. 10.45).

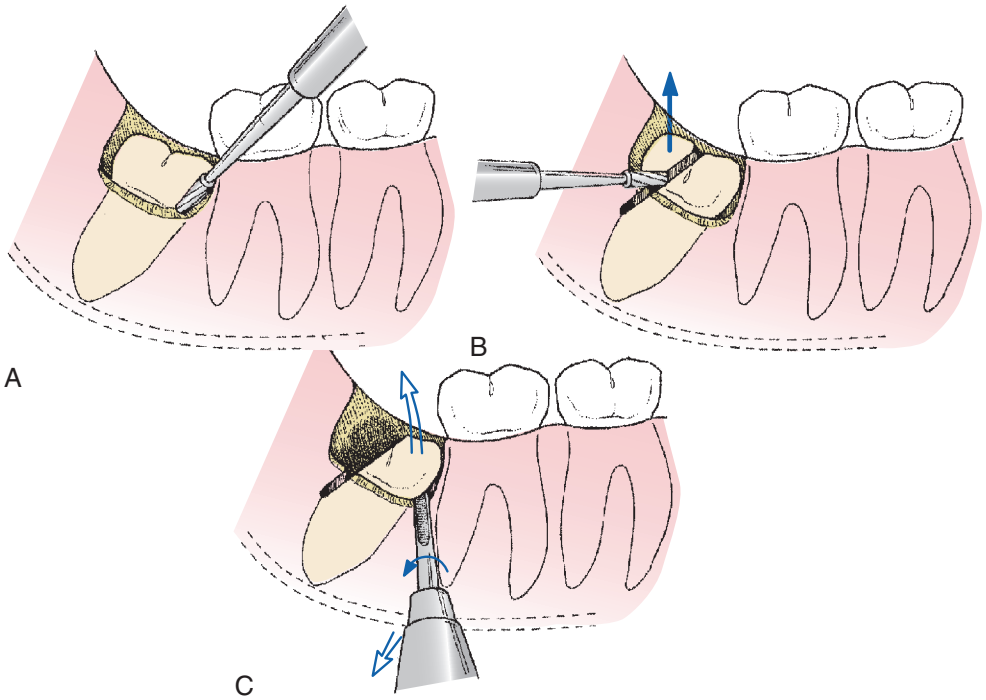
The next impaction with respect to difficulty to remove is the horizontal impaction. After sufficient bone has been removed down to the cervical line to expose the superior aspect of the distal root and the majority of the buccal surface of the crown, the tooth is sectioned by dividing the crown of the tooth from the roots at the cervical line. The crown of the tooth is removed, and the roots are displaced with a Cryer elevator into the space previously occupied by the crown. If the roots of an impacted third molar are divergent, they may require sectioning into two separate portions to be delivered individually (Fig. 10.46).

The vertical impaction is one of the two most difficult impactions to remove. The procedure of bone removal and sectioning is similar to the mesioangular impaction; that is, the occlusal buccal and distal bone is removed. The distal half of the crown is sectioned and removed, and the tooth is elevated by applying an elevator at the mesial aspect of the cervical line of the tooth. This is more difficult than a mesioangular removal because access around the mandibular second molar is difficult to obtain and requires the removal of substantially more bone on the buccal and distal sides (Fig. 10.47).

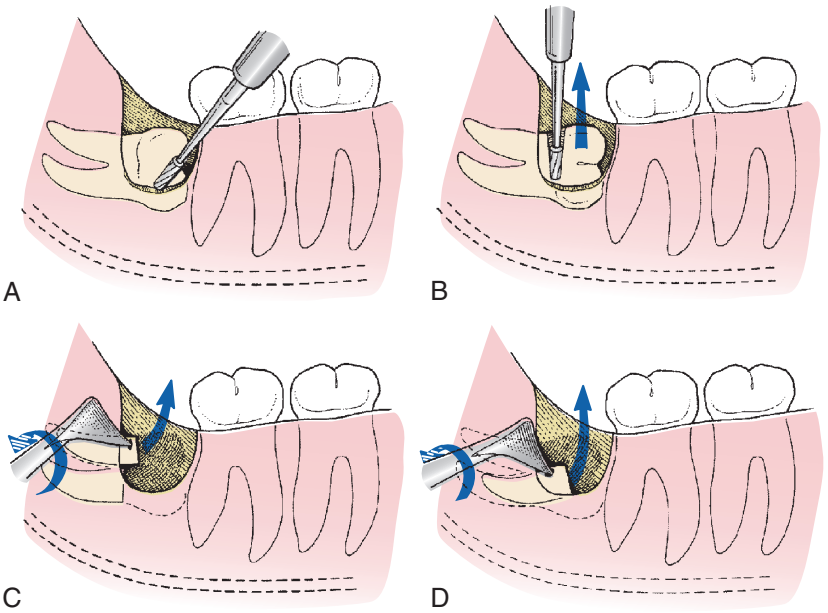
The most difficult tooth to remove is the distoangular impaction. After sufficient bone is removed from the bucco-occlusal and the distal sides of the tooth, the crown is sectioned from the roots just above the cervical line. The entire crown is usually removed because it interferes with visibility and access to the root structure of the tooth. If the roots are fused, a Cryer or a straight elevator can be used to elevate the tooth into the space previously occupied by the crown. If the roots are divergent, they are usually sectioned into two pieces and individually delivered. Extracting this impaction is difficult because so much distal bone must be removed and the tooth tends to rotate distally when elevated, running into the ramus portion of the mandible (Fig. 10.48).

Impacted maxillary teeth are rarely sectioned because the overlying bone is usually thin and relatively elastic. In situations in which the bone is thicker or the patient is older (and therefore the bone not so elastic), tooth extraction is usually accomplished by bone removal rather than by tooth sectioning.

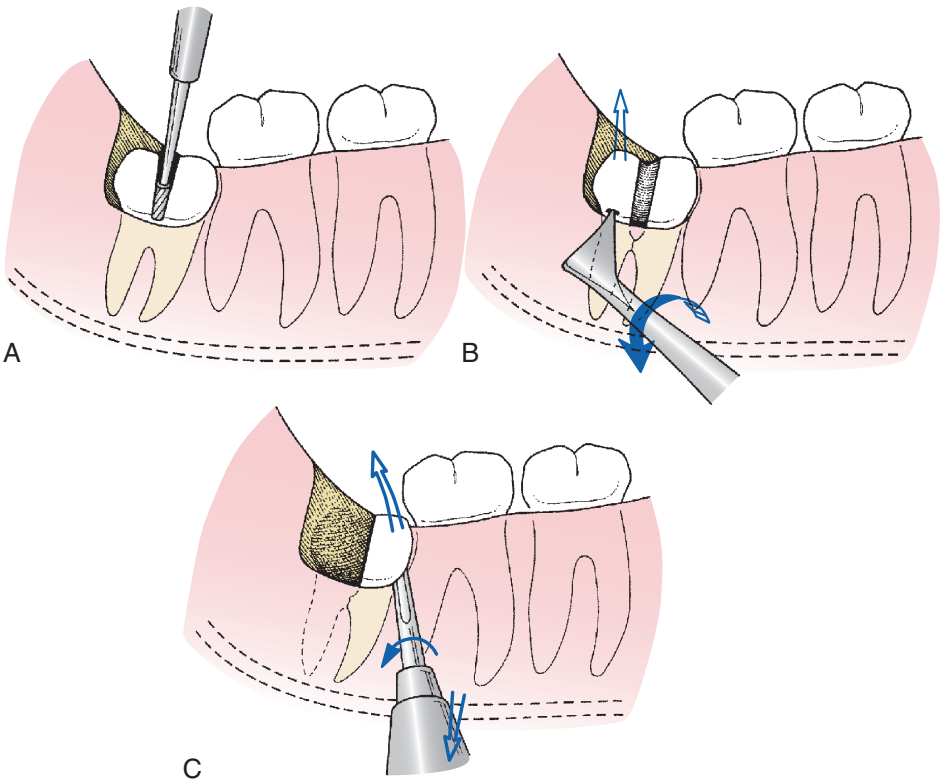
In general, impacted teeth elsewhere in the mouth are usually sectioned only at the cervical line. This permits removal of the crown portion of the tooth, displacement of the root portion into



• **Fig. 10.45** (A) When removing a mesioangular impaction, buccodistal bone is removed to expose the crown of the tooth to the cervical line. (B) The distal aspect of the crown is then sectioned from the tooth. Occasionally, it is necessary to section the entire tooth into two portions rather than to section the distal portion of the crown only. (C) After the distal portion of the crown has been delivered, a small straight elevator can be inserted into the surgically exposed mesial aspect of the crown to deliver the remainder of the tooth as shown. Alternatively, a purchase point can be placed near the base of the crown near the mesial aspect of the tooth and a Crane pick used to elevate the tooth (not shown).



• **Fig. 10.46** (A) During the removal of a horizontal impaction, bone overlying the tooth (i.e., bone on the distal and buccal aspects of the tooth) is removed with a burr. (B) The crown is then sectioned from the roots of the tooth and delivered from the socket. (C) Roots are then delivered together or independently by the Cryer elevator used with a rotational motion. Roots may require separation into two parts; occasionally, a purchase point is made in the root to allow the Cryer elevator to engage it. (D) The mesial root of the tooth is elevated in a similar fashion.



• **Fig. 10.47** (A) When removing vertical impaction, the bone on the occlusal, buccal, and distal aspects of the crown is removed and the tooth is sectioned into mesial and distal sections. If the tooth has a single-fused root, the distal portion of the crown is sectioned off in a manner similar to that depicted for mesioangular impaction. (B) The posterior aspect of the crown is elevated first with the Cryer elevator inserted into a small purchase point in the distal portion of the tooth. (C) A small straight No. 301 elevator is then used to elevate the mesial aspect of the tooth by a rotary-and-lever type of motion.

the space previously occupied by the crown, and removal of the root portion.

Step 4: Delivery of the Sectioned Tooth With Elevator

Once adequate bone has been removed to expose the tooth and the tooth has been sectioned in the appropriate fashion, the tooth is delivered from the alveolar process with dental elevators. In the mandible the most frequently used elevators are the straight elevator, the paired Cryer elevator, or the Crane pick.

An important difference between the removal of an impacted mandibular third molar and of a tooth elsewhere in the mouth is that almost no luxation of the tooth occurs for the purpose of expansion of the buccal or linguocortical plate. Instead, bone is removed, and teeth are sectioned to prepare an unimpeded pathway for delivery of the tooth.

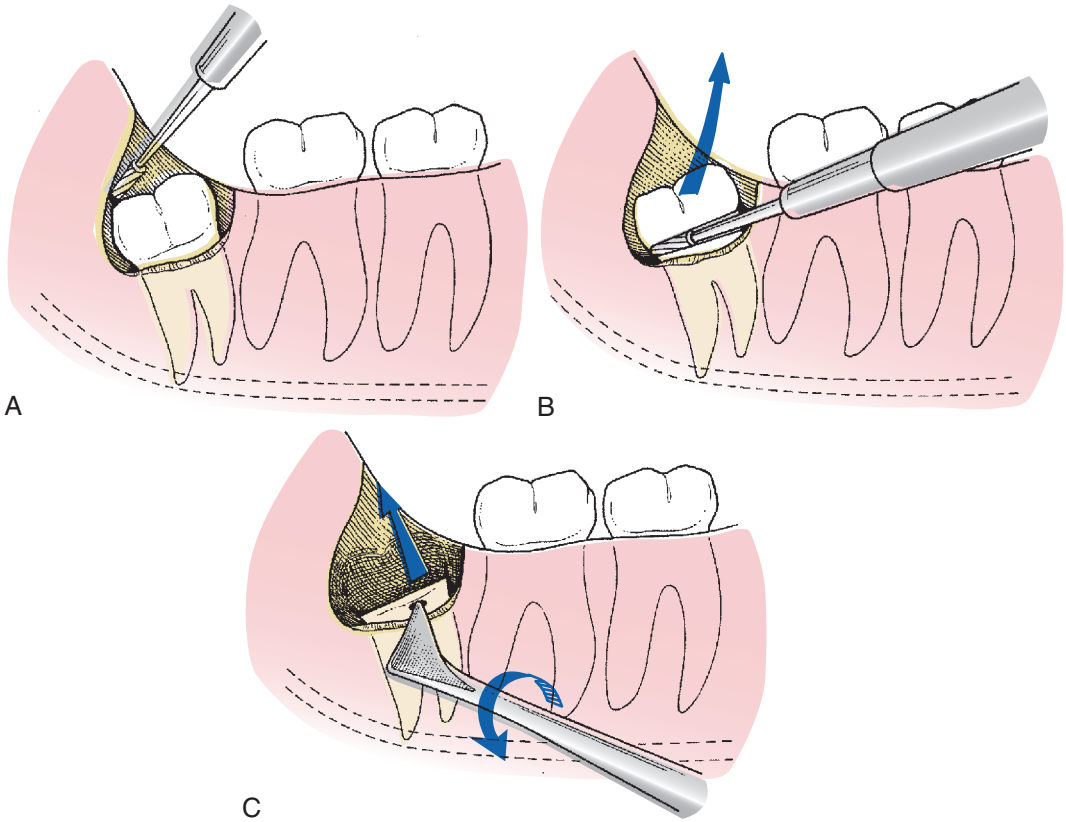
Application of excessive force may result in unfavorable fracturing of the tooth, of excessive buccal bone, of the adjacent second molar, or possibly of the entire mandible.

Elevators are designed not to deliver excessive force but to engage the tooth or tooth root and to apply force in the proper direction. Some surgeons use a root tip pick to remove sectioned roots from their sockets. Because the impacted tooth has never sustained occlusal forces, the periodontal ligaments are weak and permit displacement of the tooth root if appropriate bone is removed and force is delivered in the proper direction.

Delivery of maxillary third molars is accomplished with small straight elevators, which distobuccally luxate the tooth. Some surgeons prefer angled elevators such as Potts, Miller, or Warwick elevators, which aid in gaining access to the impacted tooth. The elevator tip is inserted into the area at the mesial cervical line, and pressure is applied to displace the tooth in the distobuccal direction (Fig. 10.49). The surgeon should be cautious about applying excessive pressure anteriorly to avoid damage to the root of the maxillary second molar. In addition, as pressure is applied to displace the tooth posteriorly, the surgeon should have a finger on the tuberosity of the maxilla (especially if the impaction is mesioangular) so that if a fracture does occur, steps can be taken to salvage the tuberosity of the maxilla by maintaining the soft tissue attachments. Palpation during elevation also helps the surgeon determine if the tooth is being delivered through the open wound or is, instead, being misdirected into the infratemporal space.

Step 5: Preparing for Wound Closure

A bone file is used to smooth any sharp, rough edges of bone, particularly where an elevator was in bony contact. The surgeon should next direct attention to removing all particulate bone chips and debris from the wound. This is done with vigorous irrigation with sterile saline. Special care should be taken to irrigate thoroughly under the reflected soft tissue flap. A small hemostat can be used to remove any remnants of the dental follicle, if present. Once the follicle is grasped, it is lifted with a slow, steady pressure, and it



• **Fig. 10.48** (A) For distoangular impaction, occlusal, buccal, and distal bone is removed with a burr. It is important to remember that more distal bone must be taken off than for vertical or mesioangular impaction. (B) The crown of the tooth is sectioned off with a burr, and the crown is delivered with a straight elevator. (C) The purchase point is put into the remaining root portion of the tooth, and the roots are delivered with the Cryer elevator with a wheel-and-axle type of motion. If the roots diverge, it may be necessary, in some cases, to split them into independent portions.

will pull free from the surrounding hard and soft tissues. A final irrigation and a thorough inspection should be performed before the wound is closed.

The surgeon should check for adequate hemostasis. Bleeding can occur from a vessel in the flap from the bone marrow that has been cut with a burr or from the inferior alveolar vessels. Specific bleeding points should be controlled if they exist. If brisk generalized ooze is seen after the sutures are placed, the surgeon should apply firm pressure with a small, moistened gauze pack. Postoperative bleeding to some degree occurs relatively frequently after third molar extraction but is usually self-limited if adequate hemostasis is achieved at the time of the operation.

At this point, many surgeons deliver an antibiotic such as tetracycline into the sockets of lower third molars to help prevent osteitis sicca (dry socket).

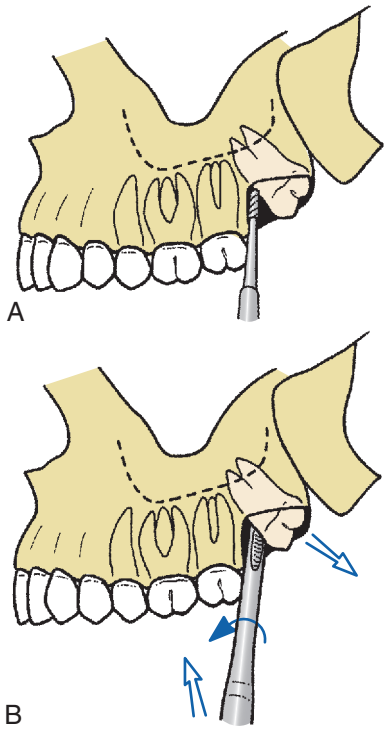
The closure of the incision made for an impacted third molar is usually a primary closure. If the flap was well designed and not traumatized during the surgical procedure, it will fit into its original position. The initial suture should be placed through the attached tissue on the posterior aspect of the second molar. Additional sutures are placed posteriorly from that position and anteriorly through the papilla on the mesial side of the second molar. Usually, only two or three sutures are necessary to close an envelope incision. If a releasing incision was used, attention must be directed to closing that portion of the incision as well. If the flap for a maxillary third molar rests passively in place postoperatively, suturing may not be necessary.

Perioperative Patient Management

The removal of impacted third molars is a surgical procedure that is usually associated with a great deal of patient anxiety. In addition, this surgical procedure can involve unpleasant noises and sensations. As a result, surgeons who routinely remove impacted third molars commonly recommend to their patients some type of profound anxiety control such as intravenous deep sedation or ambulatory general anesthesia.

The choice of technique is based on the surgeon's preference. However, the goals are to achieve a level of patient consciousness that allows the surgeon to work efficiently and that reduces the likelihood of an unpleasant experience for the patient.

In addition to the increased need for anxiety control, a variety of medications are used to control the sequelae of third molar extraction surgery. Combinations of codeine or codeine congeners with aspirin or acetaminophen are commonly used; however, recognize that codeine may be ineffective in many patients. The use of long-acting local anesthetics should be considered in the mandible. These anesthetics provide the patient with a pain-free period of 6 to 8 hours, during which prescriptions can be filled and analgesics taken. Analgesics are best begun at the point when



• **Fig. 10.49** Delivery of an impacted maxillary third molar. (A) Once soft tissue has been reflected, a small amount of buccal bone is removed with a burr or the pointed end of a periosteal elevator. (B) The tooth is then delivered with a small straight elevator, with a rotary-and-lever type of motion. The tooth is delivered in the distobuccal and occlusal directions. Note that in most circumstances, bone removal using a burr is not required when removing impacted maxillary third molars.

the patient first begins to recognize the return of sensation. Some surgeons even have patients begin analgesics before any return of sensation. The surgeon should consider writing a prescription for a potent oral analgesic for every patient who undergoes surgical removal of an impacted third molar, and, if the surgeon does separate consultation appointments, he or she should prescribe postoperative medications at that time so the patient and the patient's escort do not need to stop on the way home from the procedure. Enough doses should be prescribed to last for at least 3 or 4 days. Combinations of codeine or codeine congeners with aspirin or acetaminophen are commonly used. Nonsteroidal antiinflammatory drugs such as ibuprofen also may be of value for patients to use when the discomfort is less significant.

To minimize the swelling that is common after the surgical removal of impacted third molars, some surgeons give parenteral corticosteroids. Intravenous administration of a glucocorticoid steroid provides sufficient antiinflammatory activity to greatly limit edema. Although many different regimens and protocols for intravenous steroid administration exist, a relatively common one is the single administration of 8 mg dexamethasone before surgery. Dexamethasone is a long-acting steroid, and its efficacy in controlling third molar postsurgical edema is documented. This drug can then be continued in an oral dose of 0.75 to 1.25 mg twice a day for 2 to 3 days to continue edema control. Although steroids given in this manner have few side effects or contraindications, the general philosophy of weighing the risks and benefits of drug administration must be carefully followed before the decision is made to give any drugs routinely.

Some surgeons recommend the use of ice packs or packages of frozen peas on the face to help prevent postoperative swelling, even though studies show that it is unlikely that the ice has much effect on preventing or limiting swelling. However, patients frequently report that the coldness makes them feel more comfortable.

Another medication that is sometimes used is an antibiotic. If a patient has a preexisting pericoronitis or periapical abscess, it is common to prescribe antibiotics for a few days after surgery. However, if the patient is healthy and the clinician finds no systemic indication for antibiotics or a preexisting local infection, systemic antibiotics are usually not indicated. The use of a topical antibiotic, such as minocycline, has been scientifically shown to greatly lower the incidence of osteitis sicca (dry socket) in mandibular molar extraction sites.

The normal postoperative experience of a patient after surgical removal of an impacted third molar is more involved than after a routine extraction. The patient can expect a modest amount of edema in the area of the surgery for 3 to 4 days, with the swelling completely dissipating by about 5 to 7 days. The amount of swelling depends on the degree of tissue trauma and the variability among patients with the potential for swelling.

A modest amount of discomfort usually follows the procedure, the degree of which depends on the amount of surgical trauma necessary to remove impacted teeth. This discomfort can be effectively controlled with oral analgesics. Patients usually require analgesics for 2 or 3 days routinely and intermittently (particularly at bedtime) for several more days. The patient may have some mild soreness in the region for up to 2 to 3 weeks after the surgery.

Patients who have had mandibular third molars surgically removed frequently have mild to moderate trismus. This inability to open the mouth interferes with the patient's normal oral hygiene and eating habits. Patients should be warned that they will be unable to open their mouths normally after surgery. The trismus gradually resolves, and the ability to open the mouth should return to normal by 7 to 10 days after surgery.

If pain, edema, and trismus have not greatly improved by 7 days after surgery, the surgeon should investigate the cause.

All of the sequelae of the surgical removal of impacted teeth are of less intensity in the young, healthy patient and of far greater intensity in the older, more debilitated patient. Even healthy adult patients between the ages of 35 and 40 years have a significantly more difficult time after extraction of impacted third molars than do most healthy teenaged patients.

See Chapter 11 for a more detailed description of postoperative care.

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11

Postextraction Patient Management

JAMES R. HUPP

CHAPTER OUTLINE

Many patients have more preoperative concerns about the sequelae of surgery—such as pain, swelling, and complications—than about the procedure itself. This is particularly true if they have confidence in the surgeon and planned anesthesia. The surgeon can do many things to mitigate the common problems patients face after surgery. This chapter discusses those strategies. This chapter also discusses the most common complications, some minor and some more serious, that occur during and after oral surgical procedures. These are surgical complications, as opposed to medical complications, which are discussed in Chapter 2.

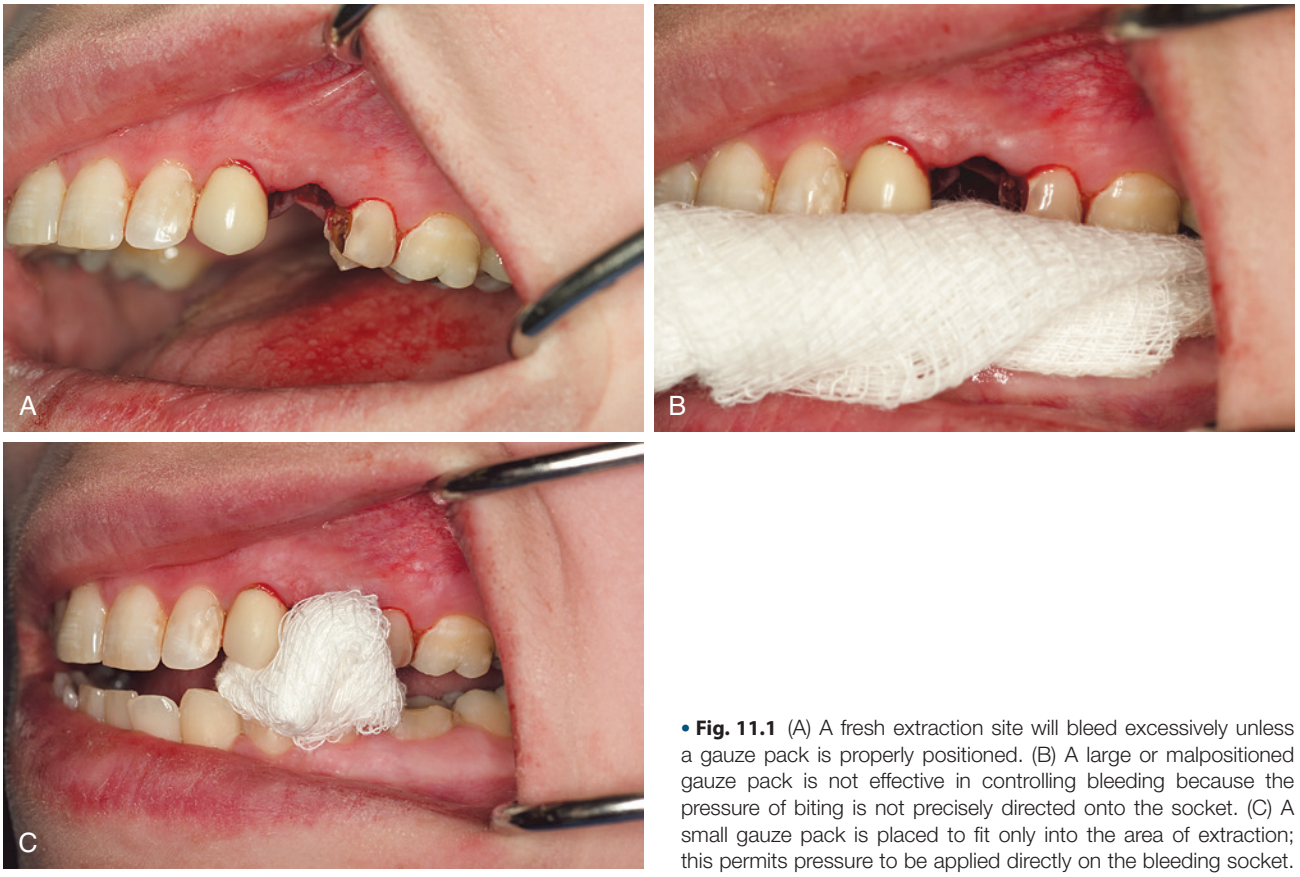
Once the surgical procedure has been completed, the patient and anyone accompanying him or her should be given proper instructions on how to care for common postsurgical sequelae that may occur on the day of surgery and that often last for a few days. Postoperative instructions should explain what the patient is likely to experience, why these phenomena occur, and how to manage and control typical postoperative situations. The instructions should be given to the patient verbally and in written or printed form on paper, in easily understood layperson terms. These postoperative instructions should describe the most common complications and how to identify them so that problems such as infection can be caught at an early stage. The instructions should also include a telephone number at which the surgeon or covering on-call doctor can be reached in case of an emergency.

Control of Postoperative Sequelae

Hemorrhage

Once an extraction has been completed, the initial maneuver to control postoperative bleeding is the placement of a folded gauze directly over the socket. Large packs that cover the occlusal surfaces of teeth adjacent to the extraction site do not apply pressure to the bleeding socket and are therefore ineffective (Fig. 11.1). The gauze may be moistened so that the oozing blood does not coagulate in the gauze and then dislodge the clot when the gauze is removed. The patient should be instructed to bite firmly on this gauze for at least 30 minutes and not to chew on the gauze. The patient should hold the gauze in place without opening the mouth.

Patients should be informed that it is normal for a fresh extraction site to ooze slightly for up to 24 hours after the extraction procedure. Patients should be warned that a small amount of blood mixed with a large amount of saliva might appear to be a large amount of blood. If the bleeding is more than a slight ooze, the patient should be told how to reapply a folded piece of gauze directly over the area of the extraction. The patient should be instructed to hold this second



• **Fig. 11.1** (A) A fresh extraction site will bleed excessively unless a gauze pack is properly positioned. (B) A large or malpositioned gauze pack is not effective in controlling bleeding because the pressure of biting is not precisely directed onto the socket. (C) A small gauze pack is placed to fit only into the area of extraction; this permits pressure to be applied directly on the bleeding socket.

gauze pack in place for as long as 1 hour to gain control of bleeding. Further control can be attained, if necessary, by the patient placing a tea bag in the socket and biting on it for 30 minutes. The tannic acid in regular tea serves as a local vasoconstrictor.

Patients should be cautioned to avoid things that may aggravate the bleeding. Talking should be kept to a minimum for an hour. Tobacco smoke and nicotine interfere with wound healing, so patients should be encouraged to stop or limit smoking. The patient should also be told not to suck thick fluids through a straw when drinking because this creates negative intraoral pressure. The patient should not spit during the first 12 hours after surgery. The process of spitting involves negative pressure and mechanical agitation of the extraction site, which may trigger fresh bleeding. Patients who strongly dislike having blood in the mouth should be encouraged to bite firmly on a piece of gauze to control the hemorrhage and to swallow their saliva instead of spitting it out. Finally, no strenuous exercise should be performed for the first 12 to 24 hours after extraction because the increased blood pressure may result in greater bleeding.

Patients should be warned that there may be some oozing and staining of their saliva while they are asleep and that they will probably have some blood stains on their pillowcases in the morning. Forewarning them of this probability will prevent many frantic telephone calls to the surgeon in the middle of the night. Patients should also be instructed that if they are worried about their bleeding, they should call to get additional advice. Prolonged oozing, bright red bleeding, or large clots in the patient's mouth are indications for a return visit. The dentist should then examine the area closely and apply appropriate measures to control the hemorrhage and consider having a surgical specialist assist with patient management.

Pain and Discomfort

All patients expect a certain amount of discomfort after any surgical procedure, so it is useful for the dentist to discuss this issue carefully with each patient before the procedure begins. The surgeon should help the patient have a realistic expectation of what type of pain may occur and correct any misconceptions of how much pain is likely to occur.

Patients who make a point of informing the surgeon that they expect a great deal of pain after surgery should not be ignored or automatically told to take an over-the-counter analgesic because these patients are most likely to experience pain postoperatively. It is important for the surgeon to assure patients that their postoperative discomfort can and will be effectively managed.

The pain a patient may experience after a surgical procedure such as tooth extraction is highly variable and to a great extent depends on the patient's preoperative expectations. The surgeon who spends some time discussing these issues with the patient before surgery will be able to design the most appropriate analgesic regimen.

All patients should be given instruction concerning analgesics before they are discharged. Even when the surgeon believes that no prescription analgesics are necessary, the patient should be told to take ibuprofen or acetaminophen postoperatively to prevent initial discomfort before the effects of the local anesthetic disappear. Patients who are expected to have a higher level of pain should be given a prescription analgesic to help control the pain. The surgeon should also take care to advise the patient that the goal of analgesic medication is management of pain and not elimination of all discomfort.

It is useful for the surgeon to understand the three characteristics of the pain that occurs after routine tooth extraction: (1) The pain

is usually not severe and can be managed in most patients with over-the-counter analgesics, (2) the peak pain experience occurs about 12 hours after the extraction and diminishes rapidly after that, and (3) significant pain from extraction rarely persists longer than 2 days after surgery. With these three factors in mind, patients can be appropriately advised regarding the effective use of analgesics.

The first dose of analgesic medication should be taken before the effects of the local anesthetic subside. If this is done, the patient is less likely to experience the intense, sharp pain after the effects of local anesthesia subside. Postoperative pain is much more difficult to manage if administration of analgesic medication is delayed until the pain is severe. It may take 60 to 90 minutes for the analgesic to become fully effetive. If the patient waits to take the first dose of analgesic until the effects of local anesthesia have subsided, the patient may become impatient, waiting for the effect, and may take additional medication thus increasing the likelihood of nausea and vomiting.

The strength of the analgesic is also important. Potent analgesics are not required in most routine postextraction situations; instead, analgesics with a lower potency per unit dose are typically sufficient. The patient can then be told to take one or two unit doses as necessary to control pain. More precise pain control is achieved when the patient takes an active role in determining the amount of medication to take.

Patients should be warned that taking narcotic medications often results in drowsiness and an increased chance of gastric upset. In most situations, patients should avoid taking narcotic pain medications on an empty stomach. Prescriptions should be written with instructions to the patient to have a snack or a meal before taking a narcotic analgesic.

Ibuprofen has been demonstrated to be an effective medication to control discomfort from a tooth extraction. Ibuprofen has the disadvantage of causing a decrease in platelet aggregation and bleeding time, but this does not appear to have a clinically important effect on postoperative bleeding in most patients. Acetaminophen does not interfere with platelet function and may be useful in certain situations in which the patient has a platelet defect and is likely to bleed. If the surgeon prescribes a combination drug containing acetaminophen and narcotic, it should be a combination that delivers 500 to 650 mg of acetaminophen per dose.

Drugs that are useful in situations in which patients have varying degrees of pain are listed in Table 11.1. Centrally acting opioid analgesics are frequently used to control pain after tooth extraction. The most commonly used drugs are codeine, the codeine congeners oxycodone and hydrocodone, and tramadol. These narcotics are well absorbed from the gut but may produce drowsiness and gastrointestinal upset. Opioid analgesics are rarely used alone in dental prescriptions; instead, they are formulated with other analgesics, primarily aspirin or acetaminophen. Codeine can be a useful postextraction analgesic because it carries little narcotic abuse potential. However, it is important to note that a large percentage of the population lacks the enzyme necessary to make codeine effective. When codeine is used, the amount of codeine is frequently designated by a numbering system. Compounds labeled No. 1 have 7.5 mg codeine; No. 2, 15 mg; No. 3, 30 mg; and No. 4, 60 mg. When a combination of analgesic drugs is used, the dentist must keep in mind that it is necessary to provide 500 to 1000 mg aspirin or acetaminophen every 4 hours to achieve maximal effectiveness from the nonnarcotic. Many of the compound drugs have only 300 mg aspirin or acetaminophen added to the narcotic. An example of a rational approach would be to prescribe a compound containing 300 mg of acetaminophen and either 30 mg codeine (No. 3) or 5 mg hydrocodone. The usual adult dose would be 2 tablets of the compound every 4 hours. Should the patient require stronger analgesic action, 2 tablets of acetaminophen and codeine may be taken for increased effectiveness. Doses that supply 30 to 60 mg of codeine or 5 mg of hydrocodone but only 300 mg of acetaminophen fail to provide full advantage of the analgesic effect of acetaminophen (Table 11.2).

The Drug Enforcement Administration controls narcotic analgesics. To write prescriptions for these drugs, the dentist must

TABLE 11.1 Analgesics for Postextraction Pain

Oral Narcotic	Usual Dose
Mild Pain Situations	
Ibuprofen	400–800 mg q4h
Acetaminophen	325–500 mg q4h
Moderate Pain Situations	
Codeine	15–60 mg
Hydrocodone	5–10 mg
Severe Pain Situations	
Oxycodone	2.5–10 mg
Tramadol	50–100 mg

q4h, Every 4 hours.

TABLE 11.2 Commonly Used Combination Analgesics

Brand Name	Amount (mg)	Amount (mg)
Codeine–Acetaminophen	**Codeine**	**Acetaminophen**
Tylenol No. 2	15.0	300
Tylenol No. 3	30.0	300
Tylenol No. 4	60.0	300
Oxycodone–Aspirin	**Oxycodone**	**Aspirin**
Percodan	5.0	325
Percodan-demi	2.5	325
Oxycodone–Acetaminophen	**Oxycodone**	**Acetaminophen**
Percocet	2.5	325
	5.0	325
Tylox	5.0	325
Hydrocodone–Aspirin	**Hydrocodone**	**Aspirin**
Lortab ASA	5.0	325
Hydrocodone–Acetaminophen	**Hydrocodone**	**Acetaminophen**
Vicodin	5.0	325
Vicodin ES	7.5	325
Lorcet HD	5.0	325
Lortab Elixir	2.5 mg/5 mL	170 mg/5 mL

ASA, Acetylsalicylic acid.

have a Drug Enforcement Administration permit and number. The drugs are categorized into four basic schedules based on their potential for abuse. Several important differences exist between schedule II and schedule III drugs concerning writing prescriptions (see Appendix 2). Unfortunately, prescription narcotics are susceptible to misuse. Oxycodone- and hydrocodone-containing drugs are particularly sought after and abused. Narcotics tend to be addictive, leading to problems such as patients seeking drugs even when not in pain or nonpatients stealing drugs for their own use or to sell to others. The dental profession and others have developed guidelines for dentists to help limit the overprescription of narcotics and to manage any unused doses that might otherwise fall into the hands of a patient's family members or others with access to the patient's medications. Dentists should take advantage of professional educational offerings related to managing patient pain and the use of analgesic medications. Dentists should also have frank discussions with patients about the problem of opioid abuse and how they can help avoid its impact in their own lives.

It is important to emphasize that the most effective method of controlling pain is the establishment of a close relationship between the surgeon and the patient. A specific amount of time must be spent discussing the issue of postoperative discomfort, with the surgeon clearly demonstrating his or her concern for patient comfort. A prescription should be given with clear instructions about when to begin the medication and at what intervals it should be taken. If these procedures are followed, mild analgesics given for a short time (usually no longer than 2 to 3 days) are usually all that is required.

Diet

Patients who have had extractions may avoid eating because of local pain or fear of pain occurring when eating. In addition, the physical and emotional stress of undergoing surgery frequently lessens the appetite. Therefore they should be given specific instructions regarding their postoperative diet. A high-calorie, high-volume liquid or soft diet is best for the first 12 to 24 hours.

The patient must have an adequate intake of fluids, usually at least 2 L, during the first 24 hours. The fluids can be juices, milk, water, or any other nonalcoholic beverage that appeals to the patient.

Food in the first 12 hours should be soft and cool. Cool and cold foods help keep the local area comfortable. Ice cream and milkshakes, unlike harder solid foods, have less tendency to cause local trauma or initiate rebleeding episodes.

If the patient had multiple extractions in all areas of the mouth, a soft diet is recommended for several days after the surgical procedure. However, the patient should be advised to return to a normal diet as soon as possible.

Patients who have diabetes should be encouraged to return to their normal insulin and caloric intake as soon as possible. For such patients, the surgeon may plan surgery on only one side of the mouth at each surgical appointment, thus not overly interfering with normal caloric intake.

Oral Hygiene

Patients should be advised that keeping the teeth and the whole mouth reasonably clean results in a more reliable healing of surgical wounds. Postoperatively, on the day of surgery, patients may gently brush the teeth that are away from the area of surgery in the usual fashion. They should avoid brushing the teeth immediately adjacent to the extraction site to prevent a new bleeding episode and to avoid disturbing sutures and inducing more pain.

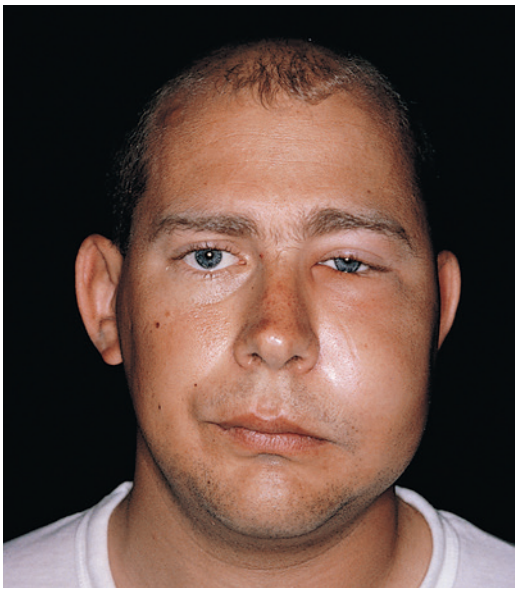
The the first postoperative day, patients should begin gentle rinses with dilute salt water. The water should be warm but not hot enough to burn the tissue. Most patients can resume their preoperative oral hygiene measures by the third or fourth day after surgery. Dental floss should be used in the usual fashion on teeth anterior and posterior to the extraction sites as soon as the patient is sufficiently comfortable doing so.

If oral hygiene is likely to be difficult after extractions in multiple areas of the mouth, mouth rinses with agents such as dilute hydrogen peroxide may be used. Rinsing three to four times a day for approximately 1 week after surgery may result in more reliable healing.

Edema

Some oral surgical procedures result in a certain amount of edema or swelling after surgery. Routine extraction of a single tooth will probably not result in swelling that the patient can see, whereas the extraction of multiple impacted teeth with reflection of soft tissue and removal of bone may result in moderately large amounts of swelling (Fig. 11.2). Swelling usually reaches its maximum 36 to 48 hours after the surgical procedure. Swelling begins to subside on the third or fourth day and is usually resolved by the end of the first week. Increased swelling after the third day may be an indication of infection rather than renewed postsurgical edema.

Once the surgery is completed and the patient is ready to be discharged, some dentists use ice packs or bags of frozen peas to help minimize the swelling and make the patient feel more comfortable; however, there is no evidence that the cooling actually controls this type of edema. Ice should not be placed directly on the skin; preferably a layer of dry cloth should be placed between the ice container and the tissue to prevent superficial tissue damage. The ice pack or small bags of frozen peas should be kept on the local area for 20 minutes and then kept off for 20 minutes over a period of 12 to 24 hours. The bags of peas should be refrozen after they warm.



• **Fig. 11.2** Extraction of impacted left maxillary and mandibular third molars was performed 2 days before this photograph was taken. The patient exhibits a moderate amount of facial edema, which resolved within 1 week of surgery.

On the second postoperative day, neither ice nor heat should be applied to the face. On the third and subsequent postoperative days, application of heat may help to resolve the swelling more quickly. Heat sources such as hot water bottles and heating pads are recommended. Patients should be warned to avoid high-level heat for long periods to prevent injuring the skin.

It is important to inform patients that some amount of swelling is to be expected. They should also be warned that the swelling may tend to wax and wane, occurring more in the morning and less in the evening because of postural variation. Sleeping in a more upright position by using extra pillows will help reduce facial edema. Patients should be informed that a moderate amount of swelling is a normal and healthy reaction of tissue to the trauma of surgery. Patients should not be concerned or frightened by swelling because it will resolve within a few days.

Trismus

Extraction of teeth, administration of a mandibular block, or both may result in trismus (limitation in mouth opening). Trismus results from trauma and the resulting inflammation involving the muscles of mastication. Trismus may also result from multiple injections of the local anesthetic, especially if the injections have penetrated muscles. The muscle most likely to be involved is the medial pterygoid muscle, which may be penetrated by the local anesthetic needle during the inferior alveolar nerve block.

Surgical extraction of impacted mandibular third molars usually results in some degree of trismus because the inflammatory response to the surgical procedure is sufficiently widespread to involve several muscles of mastication. Trismus is usually not severe and does not hamper the patient's normal activities. However, to prevent alarm, patients should be warned that this phenomenon might occur and that it will likely resolve within a week.

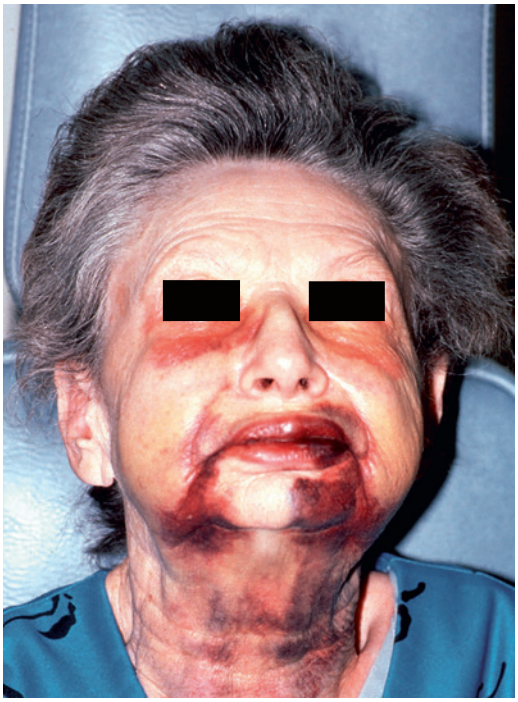
Ecchymosis

In some patients, blood oozes submucosally and subcutaneously; this appears as a bruise in the oral tissues, the face, or both (Fig. 11.3). Blood in the submucosal or subcutaneous tissues is known as *ecchymosis*. Ecchymosis is usually seen in older patients because of their decreased tissue tone, increased capillary fragility, and weaker intercellular attachments. Ecchymosis is not dangerous and does not increase pain or infection. Patients should, however, be warned that ecchymosis may occur because if they awaken on the second postoperative day and see bruising in the cheek, submandibular area, or anterior neck, they may become apprehensive. This anxiety is easily prevented by postoperative instructions. Typically the onset of ecchymosis is 2 to 4 days after surgery and it usually resolves fully within 7 to 10 days.

Postoperative Follow-up

All patients seen by novice surgeons should be given a return appointment so that the surgeon can check the patient's progress after the surgery and learn about the appearance of a normally healing socket. In routine, uncomplicated procedures, a follow-up visit at 1 week is usually adequate. Sutures should be removed, as needed, at the 1-week postoperative appointment.

Patients should be informed that if any question or problem arises, they should call the dentist and, if necessary, request an earlier follow-up visit. The most likely reasons for an earlier visit are prolonged bleeding, pain that is not responsive to the prescribed medication, and suspected infection.



• **Fig. 11.3** Moderate widespread ecchymosis of right side of face and neck is exhibited in an older patient after extraction of several mandibular teeth.

If a patient who has had surgery begins to develop swelling with surface redness, fever, pain, or all of these symptoms on the third postoperative day or later, it can be assumed that the patient has developed an infection until proven otherwise. The patient should be instructed to call the dentist's office immediately. The surgeon should then inspect the patient carefully to confirm or rule out the presence of an infection. If an infection is diagnosed, appropriate therapeutic measures should be taken (see Chapter 16).

Postsurgical pain that decreases at first but begins to increase on the third or fourth day, although not accompanied by swelling or other signs of infection, is probably a symptom of dry socket. This problem is usually confined to lower molar sockets and does not represent an infection. This annoying problem is straightforward to manage but may require that the patient return to the office several times (see Chapter 10).

Operative Note

The surgeon must enter into the records a note of what transpired during each visit. Whenever surgery is performed, some critical factors should be entered into the record. The first is the date of the operation and a brief identification of the patient; then the surgeon states the diagnosis and reason for the extraction (e.g., nonrestorable teeth due to caries or severe periodontal disease).

Comments regarding the patient's pertinent medical history, medications, and vital signs should be noted in the chart. The oral examination done at the time of surgery should be documented briefly in the record.

The surgeon should record the type and amount of anesthetic used. For example, if the drug prescribed was lidocaine with a

• BOX 11.1 Elements of an Operative Note

- Date
- Patient name and identification
- Diagnosis of problem to be managed surgically
- Review of medical history, medications, and vital signs
- Oral examination
- Anesthesia (amount used)
- Procedure (including description of surgery and complications)
- Discharge instructions
- Medications prescribed and their amounts (or attach copy of prescription)
- Need for follow-up appointment
- Signature (legible or printed underneath)

vasoconstrictor, the dentist would write down the dosages of lidocaine and epinephrine in milligrams.

The surgeon should then write a brief note about the procedure performed and any problems that occurred intraoperatively.

A comment concerning discharge instructions, including postoperative instructions that were given to the patient, should be recorded. The prescribed medications are listed, including the name of the drug, its dose, and the total number of doses. Alternatively, copies of the prescriptions can be added to the record. Finally, the need for a return appointment is recorded if indicated (Box 11.1; see Appendix 1).

With electronic record keeping, built-in fields are often present to document certain aspects of patient visits. The requirements for patient documentation described previously still apply, but these details may be recorded in various ways, depending on the software program used.

Prevention and Management of Complications

As in the case of medical emergencies, the best way to manage surgical complications is to prevent them from happening. Prevention of surgical complications is ideally accomplished by a thorough preoperative assessment and comprehensive treatment plan followed by careful execution of the surgical procedure. Only when these are routinely performed can the surgeon expect to have few complications. However, even with such planning and the use of excellent surgical techniques, complications still occasionally occur. In situations where the dentist has planned carefully, the complication is often predictable and can be managed routinely. For example, in extracting a maxillary first premolar that has long thin roots, it is far easier to remove the buccal root than the palatal root. Therefore the surgeon will use more force toward the buccal root than toward the palatal root so that if a root does fracture, it will more likely involve the buccal root rather than the palatal root. In most cases buccal root retrieval is more straightforward.

Dentists must perform surgery that is within the limits of their capabilities. They must therefore carefully evaluate their training and abilities before deciding to perform a specific surgical task. Thus, for example, it is inappropriate for a dentist with limited experience in the management of impacted third molars to undertake the surgical extraction of an embedded tooth. The incidence of operative and postoperative complications is unacceptably high in this situation. Surgeons must be cautious of unwarranted optimism, which can cloud their judgment and prevent them from delivering the best possible care. The dentist must keep in mind that referral to a specialist is an option that should always be exercised if the planned surgery is beyond the dentist's own skill level. In some situations, this is not only a moral obligation but also wise medicolegal risk management and provides peace of mind.

In planning a surgical procedure, the first step is always a thorough review of the patient's medical history. Several of the complications discussed in this chapter can be caused by inadequate attention to medical histories that would have revealed the presence of a factor that would increase surgical risk.

One of the primary ways to prevent complications is by obtaining adequate images and carefully reviewing them (see Chapter 8). Radiographs must include the entire area of surgery, including the apices of the roots of the teeth to be extracted as well as local and regional anatomic structures such as the adjacent parts of the maxillary sinus or the inferior alveolar canal. The surgeon should look for the presence of abnormal tooth root morphology or signs that the tooth may be ankylosed. After careful examination of the radiographs, the surgeon may need to alter the treatment plan to prevent or limit the magnitude of the complications that might be anticipated with a closed extraction. Instead, the surgeon should consider surgical approaches to removing teeth in such cases.

After an adequate medical history has been taken and the radiographs have been analyzed, the surgeon goes on to preoperative planning. This is not simply a preparation of a detailed surgical plan and needed instrumentation but also a plan for managing patient pain and anxiety and postoperative recovery (instructions and modifications of normal activity for the patient). Thorough preoperative instructions and explanations for the patient are essential in preventing or limiting the impact of the majority of complications that occur in the postoperative period. If the instructions are not carefully explained and the importance of compliance made clear, the patient is less likely to comply with them.

To keep complications at a minimum, the surgeon must always follow basic surgical principles. There should be clear visualization and access to the operative field, which requires adequate light, adequate soft tissue retraction and reflection (including lips, cheeks, tongue, and soft tissue flaps), and adequate suction. The teeth to be removed must have an unimpeded pathway for removal. Occasionally bone must be removed and teeth sectioned to achieve this goal. Controlled force is of paramount importance; this means finesse, not force. The surgeon must follow the principles of asepsis, atraumatic handling of tissues, hemostasis, and thorough debridement of the wound after the surgical procedure. Violation of these principles can lead to an increased incidence and severity of surgical complications.

Prevention of complications should be a major goal. When complications do occur, skillful management is the most essential requirement of the competent surgeon.

Soft Tissue Injuries

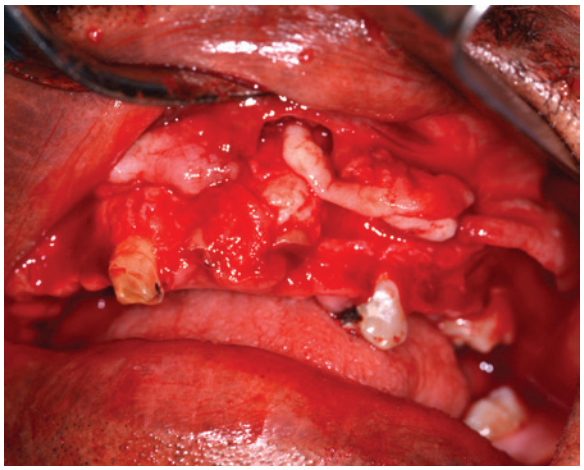
Injuries to the soft tissue of the oral cavity are almost always the result of the surgeon's lack of adequate attention to the delicate nature of the mucosa, attempts to do surgery with inadequate access, rushing during surgery, or the use of excessive and uncontrolled force. The surgeon must continue to pay careful attention to soft tissue while operating on bone and tooth structures (Box 11.2).

Tear of a Mucosal Flap

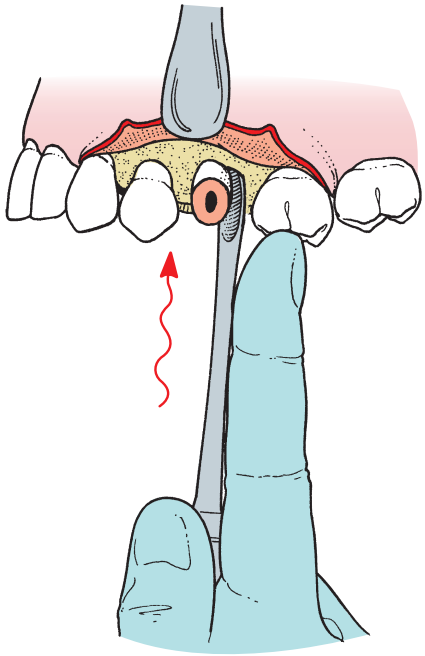
The most common soft tissue injury during oral surgery is tearing of the mucosal flap during surgical extraction of a tooth. This

• BOX 11.2 Prevention of Soft Tissue Injuries

- Pay strict attention to soft tissue injuries.
- Develop adequate-sized flaps.
- Use minimal force for retraction of soft tissue.



• Fig. 11.4 Mucoperiosteal flap badly torn due to inadequate care during its reflection.



• Fig. 11.5 The small straight elevator can be used to luxate a fractured root. When a straight elevator is used in this position, the surgeon's hand must be securely supported on adjacent teeth to prevent inadvertent slippage of the instrument from the tooth and subsequent injury to adjacent tissue.

usually results from an initially inadequately sized envelope flap that, as the surgeon tries to gain needed surgical access, is then forcibly retracted beyond the ability of the tissue to stretch (Fig. 11.4). This results in tearing, usually at one end of the incision. Prevention of this complication is threefold: (1) creating adequately sized flaps to prevent excess tension on the flap, (2) using controlled amounts of retraction force on the flap, and (3) creating releasing incisions when indicated. If a tear does occur in the flap, the flap should be carefully repositioned once the surgery is completed. If the surgeon or assistant sees a flap beginning to tear, the hard tissue surgery should be stopped while the incision is lengthened or while a releasing incision is created to gain better access. In most patients, careful suturing of the tear results in adequate but somewhat delayed healing. If the tear is especially jagged, the surgeon may consider excising the edges of the torn flap to create a smooth flap margin before closure. This step should be performed with caution because excision of excessive amounts of tissue leads to closure of the wound under tension and probable wound dehiscence, or it might compromise the amount of attached gingiva adjacent to a tooth.

Puncture Wound

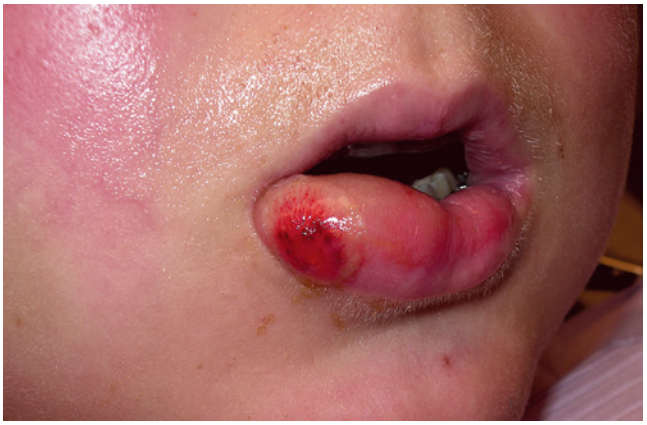
The second soft tissue injury that occurs with some frequency is inadvertent puncturing of soft tissue. An instrument such as a straight elevator or a periosteal elevator may slip from the surgical field and puncture or tear adjacent soft tissue.

Once again, this injury is the result of using uncontrolled force and is best prevented by the use of controlled force, with special attention given to using finger rests or support from the opposite hand if slippage is anticipated. If the instrument slips from the tooth or bone, the surgeon's fingers can catch the operating hand before injury occurs (Fig. 11.5). If a puncture wound does occur in the mucosa, the ensuing treatment is primarily aimed at preventing infection and allowing healing to occur, usually by secondary intention. If the wound bleeds excessively, the hemorrhage should be controlled by direct pressure applied to the wound. Once hemostasis is achieved, the wound is usually left open unsutured; thus even if a small infection were to occur, there would be an adequate pathway for drainage.

Abrasion or Burn

Abrasions or burns to lips, corners of the mouth, or flaps usually result from the rotating shank of the burr rubbing on soft tissue or from a metal retractor coming in contact with soft tissue (Fig. 11.6). When the surgeon is focused on the cutting end of the burr, the assistant should be aware of the location of the shank of the burr in relation to the patient's cheeks and lips. However, the surgeon should also remain aware of the shaft's location. Soft tissue burns can occur if instruments freshly out of the autoclave or dry heat sterilizer are not allowed to cool before coming in contact with the patient's skin or mucosa.

If an area of oral mucosa is abraded or burned, little treatment is possible other than keeping the area clean with regular oral rinsing. Usually such wounds heal in 4 to 7 days (depending on the depth of damage) without scarring. If such an abrasion or burn does develop on the skin, the dentist should advise the patient to keep it covered with an antibiotic ointment. The patient must apply the ointment only on the abraded area and not spread it onto intact skin because the ointment may cause ulceration or a rash. These abrasions usually take 5 to 10 days to heal. The patient should keep the area moist with small amounts of ointment during the entire healing period to prevent eschar formation and delayed healing and to keep the area reasonably comfortable. Scarring or permanent discoloration of the affected skin may occur but is usually prevented with proper wound care.



• **Fig. 11.6** Abrasion of lower lip as a result of shank of burr rotating on soft tissue. The abrasion represents a combination of friction and heat damage. The wound should be kept covered with antibiotic ointment until an eschar forms, taking care to keep the ointment off uninjured skin as much as possible. (Courtesy Dr. Myron Tucker.)

• BOX 11.3 Prevention of Root Fracture and Displacement

- Always consider the possibility of root fracture.
- Use surgical (i.e., open) extraction if high probability of fracture exists.
- Do not use strong apical force on a broken root.

Problems With a Tooth Being Extracted

Root Fracture

The most common problem associated with the tooth being extracted is fracture of its roots. Long, curved, divergent roots that lie in dense bone are the most likely to be fractured. The main methods of preventing the fracture of roots is to perform surgery in the manner described in previous chapters or to use an open extraction technique and remove bone to decrease the amount of force necessary to remove the tooth (Box 11.3). Recovery of a fractured root with a surgical approach is discussed in Chapter 9.

Root Displacement

The tooth root that is most commonly displaced into unfavorable anatomic spaces is the maxillary molar root when it is forced or lost into the maxillary sinus. If a fractured root of a maxillary molar is being removed with a straight elevator that is being used with excessive apical pressure, the root can be displaced into the maxillary sinus. Other teeth or roots can be displaced into the maxillary sinus in a similar manner. If a root or tooth is pushed into the maxillary sinus, the surgeon must make several assessments to determine the appropriate treatment. First, the surgeon must identify the size of the root lost into the sinus. It may be a root tip of several millimeters or an entire tooth or root. The surgeon must next assess whether there has been any infection of the tooth or periapical tissues. If the tooth was not infected, management is more straightforward than if the tooth has been acutely infected. Finally, the surgeon must assess the preoperative condition of the maxillary sinus. For the patient who has a healthy maxillary sinus, it is more straightforward to manage a displaced root than if the sinus is or has been chronically infected.

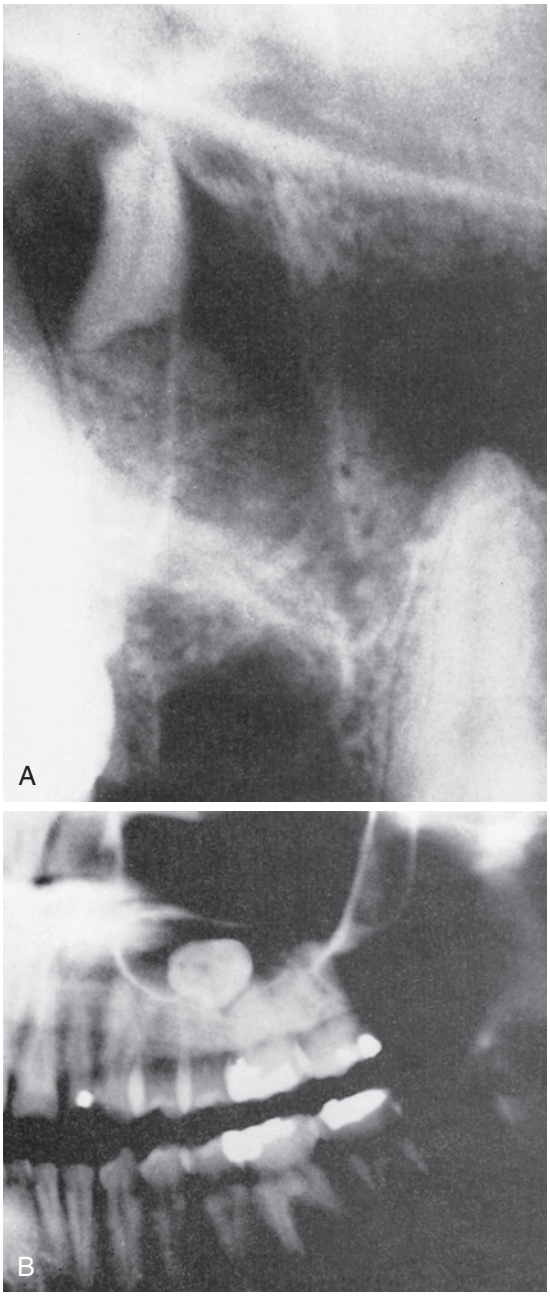
If the displaced tooth fragment is a small 2- or 3-mm root tip and the tooth and sinus have no preexisting infection, the surgeon should make a brief attempt at removing the root. First, a radiograph of the fractured tooth root should be taken to document its position and size. Once that has been accomplished, the surgeon should irrigate through the small opening in the socket apex and then suction the irrigating solution from the sinus via the socket. This occasionally flushes the root apex from the sinus through the socket. The surgeon should check the suction solution and confirm radiographically that the root has been removed. If this technique is not successful, no additional surgical procedure should be performed through the socket, and the root tip should be left in the sinus. A small, noninfected root tip can be left in place because it is unlikely to cause any troublesome sequelae. Additional surgery in this situation causes more patient morbidity than leaving the root tip in the sinus. If the root tip is left in the sinus, the surgeon should take measures similar to those taken in leaving any root tip in place. The patient must be informed of the decision and given proper follow-up instructions for regular monitoring of the root and the sinus.

The oroantral communication should be managed as discussed later, with a figure-of-eight suture over the socket, sinus precautions, antibiotics, and a nasal spray to lessen the chance of infection by keeping the ostium open. The most likely occurrence is that the root apex will fibrose onto the sinus membrane with no subsequent problems. If the tooth root is infected or the patient has chronic sinusitis, the patient should be referred to an oral-maxillofacial surgeon for removal of the root tip via a Caldwell-Luc or endoscopic approach.

If a large root fragment or the entire tooth is displaced into the maxillary sinus, it should be removed (Fig. 11.7). The usual method is a Caldwell-Luc approach into the maxillary sinus in the canine fossa region followed by removal of the tooth. This procedure should be performed by an oral-maxillofacial surgeon (see Chapter 20).

Impacted maxillary third molars are occasionally displaced into the maxillary sinus (from which they are removed via a Caldwell-Luc approach). However, if displacement occurs, it more commonly does so into the infratemporal space. During elevation of the tooth, the elevator may force the tooth posteriorly through the periosteum into the infratemporal fossa. The tooth is usually lateral to the lateral pterygoid plate and inferior to the lateral pterygoid muscle. If good access and light are available, the surgeon should make a single cautious effort to retrieve the tooth with a hemostat. However, the tooth is usually not visible, and blind probing results in further displacement. If the tooth is not retrieved after a single effort, the incision should be closed and the operation stopped. The patient should be informed that the tooth has been displaced and will be removed later. Antibiotics should be given to help decrease the possibility of an infection, and routine postoperative care should be provided. During the initial healing time, fibrosis occurs and stabilizes the tooth in a firm position. The tooth is removed later by an oral-maxillofacial surgeon after radiographic localization.

Lingual cortical bone over the roots of the molars becomes thinner as it progresses posteriorly. Mandibular third molars, for example, frequently have dehiscence in overlying lingual bone and may actually be sitting in the submandibular space preoperatively. Fractured mandibular molar roots that are being removed with apical pressures may be displaced through the lingual cortical plate and into the submandibular space. Even small amounts of apical pressure can result in displacement of the root into that space. Prevention of displacement into the submandibular space is primarily



• **Fig. 11.7** (A) Large root fragment displaced into the maxillary sinus. The fragment should be removed by the Caldwell-Luc approach or sinus endoscopy. (B) The tooth in the maxillary sinus is the maxillary third molar that was displaced into the sinus during elevation of the tooth. This tooth must be removed from the sinus, potentially by the Caldwell-Luc approach.

achieved by avoiding all apical pressures when removing mandibular roots.

Triangular elevators such as the Cryer elevator are usually used to elevate broken tooth roots of mandibular molars. If the root disappears during root removal, the dentist should make a single effort to remove it. The index finger of the left hand is inserted onto the lingual aspect of the floor of the mouth in an attempt to place pressure against the lingual aspect of the mandible and force the root back into the socket. If this works, the surgeon may be able to tease the root out of the socket with a root-tip pick. If this effort is not successful at the initial attempt, the dentist should abandon the procedure and refer the patient to an oral-maxillofacial surgeon. The usual definitive procedure for removing such a root tip is to reflect a soft tissue flap on the lingual aspect of the mandible and gently dissect the overlying mucoperiosteum until the root tip can be found. As with teeth that are displaced into the maxillary sinus, if the root fragment is small and was not infected preoperatively, the oral-maxillofacial surgeon may elect to leave the root in its position because surgical retrieval of the root may be an extensive procedure or may risk serious injury to the lingual nerve.

Tooth Lost Into the Pharynx

Occasionally the crown of a tooth, a prosthetic crown, or an entire tooth may be lost in the oropharynx. If this occurs, the patient should be turned toward the surgeon and placed in a position with the mouth facing the floor as much as possible. The patient should be encouraged to cough and spit the tooth out onto the floor.

In spite of these efforts, the tooth may be swallowed or aspirated. If the patient has no coughing or respiratory distress, it is most likely that the tooth was swallowed and has traveled down the esophagus into the stomach. However, if the patient has a violent episode of coughing or shortness of breath, the tooth may have been aspirated through the vocal cords into the trachea and from there into a mainstem bronchus.

In either case, the patient should be transported to an emergency department, and chest and abdominal radiographs should be taken to determine the specific location of the tooth. If the tooth has been aspirated, consultation with regard to the possibility of removing the tooth with a bronchoscope should be requested. The urgent management of aspiration is to maintain the patient's airway and breathing. Supplemental oxygen may be appropriate if signs of respiratory distress are observed.

If the tooth has been swallowed, it is highly probable that it will pass through the gastrointestinal tract within 2 to 4 days. Because teeth are not usually jagged or sharp, unimpeded passage occurs in almost all situations. However, it may be prudent to have the patient go to an emergency room and have a radiograph of the abdomen taken to confirm that the tooth is indeed in the gastrointestinal tract and not in the respiratory tract. Follow-up radiographs are probably not necessary because swallowed teeth are ultimately passed out along with feces.

Extraction of the Wrong Tooth

A complication that every dentist believes can never happen—but happens surprisingly often—is extraction of the wrong tooth. This is usually the most common cause of malpractice lawsuits against dentists. Extraction of the wrong tooth should never occur if appropriate attention is given to the planning and execution of the surgical procedure.

This problem may be the result of inadequate attention to preoperative assessment. If the tooth to be extracted is grossly carious, it is less likely that the wrong tooth will be removed. A common reason for removing the wrong tooth is that a dentist removes a tooth for another dentist. The use of differing tooth numbering systems or differences in the mounting of radiographs can easily lead the treating dentist to misunderstand the instructions from the referring dentist. Thus the wrong tooth is sometimes extracted when the dentist is asked to remove teeth for orthodontic purposes, especially in patients who are in mixed dentition stages and whose orthodontists have asked for unusual extractions. Careful

• BOX 11.4 Prevention of Extraction of Wrong Teeth

- Focus attention on the procedure.
- Check with the patient and the assistant to ensure that the correct tooth is being removed.
- Check, then recheck, images and records to confirm the correct tooth.

• BOX 11.5 Prevention of Injury to Adjacent Teeth

- Recognize the potential to fracture a large restoration.
- Warn the patient preoperatively.
- Use elevators judiciously.
- The assistant should warn the surgeon of pressure on adjacent teeth.

preoperative planning, clear communication with the referring dentist, and attentive clinical assessment of the tooth to be removed before the elevator and forceps are applied are the main methods of preventing this complication (Box 11.4).

If the wrong tooth is extracted and the surgeon realizes this error immediately, the tooth should be replaced quickly into the tooth socket. If the extraction is for orthodontic purposes, the surgeon should contact the orthodontist immediately and discuss whether the tooth that was removed can substitute for the tooth that should have been removed. If the orthodontist believes the original tooth must be removed, the correct extraction should be deferred for 4 or 5 weeks until the fate of the replanted tooth can be assessed. If the wrongfully extracted tooth has regained its attachment to the alveolar process, then the originally planned extraction may proceed. In addition, the surgeon should not extract the contralateral tooth until a definite alternative treatment plan has been made.

If the surgeon does not recognize that the wrong tooth was extracted until the patient returns for a postoperative visit, little can be done to correct the problem. Replantation of the extracted tooth after it has dried cannot be successfully accomplished.

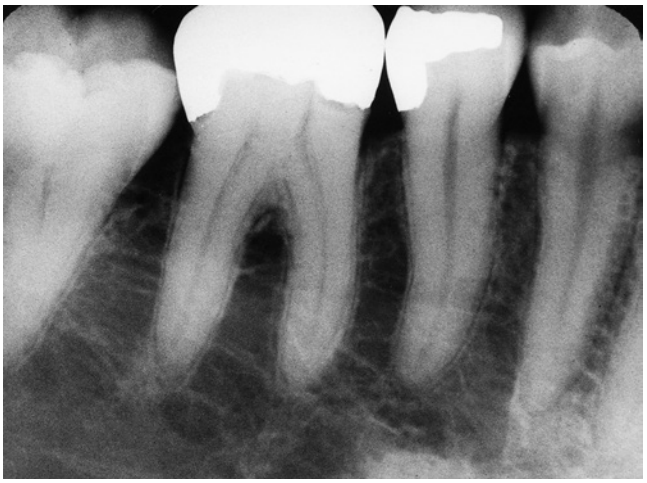
When the wrong tooth is extracted, it is important to inform the patient or the patient's parents or caregivers (if the patient is a minor) and any other dentist involved with the patient's care, such as the orthodontist. In some situations, the orthodontist may be able to adjust the treatment plan so that extraction of the wrong tooth necessitates only a minor alteration of the plan. Also, if the case did not involve orthodontic care, a dental implant–supported restoration may totally restore the patient's dental status as it was before the inadvertent extraction.

Injuries to Adjacent Teeth

When the dentist extracts a tooth, the focus of attention is on that particular tooth and the application of forces to luxate and deliver it. When the surgeon's total attention is completely focused on just this tooth, the likelihood of injury to the adjacent teeth is increased. Injury is often caused by the use of a burr to remove bone or to divide a tooth for removal. The surgeon should take care to avoid getting too close to adjacent teeth when surgically removing a tooth. This usually requires the surgeon to keep some of the focus on structures adjacent to the site of the surgery.

Fracture or Dislodgment of an Adjacent Restoration

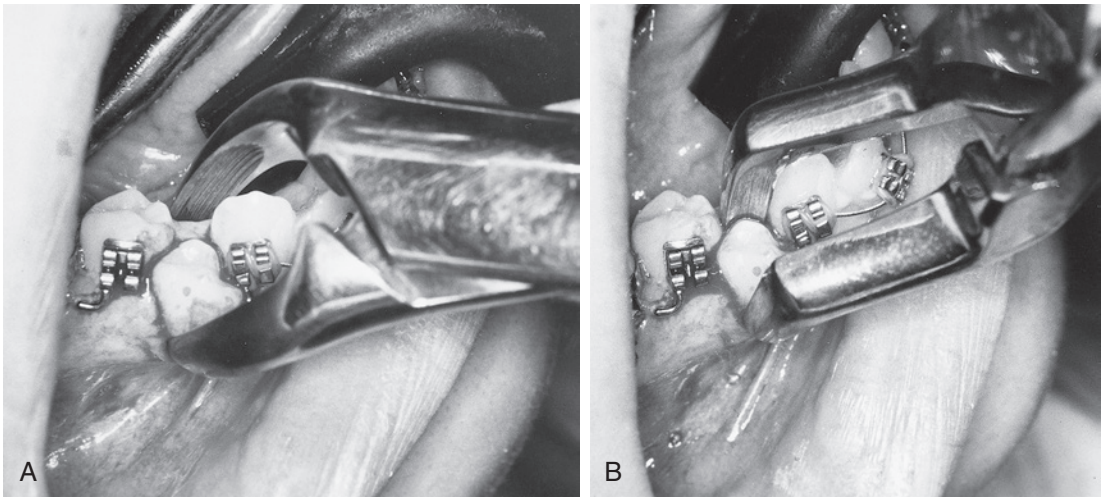
The most common injury to adjacent teeth is the inadvertent fracture or dislodgment of a restoration or damage to a severely carious tooth while the surgeon is attempting to elevate the tooth to be removed (Fig. 11.8). If a large restoration exists, the surgeon should warn the patient preoperatively about the possibility of fracturing or displacing it during the extraction. Prevention of such a fracture or displacement is primarily achieved by avoiding application of instrumentation and force on the restoration (Box 11.5). This means that the straight elevator should be used with great caution, being inserted entirely into the periodontal ligament space or not used at all to luxate the tooth before extraction when the adjacent tooth has a large restoration. If a restoration is dislodged or fractured, the surgeon should make sure that the displaced restoration is removed from the mouth and does not fall into the empty tooth socket. Once the surgical procedure has been completed, the injured tooth should be treated by replacement of the displaced crown or placement of a temporary restoration. The patient should be informed if a fracture of a tooth or restoration has occurred and that a replacement restoration is needed (see Chapter 12).



• Fig. 11.8 Mandibular first molar. If the first molar is to be removed, the surgeon must take care not to fracture amalgam in the second premolar with elevators or forceps.

Teeth in the opposite arch may also be injured as a result of uncontrolled forces. This usually occurs when buccolingual forces inadequately mobilize a tooth, excessive tractional forces are used, or both. The tooth is suddenly released from the socket, and the forceps strikes the teeth of the opposite arch, chipping or fracturing a cusp. This is more likely to occur with extraction of lower teeth because these teeth may require more vertical tractional forces for their delivery, especially when using the No. 23 (cowhorn) forceps. Prevention of this type of injury can be accomplished by several methods. The first and most important method is to avoid the use of excessive tractional forces. The tooth should be adequately luxated with apical, buccolingual, and rotational forces to minimize the need for tractional forces.

Even when this is done, however, occasionally a tooth will be released unexpectedly. The surgeon or assistant should protect the teeth of the opposite arch by holding a finger or suction tip against them to absorb the blow should the forceps be released in that direction. If such an injury occurs, the tooth should be smoothed



• **Fig. 11.9** (A) No. 151 forceps, which are too wide to grasp the premolar to extract it without luxating adjacent teeth. (B) Maxillary root forceps, which can be adapted readily to the tooth for extraction.

or restored, as necessary, to keep the patient comfortable until a permanent restoration can be constructed.

Luxation of an Adjacent Tooth

Inappropriate use of the extraction instruments may luxate an adjacent tooth. Luxation is prevented by judicious use of force with elevators and forceps. If the tooth to be extracted is crowded and has overlapping adjacent teeth, as is commonly seen in the mandibular incisor region, a thin, narrow forceps such as the No. 286 forceps may be useful for the extraction (Fig. 11.9). Forceps with broader beaks should be avoided because they will cause injury and luxation of adjacent teeth.

A small amount of luxation of an adjacent tooth frequently occurs and generally causes no damage. However, if an adjacent tooth is significantly luxated or partially avulsed, the treatment goal is to reposition the tooth into its appropriate position and stabilize it so that adequate healing can occur. This usually requires that the tooth simply be repositioned in the tooth socket and left alone. The occlusion should be checked to ensure that the tooth has not been displaced into a hyperocclusion and traumatic occlusion. Occasionally the luxated tooth is mobile. If this is the case, the tooth should be stabilized with semirigid fixation to maintain it in its position. A silk suture that crosses the occlusal table and is sutured to the adjacent gingiva is usually sufficient. Rigid fixation with circumdental wires and arch bars results in increased chances for external root resorption and ankylosis of the tooth and therefore should be avoided (see Chapter 25).

Injuries to Osseous Structures

Fracture of the Alveolar Process

The extraction of a tooth usually requires that the surrounding alveolar bone be expanded to allow an unimpeded pathway for tooth removal. However, in some situations, instead of expanding, the bone fractures and is removed still attached to the tooth. The most likely cause of fracture of the alveolar process is the use of excessive force with the forceps, which fractures the cortical plate. If excessive force is necessary to remove a tooth, a soft tissue flap should be elevated and controlled amounts of bone should be removed so that the tooth can be delivered or, in the case of multirooted teeth, the tooth should be sectioned. If this principle is not adhered to and the surgeon continues to use excessive or uncontrolled force, bone fractures commonly occur.

• BOX 11.6 Prevention of Fracture of Alveolar Process

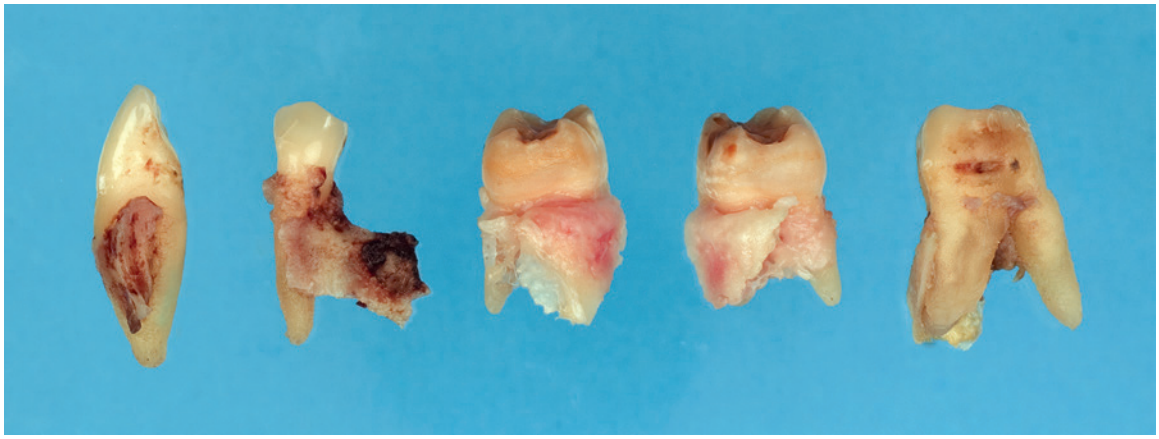
- Conduct thorough preoperative clinical and radiographic examinations.
- Do not use excessive force.
- Use surgical (i.e., open) extraction technique to reduce the force required.

The most likely places for bone fractures are the buccal cortical plate over the maxillary canine, the buccal cortical plate over maxillary molars (especially the first molar), the portions of the floor of the maxillary sinus that are associated with maxillary molars, the maxillary tuberosity, and labial bone over mandibular incisors (Fig. 11.10). All of these bone injuries are caused by excessive force from the forceps.

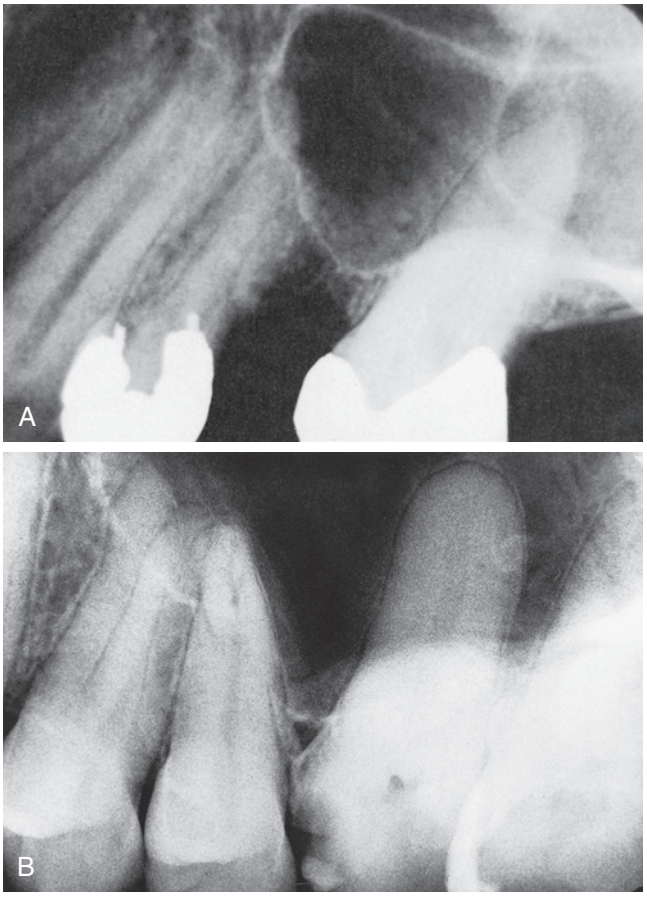
The primary method of preventing these fractures is to perform a careful preoperative examination of the alveolar process both clinically and radiographically (Box 11.6). The surgeon should inspect the root form of the tooth to be removed and assess the proximity of the roots to the maxillary sinus (Fig. 11.11). The surgeon should also consider the thickness of the buccal cortical plate overlying the tooth to be extracted (Fig. 11.12). If the roots diverge widely, if they lie close to the sinus, or if the patient has a heavy buccal cortical bone, the surgeon should take special measures to prevent fracturing excessive portions of bone. Age is a factor to be considered because the bones of older or larger patients are likely to be less elastic and therefore are more likely to fracture than to expand.

With preoperative determination of a high probability for bone fracture, the surgeon should consider performing the extraction by the open surgical technique. Utilizing this method, the surgeon can remove a smaller, more controlled amount of bone, resulting in more rapid healing and a more favorable ridge form for prosthetic reconstruction.

When the maxillary molar lies close to the maxillary sinus, surgical exposure of the tooth, with sectioning of the tooth roots



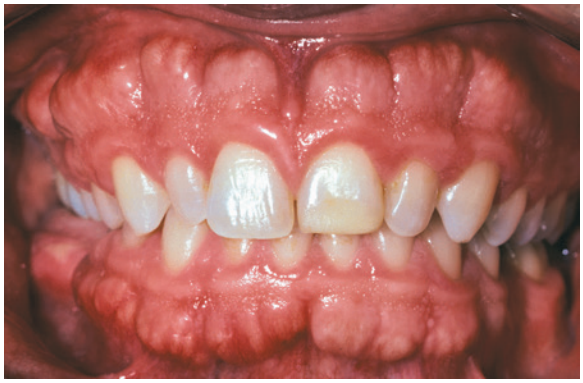
• **Fig. 11.10** Forceps extraction of these teeth resulted in removal of bone and tooth instead of just tooth.



• **Fig. 11.11** (A) Floor of sinus associated with roots of teeth. If extraction is required, the tooth should be removed surgically. (B) Maxillary molar teeth immediately adjacent to the sinus present increased danger of sinus exposure.

into two or three portions, usually prevents the removal of a portion of the maxillary sinus floor. This helps prevent the formation of an oroantral fistula, which commonly requires secondary procedures to be closed.

In summary, prevention of fractures of large portions of the cortical plate depends on preoperative radiographic and clinical assessments, avoidance of the use of excessive amounts of uncontrolled force, and the early decision to perform an open extraction with removal of controlled amounts of bone and sectioning of



• **Fig. 11.12** Patient with a heavy buccal cortical plate, requiring open extraction. (From Neville BW, Damm DD, Allen CM, et al. *Oral and Maxillofacial Pathology*. 2nd ed. St. Louis: Elsevier; 2002.)

multirooted teeth. During a forceps extraction, if the appropriate amount of tooth mobilization does not occur early, then the wise and prudent surgeon will alter the treatment plan to the surgical technique instead of pursuing the closed method.

Management of fractures of the alveolar bone takes several different forms, depending on the type and severity of the fracture. If the bone has been completely removed from the tooth socket along with the tooth, it should not be replaced. The surgeon should simply make sure that the soft tissue has been repositioned to the best extent possible over the remaining bone to prevent delayed healing. The surgeon must also smooth any sharp edges that may have been caused by the fracture. If such sharp edges of bone exist, the surgeon should reflect a small amount of soft tissue and use a bone file to round off the sharp edges or use a rongeur to remove the sharp edges.

The surgeon who has been supporting the alveolar process with the fingers during the extraction usually feels the fracture of the buccal cortical plate when it occurs. At this time, the bone remains attached to the periosteum and usually heals if it can be separated from the tooth and is left attached to the overlying soft tissue. The surgeon must carefully dissect the bone with its attached associated soft tissue away from the tooth. For this procedure the tooth must be stabilized with the forceps and a small sharp instrument such as a No. 9 periosteal elevator should be used to elevate the buccal bone from the tooth root. Once the bone and soft tissue have been elevated from the tooth, the tooth is removed and the bone and the soft tissue flap are reapproximated and

secured with sutures. When treated in this fashion, it is highly probable that the bone will heal in a more favorable ridge form for prosthetic reconstruction than if the bone had been removed along with the tooth. Therefore it is worth the special effort to dissect the bone from the tooth.

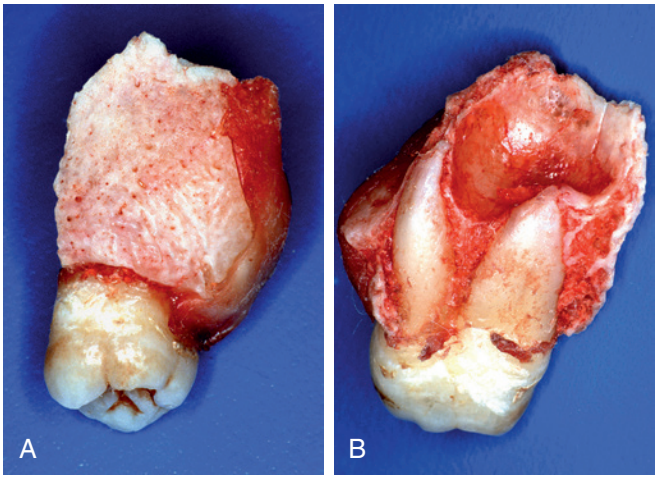
Fracture of the Maxillary Tuberosity

Fracture of a large section of bone in the maxillary tuberosity area is a situation of special concern. The maxillary tuberosity is important for the construction of a stable retentive maxillary denture. If a large portion of this tuberosity is removed along with the maxillary tooth, denture stability is likely to be compromised. An opening into the maxillary sinus may also be created. Fractures of the maxillary tuberosity most commonly result from extraction of an erupted maxillary third molar or from extraction of the second molar if it is the last tooth in the arch (Fig. 11.13).

If a tuberosity fracture occurs during an extraction, the treatment is similar to that just discussed for other bone fractures. The surgeon, using finger support for the alveolar process during the fracture (if the bone remains attached to the periosteum), should take measures to ensure the survival of the fractured bone.

However, if the tuberosity is excessively mobile and cannot be dissected from the tooth, the surgeon has several options. The first is to splint the tooth being extracted to adjacent teeth and defer the extraction by 6 to 8 weeks, allowing time for bone to heal. The tooth is then extracted with an open surgical technique. The second option is to section the crown of the tooth from the roots and allow the tuberosity and tooth root section to heal. After 6 to 8 weeks the surgeon can remove the tooth roots in the usual fashion. If the maxillary molar tooth was infected before surgery, these two techniques should be used with caution.

If the maxillary tuberosity is completely separated from soft tissue, the usual steps are to smooth the sharp edges of the remaining bone and reposition and suture the remaining soft tissue. The surgeon must carefully check for an oroantral communication and provide the necessary treatment.



• **Fig. 11.13** Tuberosity removed with the maxillary second molar, which eliminates the important prosthetic retention area and exposes the maxillary sinus. (A) Buccal view of bone removed with the tooth. (B) Superior view, looking onto the sinus floor, which was removed with the tooth. If possible, the bony segment should be dissected away from the tooth and the tooth should be removed in the usual fashion. The tuberosity is then stabilized with mucosal sutures as previously indicated. (Courtesy Dr. Edward Ellis III, University of Texas Health Science Center, San Antonio.)

A fracture of the maxillary tuberosity should be viewed as a significant complication. The major therapeutic goal of management is to maintain the fractured bone in place and provide the best possible environment for healing. This may be a situation that can best be handled by an oral-maxillofacial surgeon.

Fracture of the Mandible

Fracture of the mandible during extraction is a rare complication; it is associated almost exclusively with the surgical removal of impacted third molars. A mandibular fracture is usually the result of the application of a force exceeding that needed to remove a tooth and often occurs during the forceful use of dental elevators. However, when lower third molars are deeply impacted, even small amounts of force may cause a fracture. Fractures may also occur during removal of impacted teeth from a severely atrophic mandible. Should such a fracture occur, it must be treated by methods usually applied for treating jaw fractures. The fracture must be adequately reduced and stabilized; thus the patient should be referred to an oral-maxillofacial surgeon for definitive care.

Injuries to Adjacent Structures

Injury to Regional Nerves

The branches of the fifth cranial nerve, which provide innervation to the mucosa and skin, are the adjacent neural structures most likely to be injured during extraction. The most frequently involved specific branches are the mental, lingual, buccal, and nasopalatine nerves. The nasopalatine and buccal nerves are frequently sectioned during the creation of flaps for the removal of impacted teeth. The area of sensory innervation of these two nerves is relatively small, and reinnervation of the affected area usually occurs rapidly. Therefore the nasopalatine and long buccal nerves can be surgically sectioned without long-lasting sequelae or much bother to the patient.

Surgical removal of mandibular premolar roots or impacted mandibular premolars or periapical surgery in the area of the mental nerve and mental foramen must be performed with great care. If the mental nerve is injured, the patient will experience paresthesia or anesthesia of the lip and chin. If the injury is the result of flap reflection or manipulation, normal sensation usually returns in a few days to a few weeks. If the mental nerve is sectioned at its exit from the mental foramen or torn along its course, it is likely that mental nerve function will not return, and the patient will have a permanent state of anesthesia. If surgery is to be performed in the area of the mental nerve or the mental foramen, it is imperative that the surgeon be aware of the potential morbidity from injury to this nerve (Box 11.7). If a surgeon has any doubt about his or her ability to perform the indicated surgical procedure, the patient should be referred to an oral-maxillofacial surgeon. If a three-corner flap is to be used in the area of the mental nerve, the vertical releasing incision must be placed far enough anteriorly to avoid severing any portion of the mental nerve. On rare occasion it is advisable to make the vertical releasing incision at the interdental papilla between the canine and the first premolar.

• BOX 11.7 Prevention of Nerve Injury

- Be aware of the nerve anatomy in the surgical area.
- Avoid making incisions or stretching the periosteum in the nerve area.

The lingual nerve is usually anatomically located directly against the lingual aspect of the mandible in the retromolar pad region. Occasionally the path of the lingual nerve takes it into the retromolar pad area itself. The lingual nerve rarely regenerates if it is severely traumatized. Incisions made in the retromolar pad region of the mandible should be placed so as to avoid coming close to this nerve. Therefore incisions made for surgical exposure of impacted third molars or of bony areas in the posterior molar region should be made well to the buccal aspect of the mandible. Similarly, if dissecting a flap involving the retromolar pad, care must be taken to avoid excessive dissection or stretching of the tissues on the lingual aspect of the retromolar pad. Prevention of injury to the lingual nerve is of paramount importance to avoid this problematic complication.

Finally, the inferior alveolar nerve may be traumatized along the course of its intrabony canal. The most common place of injury is the area of the mandibular third molar. Removal of impacted third molars may bruise, crush, or sharply injure the nerve in its canal. This complication is common enough during extraction of third molars that it is important routinely to inform patients preoperatively that it is a possibility. The surgeon must then take every precaution possible to avoid injuring the nerve during the extraction.

If the lingual or inferior alveolar nerves have been damaged, the surgeon should refer the patient to an oral-maxillofacial surgeon for a consultation. This should be done promptly because, if nerve repair is indicated, the sooner the repair is made, the better the chances of full recovery of nerve function.

Injury to the Temporomandibular Joint

Another major structure that can be traumatized during an extraction procedure in the mandible is the temporomandibular joint. Removal of mandibular molar teeth frequently requires the application of a substantial amount of force. If the jaw is inadequately supported during the extraction to help counteract the forces, the patient may experience pain in this region. Controlled force and adequate support of the jaw prevent this (Box 11.8). The use of a bite block on the contralateral side may provide an adequate balance of forces so that injury does not occur. The surgeon or assistant should also support the jaw by holding the lower border of the mandible. If the patient complains of pain in the temporomandibular joint area immediately after the extraction procedure, the surgeon should recommend the use of heat, resting the jaw, a soft diet, and 600 to 800 mg of ibuprofen every 4 hours for several days. Patients who cannot tolerate nonsteroidal antiinflammatory drugs may take 500 to 1000 mg of acetaminophen.

Oroantral Communications

Removal of maxillary premolars or molars occasionally results in communication between the oral cavity and the maxillary sinus. If the maxillary sinus is greatly pneumatized, if little or no bone exists between the roots of the teeth and the maxillary sinus, and if the roots of the tooth are widely divergent, it is common for a portion of the bony floor of the sinus to be removed with the tooth or a communication to be created even if no bone comes out with the tooth. If this problem occurs, appropriate measures are necessary to prevent a variety of sequelae. The two sequelae of most concern are (1) postoperative maxillary sinusitis and (2) formation of a chronic oroantral fistula. The probability that either of these two sequelae will occur is related to the size of the oroantral communication and the management of the sinus exposure.

As with all complications, prevention is the easiest and most efficient method of managing the situation. Preoperative radiographs must be carefully evaluated for the tooth-sinus relationship whenever maxillary molars are to be extracted. If the sinus floor appears close to the tooth roots and the tooth roots are widely divergent, the surgeon should avoid a closed extraction and perform a surgical removal with sectioning of tooth roots (see Fig. 11.11). Excessive force should be avoided in the removal of such maxillary molars (Box 11.9).

The diagnosis of an oroantral communication can be made in several ways. The first is to examine the tooth once it has been removed. If a section of bone is adherent to the root ends of the tooth, the surgeon should assume that a communication between the sinus and mouth exists. If little or no bone adheres to the molars, a communication may exist anyway. Some advocate using the nose-blowing test to confirm the presence of a communication. This test involves pinching the nostrils together to occlude the patient's nose and asking the patient to blow gently through the nose while the surgeon observes the area of the tooth extraction. If a communication exists, there will be passage of air through the tooth socket and bubbling of blood in the socket area. However, if there is no communication, forceful blowing like this poses the risk of creating a communication. This is why many surgeons do not feel the nose-blowing maneuver should be used in these circumstances.

After the diagnosis of oroantral communication has been established or a strong suspicion exists, the surgeon should guess the approximate size of the communication because the treatment depends on the size of the opening. Probing a small opening may enlarge it, so if no bone comes out with the tooth, the communication is likely to be 2 mm or less in diameter. However, if a sizable piece of bone comes out with the tooth, the opening is of a considerable size. If the communication is small (≤2 mm in diameter), no additional surgical treatment is necessary. The surgeon should take measures to ensure the formation of a high-quality blood clot in the socket and then advise the patient to take sinus precautions to prevent dislodgment of the blood clot.

Sinus precautions are aimed at preventing increases or decreases in the maxillary sinus air pressure that would dislodge the clot. Patients should be advised to avoid blowing the nose, sneezing violently, sucking on straws, and smoking.

The surgeon must not probe through the socket into the sinus with a dental curette or a root-tip pick. The bone of the sinus may possibly have been removed without perforation of the sinus mucosa. To probe the socket with an instrument might unnecessarily lacerate

• BOX 11.8 Prevention of Injury to the Temporomandibular Joint

- Support the mandible during extraction.
- Do not force the mouth to open too widely.

• BOX 11.9 Prevention of Oroantral Communications

- Conduct a thorough preoperative radiographic examination.
- Use surgical extraction early, and section roots.
- Avoid excessive apical pressure on maxillary posterior teeth.

the membrane. Probing of the communication may also introduce foreign material, including bacteria, into the sinus, thereby further complicating the situation. Probing of the communication is therefore contraindicated.

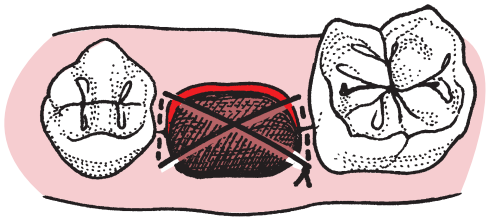
If the opening between the mouth and sinus is of moderate size (2 to 6 mm), additional measures should be taken. To help ensure the maintenance of the blood clot in the area, a figure-of-eight suture should be placed over the tooth socket (Fig. 11.14). Some surgeons also place some clot-promoting substances such as a gelatin sponge into the socket before suturing. The patient should also be told to follow sinus precautions. Finally, the patient should be prescribed several medications to reduce the risk of maxillary sinusitis. Antibiotics—usually amoxicillin, cephalexin, or clindamycin—should be prescribed for 5 days. In addition, a decongestant nasal spray should be prescribed to shrink the nasal mucosa to maintain patency of the ostium. As long as the ostium is patent and normal sinus drainage can occur, sinusitis and sinus infection will be less likely. Sometimes an oral decongestant is also recommended.

If the sinus opening is large (≥7 mm), the surgeon should consider having the sinus communication repaired with a flap procedure. This usually requires that the patient be referred to an oral-maxillofacial surgeon because flap development and closure of a sinus opening are complex procedures that require special training and experience.

The most commonly used flap for small openings is the buccal flap. This technique mobilizes buccal soft tissue to cover the opening and provide for a primary closure. This technique should be performed as soon as possible, preferably the same day the opening occurred. The same sinus precautions and medications are usually required (see Chapter 20).

The recommendations just described hold true for patients who have no preexisting sinus disease. If a communication does occur, it is important that the dentist inquire specifically about a history of sinusitis and sinus infections. If the patient has a history of chronic sinus disease, even small oroantral communications may heal poorly and may result in a chronic oroantral communication and eventual fistula. Therefore creation of an oroantral communication in a patient with chronic sinusitis is cause for referral to an oral-maxillofacial surgeon for definitive care (see Chapter 20).

The majority of oroantral communications treated by using the methods just recommended heal uneventfully. Patients should be followed carefully for several weeks to ensure that healing has occurred. Even patients who return within a few days with a small communication usually heal spontaneously if no maxillary sinusitis exists. These patients should be monitored closely and referred to an oral-maxillofacial surgeon if the communication persists for longer than 2 weeks. The usual patient complaint in such situations is the leakage of fluids from the mouth into the nose. The closure of an oroantral fistula is important because air, water, food, and bacteria go from the oral cavity into the sinus, usually causing a chronic sinusitis. In addition, if the patient is wearing a full maxillary denture, the suction seal is broken and retention of the denture is therefore compromised.



• **Fig. 11.14** A figure-of-eight stitch is usually used to help maintain the piece of oxidized cellulose in the tooth socket.

Postoperative Bleeding

Extraction of teeth is a surgical procedure that presents a severe challenge to the hemostatic mechanism of the body. Several reasons exist for this challenge: (1) the tissues of the mouth and jaws are highly vascular; (2) the extraction of a tooth leaves an open wound, with soft tissue and bone remaining open, which allows additional oozing and bleeding; (3) it is almost impossible to apply dressing material with enough pressure and sealing to prevent additional bleeding during surgery; (4) patients tend to explore the area of surgery with their tongues and occasionally dislodge blood clots, which initiates secondary bleeding, or the tongue may cause secondary bleeding by creating small negative pressures that suction the blood clot from the socket; and (5) salivary enzymes may lyse the blood clot before it has organized and before the ingrowth of granulation tissue.

As with all complications, prevention of bleeding is the best way to manage this problem (Box 11.10). One of the prime factors in preventing bleeding is taking a thorough patient history with regard to any existing problems with coagulation. The patient must be questioned thoroughly about any history of bleeding, particularly after injury or surgery, because affirmative answers to these questions should trigger special efforts to control the bleeding (see Chapter 1).

The first question that a patient should be asked is whether he or she has ever had a problem with bleeding in the past. The surgeon should inquire about bleeding after previous tooth extractions or other previous surgery or persistent bleeding after accidental lacerations. The surgeon must listen carefully to the patient's answers to these questions because what the patient considers "persistent" may actually be normal. For example, it is normal for a socket to ooze small amounts of blood for the first 12 to 24 hours after extraction. However, if a patient relates a history of bleeding that persisted for more than 1 day or that required special attention from the surgeon, the degree of suspicion should be substantially elevated.

The surgeon should inquire about any family history of bleeding. If anyone in the patient's family has or had a history of prolonged bleeding, further inquiry about its cause should be pursued. Most congenital bleeding disorders are familial, inherited characteristics. These congenital disorders range from mild to profound, and the latter require substantial efforts to control.

The patient should next be asked about any medications currently being taken that might interfere with coagulation. Drugs such as anticoagulants may cause prolonged bleeding after extraction. Patients receiving anticancer chemotherapy or aspirin, those with alcoholism, or patients with severe liver disease for any reason also tend to bleed excessively.

• BOX 11.10 Prevention of Postoperative Bleeding

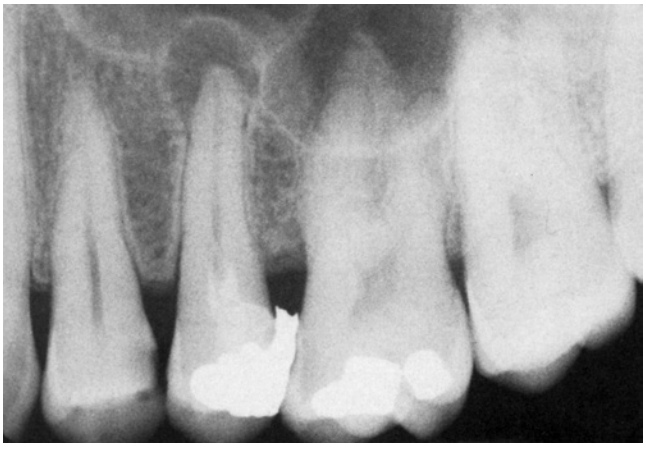
- Obtain a history of bleeding.
- Use the atraumatic surgical technique.
- Obtain good hemostasis at surgery.
- Provide excellent patient instructions.

The patient who has a known or suspected coagulopathy should be evaluated by laboratory testing before surgery is performed to determine the severity of the disorder. It is usually advisable to enlist the aid of a physician if the patient has a hereditary coagulation disorder.

The status of therapeutic anticoagulation is measured by using the international normalized ratio (INR). This value takes into account the patient's prothrombin time and the standardized control. Normal anticoagulated status for most medical indications has an INR of 2.0 to 3.0. It is reasonable to perform extractions on patients who have an INR of 2.5 or less without reducing the anticoagulant dose. With special precautions, it is reasonably safe to do minor amounts of surgery in patients with an INR of up to 3.0 if special local hemostatic measures are taken. If the INR is higher than 3.0, the patient's physician should be contacted to determine whether the physician would lower the anticoagulant dosage to allow the INR to fall.

Primary control of bleeding during routine surgery depends on gaining control of all factors that may prolong bleeding. Surgery should be as atraumatic as possible, with clean incisions and gentle management of soft tissue. Care should be taken not to crush soft tissue because crushed tissue tends to ooze for longer periods. Sharp bony spicules should be smoothed or removed. Granulation tissue should be curetted from the periapical region of the socket and from around the necks of adjacent teeth and soft tissue flaps; however, this should be deferred when anatomic restrictions such as the sinus or inferior alveolar canal are nearby (Fig. 11.15). The wound should be carefully inspected for the presence of any specific bleeding arteries. If such arteries exist in soft tissue, they should be controlled with direct pressure or, if pressure fails, by clamping the artery with a hemostat and ligating it with a nonresorbable suture.

The surgeon should also check for bleeding from the bone. Occasionally a small, isolated vessel bleeds from a bony foramen. If this occurs, the foramen can be crushed with the closed end of a hemostat, occluding the bleeding vessel. Once these measures have been accomplished, the bleeding socket is covered with a damp gauze sponge that has been folded to fit directly into the area from which the tooth was extracted. The patient bites down firmly on this gauze for at least 30 minutes. The surgeon should not dismiss the patient from the office until hemostasis has been achieved. This requires that the surgeon check the patient's extraction socket about 30 minutes after the completion of surgery. The patient should open the mouth widely, the gauze should be removed, and the area should be inspected carefully for any persistent oozing. Initial control should have been achieved by then. New gauze is then dampened, folded, and placed into position, and the patient is instructed to leave it in place for an additional 30 minutes.



• **Fig. 11.15** Granuloma of second premolar. The surgeon should not curette periapically around this second premolar to remove granuloma because the risk for sinus perforation is high.

If bleeding persists but careful inspection of the socket reveals that it is not of an arterial origin, the surgeon should take additional measures to achieve hemostasis. Several different materials can be placed in the socket to help gain hemostasis (Fig. 11.16). The most commonly used and the least expensive is the absorbable gelatin sponge (e.g., Gelfoam). This material is placed in the extraction socket and is held in place with a figure-of-eight suture placed over the socket. The absorbable gelatin sponge forms a scaffold for the formation of a blood clot, and the suture helps maintain the sponge in position during the coagulation process. A gauze pack is then placed over the top of the socket and is held with pressure.

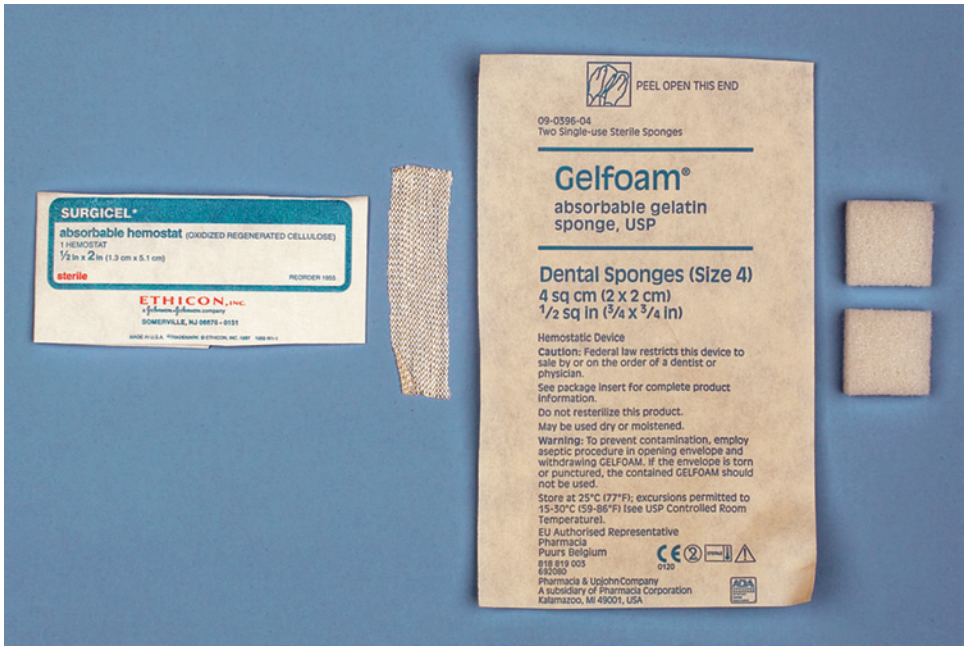
A second material that can be used to control bleeding is oxidized regenerated cellulose (e.g., Surgicel). This material promotes coagulation better than the absorbable gelatin sponge because it can be packed into the socket under pressure. The gelatin sponge becomes friable when wet and cannot be packed into a bleeding socket. When the cellulose is packed into the socket, it almost always causes some delayed healing of the socket. Therefore packing the socket with cellulose is reserved for more persistent bleeding.

If the surgeon has special concerns about the coagulability of the patient's blood, a liquid preparation of topical thrombin (prepared from human recombinant thrombin) can be saturated onto a gelatin sponge and inserted into the tooth socket. The thrombin bypasses steps in the coagulation cascade and helps convert fibrinogen to fibrin enzymatically, which forms a clot. The sponge with the topical thrombin is secured in place with a figure-of-eight suture. A gauze pack is placed over the extraction site in the usual fashion.

A final material that can be used to help control a bleeding socket is collagen. Collagen promotes platelet aggregation and thus helps accelerate blood coagulation. Collagen is currently available in several different forms. Microfibular collagen (e.g., Avitene Davol) is available as a fibular material that is loose and fluffy but can be packed into a tooth socket and held in by suturing and use of gauze packs and other materials. A more highly cross-linked collagen is supplied as a plug (e.g., Collaplug) or as a tape (e.g., Collatape). These materials are more readily packed into a socket (Fig. 11.17) and are easier to use, but they are expensive.

Even after primary hemostasis has been achieved, patients occasionally call the dentist with bleeding from the extraction site, referred to as *secondary bleeding*. The patient should be told to rinse the mouth gently with chilled water and then to place appropriate-sized damp gauze over the area and bite firmly on it. The patient should sit quietly for 30 minutes, continuing to bite firmly on the gauze. If the bleeding persists, the patient should repeat the cold rinse and bite down on a damp tea bag. The tannin in the tea frequently helps stop the bleeding. Alert the patient that herbal teas do not contain tannin and will not be effective. If neither of these techniques is successful, the patient should return to the dentist.

The surgeon must have an orderly, planned regimen to control this secondary bleeding. Ideally, a trained dental assistant will be present to help with treatment. The patient should be positioned in the dental chair and all blood, saliva, and fluids should be



• **Fig. 11.16** Examples of materials used to help control bleeding from an extraction socket. Surgicel *(left)* is oxidized regenerated cellulose and comes in a silky fabric-like form, whereas Gelfoam *(right)* is absorbable gelatin that comes as latticework that is easily crushed with pressure. Both promote coagulation.

suctioned from the mouth. Such patients frequently have large "liver clots" (clotted blood that resembles fresh liver), which must be removed from the mouth. The surgeon should observe the bleeding site carefully under effective lighting to determine the precise source of the bleeding. If it is clearly seen to be a generalized oozing, the bleeding site is covered with a folded, damp gauze sponge held in place with firm pressure by the surgeon's finger for at least 5 minutes.

This measure is sufficient to control most bleeding. The reason for the bleeding is usually some secondary trauma that is potentiated when the patient continues to suck on the area or spits out the blood instead of continuing to apply pressure with a gauze sponge.

If 5 minutes of this treatment does not control the bleeding, the surgeon must administer a local anesthetic so that the socket can be treated more aggressively. Block techniques are to be encouraged instead of local infiltration techniques. Infiltration with solutions containing epinephrine causes vasoconstriction and may control the bleeding temporarily. However, when the effects of the epinephrine dissipate, rebound hemorrhage with recurrent bothersome bleeding may occur.

Once regional local anesthesia has been achieved, the surgeon should gently curette out the tooth extraction socket and suction all areas of the old blood clot. The specific area of bleeding should be identified as clearly as possible. As with primary bleeding, soft tissue should be checked for diffuse oozing versus specific arterial bleeding. Bone tissue should be checked for small nutrient artery bleeding or general oozing. The same measures described for control of primary bleeding should be applied. The surgeon must then decide whether a hemostatic agent should be inserted into the bony socket. The use of an absorbable gelatin sponge with topical thrombin held in position with a figure-of-eight stitch and reinforced with application of firm pressure from a small damp gauze pack is standard for local control of secondary bleeding. This technique works well in almost every bleeding socket. In many situations, an absorbable gelatin sponge and gauze pressure are adequate. The patient should be given specific instructions on how to apply the gauze packs directly to the bleeding site should additional bleeding occur. Before the patient with secondary bleeding is discharged from the office, the surgeon should monitor the patient for at least 30 minutes to ensure that adequate hemostasis has been achieved.

If hemostasis is not achieved by any of the local measures just discussed, the surgeon should consider performing additional laboratory screening tests to determine whether the patient has a profound hemostatic defect. In such a case the surgeon usually requests a consultation from a hematologist, who will order typical screening tests. Abnormal test results will prompt the hematologist to investigate the patient's hemostatic system further.

A final hemostatic complication relates to intraoperative and postoperative bleeding into adjacent soft tissues. Blood that escapes into tissue spaces, especially subcutaneous tissue spaces, appears as bruising of overlying soft tissue 2 to 5 days after the surgery. This bruising is termed *ecchymosis* and is discussed earlier in this chapter.

Delayed Healing and Infection

Wound Dehiscence

Another problem of delayed healing is wound dehiscence (separation of the wound edges; Box 11.11). If a soft tissue flap is replaced and sutured without an adequate bony foundation, the unsupported soft tissue flap often sags and separates along the line of incision. A second cause of dehiscence is suturing the wound under tension. This occurs when the surgeon tries to aggressively pull the edges of a wound together with sutures. The closure is under tension if the suture is the only force keeping the edges approximated. If the edges spring apart when the suture is removed just after being placed, the wound closure is under tension. If the soft tissue flap is sutured under tension, the sutures cause ischemia of the flap margin with subsequent tissue necrosis, which allows the suture

• **Fig. 11.17** (A) Bicon resorbable collagen plug. (B) Collagen being placed into extraction socket. (C) Collagen in extraction socket. (D) Suture used to help retain collagen plug. (B–D, Courtesy Dr. Edward Ellis III, University of Texas Health Science Center, San Antonio.)

• BOX 11.11 Prevention of Wound Dehiscence

- Use aseptic technique.
- Perform atraumatic surgery.
- Close the incision over intact bone.
- Suture without tension.

to pull through the flap margin and results in wound dehiscence. Therefore sutures should always be placed in tissue without tension and tied loosely enough to prevent blanching of the tissue.

A common area of exposed bone after tooth extraction is the internal oblique ridge. After extraction of the first and second molars, during initial healing, the lingual flap becomes stretched over the internal oblique (mylohyoid) ridge. Occasionally bone perforates through the thin mucosa, causing a sharp projection of bone in the area.

The two major treatment options are (1) to leave the projection alone or (2) to smooth it with bone file. If the area is left to heal untreated, the exposed bone will slough off in 2 to 4 weeks. If the sharp bone does not cause much irritation, this is the preferred method. If a bone file is used, no flap should be elevated because this will result in an increased amount of exposed bone. The file is used only to smooth off the sharp projections of bone. This procedure usually requires local anesthesia.

Dry Socket

Dry socket or alveolar osteitis is delayed healing but is not associated with an infection. This postoperative complication causes significant pain but is without the usual signs and symptoms of infection, such as fever, swelling, and erythema. The term *dry socket* describes the appearance of the tooth extraction socket when the pain begins. In the usual clinical course, pain develops on the third or fourth day after removal of the tooth. Almost all dry sockets occur after

the removal of lower molars. On examination, the tooth socket appears to be empty, with a partially or completely lost blood clot, and some bony surfaces of the socket are exposed. The exposed bone is sensitive and is the source of the pain. The dull, aching pain is moderate to severe, usually throbbing in nature and frequently radiating to the patient's ear. The area of the socket has a bad odor, and the patient frequently complains of a foul taste.

The cause of alveolar osteitis is not fully clear, but it appears to result from high levels of fibrinolytic activity in and around the tooth extraction socket. This fibrinolytic activity results in lysis of the blood clot and subsequent exposure of bone. The fibrinolytic activity may result from subclinical infections, inflammation of the marrow space of the bone, or other factors. The occurrence of a dry socket after a routine tooth extraction is rare (2% of extractions), but it is frequent after the removal of impacted mandibular third molars and other lower molars (20% of extractions in some series).

Prevention of the dry socket syndrome requires that the surgeon minimize trauma and bacterial contamination in the area of surgery. The surgeon should perform atraumatic surgery with clean incisions and soft tissue reflection. After the surgical procedure, the wound should be irrigated thoroughly with large quantities of saline delivered under pressure, as from a plastic syringe. Small amounts of antibiotics (e.g., a tetracycline) placed in the socket alone or on a gelatin sponge have been shown to substantially decrease the incidence of dry socket in mandibular third molars and other lower molar sockets.

The treatment of alveolar osteitis is dictated by the single therapeutic goal of relieving the patient's pain during the period of healing. If the patient receives no treatment, no sequela other than continued pain will exist (treatment does not hasten healing). Treatment is straightforward and consists of irrigation and the insertion of a medicated dressing. First, the tooth socket is gently irrigated with sterile saline. The socket should not be curetted down to bare bone because this increases the amount of exposed bone and pain. Usually the entire blood clot is not lysed, and the part that is intact should be retained. The socket is gently suctioned of all excess saline, and a small strip of iodoform gauze soaked in or coated with the medication is inserted into the socket with a small tag of gauze left trailing out of the wound. The medication contains the following principal ingredients: eugenol, which obtunds the pain from the bone tissue; a topical anesthetic such as benzocaine; and a carrying vehicle such as balsam of Peru. The medication can be made by the surgeon's pharmacist or can be obtained as a commercial preparation from a dental supply house.

The medicated gauze is gently inserted into the socket, and the patient usually experiences profound relief from pain within 5 minutes. The dressing is changed every other day for the next 3 to 5 days, depending on the severity of pain. The socket is gently irrigated with saline at each dressing change. Once the patient's pain has decreased, the dressing should not be replaced because it acts as a foreign body and further prolongs wound healing.

Infection

The most common cause of delayed wound healing is infection. Infections are a rare complication after routine dental extraction and are primarily seen after oral surgery that involves the reflection of soft tissue flaps and bone removal. The most important measure to prevent infection following routine extractions is for the surgeon to adhere carefully to the basic principles of surgery. These principles are to minimize tissue damage, remove sources of infection, and cleanse the wound. No other special measures need be taken with the average patient. Careful asepsis and thorough wound debridement after surgery can best prevent infection after surgical flap procedures. This means that the area of bone removal under the flap must be copiously irrigated with saline under pressure and that all visible foreign debris must be removed with a curette.

Some patients, especially those with depressed immune host-defense responses, may require antibiotics to prevent infection. Antibiotics in these patients should be administered before the surgical procedure is begun (see Chapter 16). Additional antibiotics after the surgery are usually not necessary for routine extractions in healthy patients.

Infections after routine extractions exhibit the typical signs of a fever, increased swelling, reddening of skin, a foul taste in the mouth, or worsening pain 3 to 4 days after surgery. Infected oral wounds look inflamed, and some purulence is usually present. The management of such infections is discussed in Chapter 16.

12
Medicolegal Considerations

MYRON R. TUCKER AND JAMES R. HUPP

CHAPTER OUTLINE

Dentistry is a discipline in which most practitioners regularly perform invasive procedures. Thus, similar to physicians, particularly those who commonly do procedures, dentists are subject to claims of dental malpractice. Some of the most common lawsuits against dentists relate to the extraction of the wrong tooth, failure to diagnose a problem, and lack of proper informed consent, which are all problems that may occur when a patient requires oral surgery. Malpractice claims arise when a patient believes that his or her dentist, or an employee of the dentist, was negligent in some manner. Whether or not this is true, malpractice cases move forward through the legal system. Such cases take a toll on dental professionals, both financially and emotionally. To avoid the financial costs of paying for one's legal defense and, in some cases, the costs if a case is lost or settled, dentists practice risk management and purchase malpractice (liability) insurance. In addition, many dentists feel pressured into practicing "defensive dentistry," second-guessing sound clinical decisions because of concerns about potential litigation.

The influence of litigation on dentistry has resulted in an effort by the profession to reduce the risk of legal liability by more closely examining treatment decisions, improving documentation of care, and strengthening dentist-patient relationships. Although no substitute exists for sound clinical practice, nontreatment issues prompt many lawsuits. These issues often include miscommunication and misunderstanding between the dentist and the patient and poor record keeping, which, in turn, create opportunities for patients' lawyers to establish grounds for lawsuits.

This chapter reviews concepts of liability, risk management, methods of risk reduction, and actions that should be taken if a malpractice suit is filed against the dentist or the dentist's employee.

Legal Concepts Influencing Liability

To understand the value of and responsibility of the dentist in risk management, it is important to review several legal concepts pertaining to dental practice.

Malpractice is defined by the legal system as professional negligence. This occurs when treatment provided by the dentist fails to comply with the standard of care exercised by other similarly trained dentists in similar situations. In other words, professional negligence occurs when professionals fail to have or exercise the degree of judgment and skill ordinarily possessed and demonstrated by members of their profession practicing under similar circumstances.

In most states, *standard of care* is defined as that which an ordinarily skilled, educated, and experienced dentist would do (or not do) under similar circumstances. Most states adhere to a national standard for dental specialists but may follow a more regional standard for general dentists. The dentist is considered to have practiced negligently when a patient and his or her dental expert(s) convince a judge or jury that the dentist failed to comply with this minimal level of care and that such failure caused an injury.

In most malpractice cases, the patient must prove all of the following four elements of a malpractice claim: (1) existence of a duty—usually implied by the doctor-patient relationship; (2) breach of the duty—in malpractice, not practicing up to the standard of

care; (3) damages—in nonlegal terms, an injury; and (4) causation—a causal connection between the failure to meet the standard of care and the injury. The initial burden of proving malpractice lies with the plaintiff (patient). The patient must prove by a preponderance (more than 50%) of the evidence that all four elements of the claim were met.[1]

Duty

A professional relationship must exist between the dentist and the patient before a legal duty or obligation is owed to exercise appropriate care. This relationship can be established if the dentist accepts the patient or otherwise begins treatment. Accepting a patient can occur automatically, as when a dentist is on call for emergencies and a patient presents for care. But normally a dentist does not legally establish a duty to a patient until the dentist agrees (verbally or in writing) to treat the patient. A new patient simply turning up in a dentist's office does not establish a dentist-patient relationship or legal duty.

Breach of Duty

A dentist has a duty to provide care to a patient that at least meets the standard of good dental care. Such standards are not written down anywhere but are typically determined in individual cases by dental experts hired during dental malpractice cases to give the judge or jury their opinion of what is the standard of care required by the dentist in the circumstances surrounding the case. This standard of care does not obligate the dentist to provide the highest level of treatment exercised by the most skilled dentist or that which is taught in dental school. The standard of care is intended to be a common denominator defined by what average practitioners would ordinarily do under similar circumstances.

Damages

Some form of actual damage must be demonstrated. Damages may be physical, mental, or both. However, a patient suing out of simple revenge or a payment dispute cannot successfully win a malpractice case if he or she cannot show any actual damages.

Causation

It must be shown that the failure to provide standard care was the cause of the patient's injury. If something occurred between the time that the dentist provided treatment and when the damages occurred, there may not be a connection between the dentist's care and the patient's injury.

Dentists are not liable for inherent risks of treatment that occur in the absence of negligence. For example, a dentist is not liable if a patient experiences numbness of lips after a properly performed third molar extraction. This is a complication recognized in the scientific literature. A dentist can be legally liable for numbness of lips if the patient proves it was caused by negligence (e.g., the numbness was caused by a careless incision or by careless use of a burr or other instrument) or if the patient was not told before the surgery that lip numbness was a risk of the procedure.

Malpractice suits may arise even when a practitioner has done everything correctly but a complication occurs that is a known risk of the procedure and damages the patient. This is an aberrancy in malpractice law that normally requires some form of negligence to occur for a lawsuit to be successful. In this case, the patient's suit can be successful if the doctor did not inform the patient of the significant risks of the planned procedure and obtain written consent to perform the surgery. Further discussion of this concept appears in the section on risk management.

Marketing pressures can sometimes lead to written advertisements or promotions that can be interpreted as guaranteeing results. Patients who have difficulty chewing after receiving new dentures, if originally promised that they would be able to eat any type of food without difficulty, might consider such promises breach of contract or breach of warranty. Dissatisfaction with esthetics or function is often linked to unreasonable expectations, sometimes fueled by ineffective communication or excessive salesmanship. Similar problems can occur if a dentist's promotional materials claim the ability to perform painless or bloodless surgery.

The statute of limitations generally provides a certain period for filing a malpractice suit against an individual or a corporation and thereby can limit how long a person may wait to file a lawsuit. This limit, however, varies widely from state to state. In some states the statute of limitations begins when an incident occurs. In other states, the statute of limitations is extended for a short period after the alleged malpractice is discovered (or when a "reasonable" person would have discovered it). Several other factors can extend the statute of limitations in many states. These factors include patients who are children or younger than 18 years or the age of majority, fraudulent concealment of negligent treatment by the dentist, and leaving a nontherapeutic foreign object in the body (e.g., broken burr or file). As previously mentioned, the more recent development of trade practices and breach of contract claims can be traced in part to a longer statute of limitations period for contract actions and the common triple damages provisions of the deceptive trade practices acts.

Risk Reduction

The foundation for all dental practice should be sound clinical procedures, but even when practitioners try to do all that they can to make sure that a procedure goes well, problems can still occur. To manage this possibility, risk reduction strategies should be adopted to properly address various aspects of patient care and office policy and to reduce potential legal liability. These aspects include ensuring effective dentist-patient and staff-patient communication, patient information, informed consent, proper documentation, and appropriate management of complications. Additionally, clinicians should note that patients with reasonable expectations and a favorable relationship with their dentist are much less likely to sue and more likely to tolerate complications.

Patient Information and Office Communication

A solid dentist-patient relationship is the cornerstone of any risk management program. Well-informed patients generally have a much better understanding of potential complications and more realistic expectations about treatment outcomes. The education of patients can be accomplished by providing them with as much information as possible about the proposed treatment, alternatives to and risks of the planned surgery, and benefits and limitations of each reasonable clinical option. Patients are given this information to help them better understand their care so that they can make informed decisions. The information should be communicated in a positive manner and not in a defensive way. If done properly, the informed consent process can improve dentist-patient rapport.

Patients value and expect a discussion with their dentist about their care. Brochures and other types of informational packages help provide patients with general and specific information about general dental and oral surgical care. Patients requiring oral surgical procedures will benefit from information on the nature of the problem, recommended treatment and alternatives, expectations, and possible complications. This information should be presented in a well-organized, easy-to-understand format and in layperson language. Informed consent is discussed in detail in the following section.

When a dentist has a specific discussion with a patient or gives the patient an informational package, it should be documented in the patient's chart. Information about complications discussed earlier can be reviewed if complications do occur later. In general, patients with reasonable expectations create fewer problems (a theme repeated throughout this chapter).

Informed Consent

In addition to providing quality care, effective communication should be a standard practice in the dentist's office. Dentists can be sued not only for negligent treatment but also for failing to inform patients properly about the diagnosis; the treatment to be provided; reasonable treatment alternatives; and the reasonable benefits, risks, and complications of each treatment option. Treatment without proper informed consent can be considered *battery*—that is, intentionally touching a person without his or her consent.

The concept of informed consent is that the patient has a right to consider known risks and complications inherent in a treatment. This enables the patient to make a knowledgeable, voluntary decision whether to proceed with the recommended treatment or choose another option. If a patient is properly advised of inherent risks, even if a complication occurs, the dentist is not legally liable in the absence of negligence. However, a dentist can be held liable when an inherent risk occurs after the dentist fails to obtain the patient's informed consent. The rationale for liability is that the patient was denied the opportunity to refuse treatment after being properly advised of risks associated with the treatment and reasonable options.

Current concepts of informed consent are based as much on providing the patient with the necessary information as on actually obtaining a consent or signature for a procedure. In addition to fulfilling the legal obligations, obtaining the proper informed consent from patients benefits the clinician in several ways. First, obtaining an informed consent offers the dentist the opportunity to develop better rapport with the patient by demonstrating a greater personal interest in the patient's well-being. Second, well-informed patients who understand the nature of the problem and have realistic expectations are less likely to sue. Finally, a properly presented and documented informed consent often prevents frivolous claims based on misunderstanding or unrealistic expectations.

The requirements of an informed consent vary from state to state. Initially the informed consent process involved informing patients that bodily harm or death may result from a procedure. Discussions regarding minor, unlikely complications that seldom occur and infrequently result in significant ill effects are not required. However, some states have adopted the concept of *material risk,* which requires dentists to discuss all aspects material to the patient's decision to undergo treatment, even if it is not customary in the profession to provide such information. A risk is material when a reasonable person is likely to attach significance to it in assessing whether to have the proposed therapy. When the word "reasonable" appears in a legal definition and if a lawsuit occurs over the matter, the jury will decide what it means. The implications of this are discussed later in this chapter.

In most states dentists have a duty to obtain the patient's consent; they cannot delegate the entire responsibility. Although staff members in the dental office can present the consent form and the patient may be shown a video that provides information as part of the informed consent process, the dentist should meet with the patient to review treatment recommendations, options, and the risks and benefits of each option; the dentist must also be available to answer questions. Although not required by the standard of care in many states, it is advisable to get the patient's written consent for invasive dental procedures. Parents or legal guardians must sign for minors. Legal guardians must sign for individuals with mental incapacities. In certain regions of the United States, it is helpful to have consent forms written in other languages or have multilingual staff members available to assist with communication.

Informed consent consists of three phases: (1) informing, (2) written consent, and (3) documentation in the patient's chart. In obtaining informed consent, the clinician should conduct a frank discussion and provide information about seven areas: (1) the specific problem, (2) the proposed treatment, (3) anticipated or common side effects, (4) possible complications and approximate frequency of occurrence, (5) planned anesthesia and any material risks of the anesthesia, (6) treatment alternatives, and (7) uncertainties about final outcome, including a statement that the planned treatment has no absolute guarantees of success.

This information must be presented in such a manner that the patient has no difficulty understanding it. In the event of a lawsuit, the jury will determine whether the information was provided in an understandable manner. Thus the dentist should provide information such that the average juror would be able to understand descriptions of treatment plans and risks. Video presentations, including Internet-based interactive education, describing dental and surgical procedures and the associated risks and benefits are available. These can be used as part of the informed consent process but should not replace direct discussions between the dentist and the patient. At the conclusion of the presentation, the patient should be given an opportunity to ask any additional questions.

After these presentations or discussions, the patient should sign a written informed consent. The written consent should summarize, in easily understandable terms, the items presented. Some states presume that if the information is not on the form, it was not discussed. Whether the patient can read and speak English should also be documented; if the patient does not read or speak English, the presentation and written consent should be given in the patient's spoken language. To ensure that the patient understands each specific paragraph of the consent form, the dentist should consider having the patient initial each paragraph on the form.

An example of an informed consent document appears in Appendix 4. At the conclusion of the discussion, the patient, the dentist, and at least one witness should sign the informed consent document. In the case of a totally electronic record system, signature pads should be used to obtain the patient's consent. In the case of a minor, the patient and the parent or legal guardian should sign the informed consent. In most states, the age of majority (when the patient is no longer a minor) is 18 years. There are a few exceptions, including Mississippi (21 years); Alabama, Delaware, and Nebraska (19 years); Nevada, Ohio, Utah, and Wisconsin (18 years or graduation from high school, whichever is earlier); and Arkansas, Tennessee, and Virginia (18 years or graduation from

high school, whichever is later). In some states, minors may sign the informed consent for their own treatment if they are married or pregnant. Before assuming this to be the case, the dentist should verify local regulations.

The third and final phase of the informed consent process is to document in the patient's chart that an informed consent was obtained after the dentist discussed treatment options, risks, and benefits with the patient. The dentist should record the fact that consent discussions took place and should also record other events such as showing videos and providing educational brochures. The written consent form should be included.

In three special situations, the informed consent process may deviate from these guidelines: (1) A patient may specifically ask not to be informed of all aspects of the treatment and complications; if so, this must be specifically documented in the chart and signed by the patient. (2) It may be harmful in some cases to provide all of the appropriate information to the patient. This is termed *therapeutic privilege* for not obtaining a complete informed consent. Therapeutic privilege is controversial and would rarely apply to routine oral surgical and dental procedures. (3) A complete informed consent may not be necessary in an emergency, when the need to proceed with treatment is so urgent that the time taken to obtain an informed consent may result in further harm to the patient. This also applies to management of complications during a surgical procedure. It is assumed that if failure to manage a condition immediately would result in further harm to the patient, then treatment should proceed without obtaining specific informed consent.

Patients have the right to know whether any risks are associated with their decision to reject certain forms of treatment. This informed refusal and attempts to inform the patient of the risks and consequences of refusing treatment should be clearly documented in the chart. Patients who do not appear for needed treatment should be sent a letter warning them of potential problems that may arise if they do not seek treatment. Copies of these letters should be kept in the patient's chart.

Records and Documentation

Poor record keeping is one of the most common problems encountered in the defense of a malpractice suit. When the quality of patient care is questioned, the records supposedly reflect what was done and why. Poor records provide plaintiff attorneys with an opportunity to claim that patient care must also have been substandard. Poor documentation also makes it difficult for the dentist to recall what happened during a particular patient encounter, thus harming the dentist's defense. Even though a perfect record is neither possible nor required, records should reasonably reflect the diagnosis, treatment, consent, complications, and other key events.

Adequate documentation of the diagnosis and treatment is one of the most important aspects of patient care. A well-documented chart is the cornerstone of any risk management program. If dentists do not document fundamental clinical findings supporting the diagnosis and treatment, attorneys may question the need for treatment in the first place. Some will argue that if something was not charted, it did not happen. The following 11 items are helpful in recording in the chart:

1. Chief complaint
2. Dental history
3. Medical history
4. Current medication
5. Allergies
6. Clinical and radiographic findings and interpretations
7. Recommended treatment and other alternatives
8. Informed consent
9. Therapy actually instituted
10. Recommended follow-up treatment
11. Referrals to other general dentists, specialists, or other medical practitioners

Ten frequently overlooked pieces of information should be recorded in the chart:

1. Prescriptions and refills dispensed to the patient
2. Messages or other discussions related specifically to patient care (including telephone calls)
3. Consultations obtained
4. Results of laboratory tests
5. Clinical observations of progress or outcome of treatment
6. Recommended follow-up care
7. Appointments made or recommended
8. Postoperative instructions and orders given
9. Warnings to the patient, including issues related to lack of compliance, failure to appear for appointments, failure to obtain or take medication, instructions to see other dentists or physicians, or instructions on participation in any activity that might jeopardize the patient's health or success of a procedure
10. Missed appointments

Corrections should be made by drawing a single line through any information to be deleted. Correct information can be inserted above or added below, along with the correct date. Any crossed-out deletion should be initialed and dated. No portion of the chart should ever be discarded, obliterated, erased, or altered in any fashion. In some states, altering records with the intent to deceive is a felony.

The period for maintaining records varies from 3 to 10 years and can generally be found in each state's Dental Practice Act. Records should be kept long enough to be available should a patient decide to sue; this depends on the state's statute of limitations. In the case of minors, the statute of limitations does not begin until the patient reaches the age of majority, as described in the section on informed consent.

Electronic Records

The conversion to electronic record keeping from paper record keeping is increasing in practice; it has many potential applications for a modern dental practice. The increasing use of electronic records has raised several issues about the validity of office notes, other written documents, and radiographs. As with any medical record, it is important that records not be altered in any way after they are initially created and placed in a chart or digital file. Although alterations can be made on electronically generated documents, most software packages have tracking mechanisms in place that can detect whether documents, radiographs, or other images have been altered and when this occurred. If a change to an office note or other document is required, this should always be done as an addendum and entered into the record separately rather than by changing the original document. Today, forensic computer science can track any attempts to change records; therefore the same caveats about corrections to paper and film documentation also apply to electronic documentation.

Because many offices are completely "paperless," many documents are signed electronically. Electronic signatures are as valid as the

system in place used to protect from fraud, not unlike paper records where a signature can be forged. Most systems have some type of security measure imbedded within the software to protect the integrity of the system. As with many computer security issues, this requires the use of user identification and passwords that protect access to the documents by unauthorized individuals. When generated, stored, and protected in the appropriate manner, electronic records are as valid as any other type of medical record. Special issues related to access to patient information and the Health Information Technology for Economic and Clinical Health (HITECH) Act are discussed later in this chapter.

Referral to Another General Dentist or Specialist

In many cases, dentists may decide that the recommended treatment is beyond their scope of training or experience and may choose to refer a patient to another general dentist or specialist. A referral slip or letter should clearly indicate the basis for referral and what the specialist is being asked to do. The referral should be recorded in the chart. A written referral to a specialist should ask the specialist to provide a written report detailing the diagnosis and treatment recommendations.

A patient's refusal to pursue a referral should be clearly noted in the chart. If a patient refuses to seek treatment from a specialist, the dentist must decide whether the recommended treatment is within his or her own expertise. If not, the dentist should not provide this particular treatment, even if the patient insists. A patient's refusal to seek care from a specialist does not relieve the dentist of liability for injuries or complications resulting from care beyond his or her scope of training and expertise.

Dental specialists should carefully evaluate all referred patients. For example, extracting or treating the wrong tooth is a common allegation in court. When in doubt, the specialist should contact the referring dentist and discuss the case. Any change in the treatment plan provided by the specialist should be documented in both the referring dentist's chart and the specialist's chart. To avoid informed consent problems, the patient must approve any revised plan or recommendation.

Complications

Less than desirable results can occur despite the dentist's best efforts in diagnosis, treatment planning, and surgical technique. A poor result does not necessarily suggest that a practitioner is guilty of negligence or other wrongdoing. However, when complications occur, it is mandatory that the dentist immediately begin to address the problem in an appropriate fashion.

In most instances the dentist should advise the patient of the complication. Examples of such situations are losing or failing to recover a root tip, breaking a dental instrument such as an endodontic file in a tooth, perforating the maxillary sinus, damaging adjacent teeth, removing the wrong tooth, or inadvertently fracturing surrounding bone. In these instances the dentist should clearly outline a proposed management of the problem, including specific instructions to the patient, further treatment that may be necessary, and referral to an oral-maxillofacial surgeon, when appropriate.

It is advisable to consider and discuss alternative treatment options that may still produce reasonable results. For example, when teeth are extracted for orthodontic purposes, the first premolar may accidentally be extracted when the orthodontist wanted the second premolar extracted. Before removing any other teeth or alarming the patient and parents, the dentist should call the orthodontist to discuss the effect on treatment outcome and available treatment modifications. The patient and parents should be notified that the wrong tooth was extracted but that the orthodontist indicated that the treatment can proceed without significantly compromising the result.

Another common complication is altered sensation following third molar removal or posterior implant placement. The chart should reflect the existence and the extent of the problem. It may be useful to use a diagram to document the area involved. If possible, the density and severity of the sensory deficit should be noted after testing. The chart should reflect the progress of the condition each time the patient returns for follow-up. Early referral to an oral-maxillofacial surgeon with experience in diagnosing and treating nerve injuries is wise, since, when indicated, the earlier the attempt to repair the nerve, the better the prognosis. In most cases, the referral should occur no later than 3 months after the injury if no significant improvement is seen. Excessive delays may limit the effectiveness of future treatment. Documentation of the patient's progress will help to justify any decision to delay the referral.

Patient Management Problems

Noncompliant Patient

Dentists and staff should routinely chart lack of compliance, including missed appointments, cancelations, and failure to follow advice to take medications, seek consultations, wear appliances, or return for routine visits. Efforts to advise patients of risks associated with failing to follow instructions should also be recorded.

When the patient's health may be jeopardized by continued noncompliance, the clinician should consider writing a letter to the patient, identifying the potential harm and advising the patient that the office will not be responsible if these and other problems develop as a result of the patient's noncompliance. If the patient's care is eventually terminated, the accumulation of detailed chart entries documenting the noncompliance should justify the dentist's unwillingness to continue the patient's care.

Patient Abandonment

A legal duty is owed to the patient once a dentist-patient relationship is established. Generally duty is established when a patient has been seen in the office, the initial evaluation has been completed, and the dentist has agreed to treat the patient. The dentist is usually obligated to provide care until the treatment is completed. There may be instances, however, when it is impossible or unreasonable for a dentist to complete a treatment plan because of several problems. Such problems include the patient's failure to return for necessary appointments, follow explicit instructions, take medications, seek recommended consultations, or stop activities that may interfere with the treatment plan or otherwise jeopardize the dentist's ability to achieve acceptable results. This may include a total breakdown of communication between the dentist and the patient.

In these cases it is usually necessary for the dentist to follow certain steps before discontinuing treatment to avoid being accused of patient abandonment. First, the chart must document the activities leading to the patient's termination. The patient should be adequately warned (if possible) that termination will result if

the undesired activity does not stop. The patient should be warned of the potential harm that may result if such activity continues and the reason why the harm may occur. After being told why the office is no longer willing to provide treatment, the patient should be given a reasonable opportunity to find a new dentist (usually 30 to 45 days). The office should continue treatment during this period if the patient is in need of emergency care or if care is required to avoid harm to the patient's health or to treatment progress.

When it has been decided that the dentist-patient relationship cannot continue, the dentist must take the following steps to terminate the relationship.

A letter should be sent to the patient, indicating the intent to withdraw from the case and the unwillingness to provide further treatment. The letter should include five important pieces of information:

1. The reasons supporting the decision to discontinue treatment.
2. If applicable, the potential harm caused by the patient (or parent's) undesired activity.
3. Past warnings by the office that did not alter the patient's actions and continued to put the patient at risk (or jeopardized the dentist's ability to achieve an acceptable result).
4. A warning that the patient's treatment has not been completed and that therefore the patient should immediately seek another dentist in the area for immediate examination or consultation. (The clinician should include a warning that, if the patient fails to follow this advice, the patient's dental health may continue to be jeopardized and any treatment progress may be lost or may worsen.)
5. An offer to continue treating the patient for a specified reasonable period and for emergencies until the patient finds another dentist.

This letter should be sent by certified mail, with confirmation of delivery, to ensure and document that the patient did, in fact, receive it. If a new dentist is treating the patient, he or she should consider advising the former dentist of this decision. The clinician should consult an attorney if he or she has any concerns of confidentiality or if a particularly sensitive reason exists behind this decision.

The dentist must continue to remain available for treatment of emergency problems until the patient has had adequate time to seek treatment from another dentist. This must be communicated in the letter mentioned above. The dentist must offer to forward copies of all pertinent records that affect patient care. Nothing must be done to deter subsequent treatment to complete patient care.

The dentist-patient relationship with those who have tested positive for the human immunodeficiency virus or other infectious conditions or those who have handicaps may not be terminated or treatment refused because of their conditions, as this action may violate the Americans with Disabilities Act (ADA) and other federal or state laws. Patients who have tested positive for human immunodeficiency virus or who have acquired immunodeficiency syndrome are considered to have a handicap under these laws.[2] Legal counsel should be consulted if the clinician has another valid reason for terminating his or her professional relationship with such a patient.

Exceptions do exist to these suggested guidelines. The dentist must evaluate each situation carefully. On certain occasions the dentist may not wish to lose contact with a patient or lose the opportunity to observe and monitor a complication. Terminating treatment will often anger a patient, who may, in turn, seek legal advice if experiencing a complication. The office may elect to complete treatment in such cases. If treatment continues, the chart should carefully reflect all warnings to the patient about potential harm and the increased chance that acceptable results may not be achieved.

In certain cases, the patient may be asked to sign a revised consent form that includes three important points:

1. The patient realizes that he or she has been noncompliant or has otherwise not followed advice.
2. The previously mentioned activities jeopardized the patient's health or the dentist's ability to achieve acceptable results or unreasonably increased the chances of complications.
3. The dentist will continue treatment but makes no assurances that the results will be acceptable. Complications may occur, requiring additional care, and the patient (or the patient's legal guardian) will accept full responsibility if any of the foregoing events occur.

Common Areas of Dental Litigation

Litigation has involved all aspects of dental practice and nearly every specific type of treatment. A few types of dental treatment have a higher incidence of legal action.

Removal of the wrong tooth usually results from a communication breakdown between the general dentist and the oral surgeon or between the patient and the dentist. When in doubt, the dentist asked to extract a tooth by another dentist must confirm the identity of the tooth or teeth to be extracted with radiographic and clinical examinations as well as written instructions from, or a discussion with, the referring dentist. If opinions differ regarding the proposed treatment, the patient and the referring dentist should be notified and the outcome of any subsequent conversation documented. A short follow-up letter confirming the final decision may also be helpful in documenting this decision. If the wrong tooth is extracted, this should be handled administratively in the manner described previously in this chapter. Clinically, some experts recommend that if the removal of the wrong tooth is noticed just after its extraction, the tooth should be put back into the fresh socket and treated like a recently avulsed tooth, as discussed in Chapter 24.

Nerve injuries are often grounds for suits, with attorneys claiming that the nerve injuries resulted from extractions, implants, endodontic treatment, or other procedures. These allegations are usually coupled with allegations of insufficient informed consent or negligent performance of the procedure.

Because nerve injuries are a known complication of some mandibular extractions or mandibular implants posterior to the mental foramen, patient advocates claim that patients have the right to accept these risks as part of treatment. If the dentist can visualize conditions that increase this risk, the patient should be advised and the condition documented. An example would be to note specifically the relationship of the inferior alveolar nerve to the third molar tooth to be extracted when these appear to be in proximity on radiographs.

Failure to diagnose can be related to several areas of dentistry: One of the most common problems is a lesion that is seen on examination but is not adequately documented and no treatment or follow-up is instituted. If the lesion causes further problems or a subsequent biopsy documents a long-standing pathologic condition or a malignancy, this may be viewed as negligence. This is particularly problematic if the lesion is later diagnosed as a malignancy or other serious condition. This problem can be avoided by following

up on any potentially abnormal finding. The clinician should chart an initial diagnosis or seek a consultation from a specialist. If the lesion has resolved by the next visit, the clinician should record that fact so that the issue is closed. If the patient is referred to another doctor, the referring clinician should follow up to document the patient's progress, including whether the patient's condition was successfully treated.

Implant complications and failure are other common areas of litigation. As with any procedure, the patient should be informed of the associated reconstruction and long-term outcome of the complication. The need for careful long-term hygiene and follow-up should be explained. The potential detrimental effect of patient habits such as smoking should be explained and documented. Dentists placing implants being restored by another dentist should consider using a customized consent form, summarizing common complications and stressing the importance of receiving prosthetic care from an appropriately trained and experienced dentist.

Failure to provide appropriate referral to another dentist or specialist can be a source of legal problems. Dentists usually determine the appropriate time to refer a patient to a specialist for initial care or management of a complication. Failure to refer patients for complicated treatments not routinely performed by the dentist or delayed referral for management of a complication frequently becomes the basis for litigation. Referrals to specialists can greatly reduce liability risks. Specialists are accustomed to treating more difficult cases and complications. Specialists with whom the dentist has a good relationship can also diffuse patient management problems by being objective and caring and by reassuring angry patients. The general dentist and the specialist may discuss ways of relieving the expense of addressing a complication and completing treatment.

Temporomandibular joint disorders sometimes become more apparent after dental procedures requiring prolonged opening or manipulation, such as tooth extraction. Documentation of any preexisting condition in the pretreatment assessment is important. The risk of temporomandibular joint pain or other dysfunction as a result of a procedure should be included in the informed consent when indicated. If the patient is in dire need of care that may aggravate or cause a temporomandibular joint condition, a customized consent form should be drafted and signed. The form should clearly define the problem, giving the patient options and confirming the patient's authorization to proceed.

When a Patient Threatens to Sue

Whenever a patient, the patient's attorney or family member, or any other representative of the patient informs the dentist that a malpractice suit is being considered, several precautions should be taken.

First, all such threats should be documented and reported immediately to the malpractice insurance carrier. The dentist should follow the advice of the malpractice carrier, institutional risk management team, or the attorney assigned to the case. These individuals will usually create and send a written response to the threat. Because the first indication of a potential claim is usually a request for records, the office should comply with state law regarding what must be provided (usually copies of care and treatment records—*never* the originals).

Patients sometimes request the original chart and radiographs for a variety of reasons. Laws in most states indicate that the dental office owns the records and has a legal obligation to maintain original records for a specified period. Patients are entitled to a legible copy, and dental offices are entitled to a reasonable reimbursement for making copies. Patients do not own the records merely because they paid for care and treatment.

Second, the dentist and staff should not discuss the case with the patient (or a representative of the patient) once a lawsuit is threatened or made. All requests for information or other contact should be forwarded to the insurance carrier or attorney representing the dentist. Any arguments with the patient or representative should be avoided. The dentist should not admit liability or fault or agree to waive fees. Any such statement or admission made to the patient or patient's representative may be used against the dentist later as an admission of negligence.

Third, it is imperative that no additions, deletions, or changes of any sort be made in the patient's dental record. Records must not be misplaced or destroyed. In fact, extra efforts should be taken to make sure that the records are not lost or altered. The clinician should seek legal advice before making any attempt to clarify an entry.

During the process of malpractice litigation, the dentist may be called to give a deposition. This may be as the defendant in a case, as a subsequent person treating the patient, or as an expert witness. Although this is common for attorneys, the procedure is often unnerving and emotionally traumatic for dentists, particularly when testifying in their own defense.

The following are six suggestions that should be considered when giving a deposition related to a malpractice case:

1. The clinician should be prepared and have complete knowledge of the records. All chart entries, test results, and any other relevant information should be reviewed. In complex cases, the clinician should consider reviewing textbook knowledge of the subject; however, an attorney should be consulted before anything other than the clinician's own record is reviewed.
2. The clinician should never answer a question unless the clinician completely understands it. The clinician should listen carefully to the question, provide a succinct answer to it, and stop talking after the answer is given. A lawsuit cannot be won at a deposition, but it can be lost.
3. The clinician should not speculate. If a review of the records, radiographs, or other information is necessary, the clinician should do so before answering a question, and never guess. If the dentist cannot recall certain details, he or she should state as much if asked.
4. The clinician should be careful when agreeing that any particular expert author or text is "authoritative." It is usually best to never agree that a text is authoritative on any given topic. Once such a statement is made, the clinician may be placed in a situation where he or she may have done something or disagreed with something the "expert" has written. In most states, a clinician can be impeached by anything an author states once the clinician agrees that the author is "authoritative."
5. The clinician should not argue unnecessarily with the other attorney. The clinician should avoid any display of anger (this will only alert the clinician's adversary as to what will upset the clinician in front of a jury, who will expect the dentist to act in a professional manner).
6. The advice of the clinician's lawyer should be followed. (Even if retained by the insurance company, the attorney is required to represent the clinician's interests, not that of the insurance company or anyone else.)

Most anxiety related to litigation comes from fear of the unknown. Most dental practitioners have limited or no exposure to litigation. It must be kept in mind that dentists prevail in most

cases. Only about 10% of cases go to trial, and dentists win more than 80% of these cases.

Unfortunately, a malpractice trial requires a tremendous investment of time, energy, and emotion, all of which detracts from patient care. Most dentists have no choice; they must defend themselves. Dentists who are prepared and who possess reasonable expectations of each step of the litigation process usually experience less anxiety.

Managed Care Issues

The influence of managed health care has greatly changed many aspects of dentistry. This includes the dentist-patient relationship and the way decisions are made regarding which treatment alternatives are most appropriate. Dentists are often placed in the middle of a conflict between a desire to provide optimal treatment and the willingness of a health care plan to approve payment for appropriate or needed care.

Traditionally the patient chooses between an ideal comprehensive treatment plan, a compromised treatment plan, or no treatment. Under managed care, however, some patients are being forced to accept compromised treatment or no treatment, based on administrative decisions that may be driven more by cost containment pressures than by sound judgment based on dental science.

The American Dental Association Council on Ethics, Bylaws, and Judicial Affairs issued the following statement underscoring dentists' obligation to provide appropriate care:

> Dentists who enter into managed care agreements may be called upon to reconcile the demands placed on them to contain costs with the needs of their patients. Dentists must not allow these demands to interfere with the patient's right to select a treatment option based on informed consent. Nor should dentists allow anything to interfere with the free exercise of their professional judgment or their duty to make appropriate referrals, if indicated. Dentists are reminded that contract obligations do not excuse them from their ethical duty to put the patient's welfare first.[3]

Dentists have a responsibility to advise patients that a "compromised" treatment plan has been approved by the managed care organization. The dentist should seek the patient's consent to provide such treatment after the pertinent risks, complications, and limitations have been reviewed, along with an explanation of more optimal treatment options. Dentists should communicate in writing, to both patients and third-party payers, the outcomes that may reasonably be expected when the appropriate treatment is not available because of improper decisions by third-party providers.

The law has evolved in the area of managed care, and recent court decisions create some additional responsibilities for the dentist in advocating for appropriate patient care.[4,5] Ultimately each dentist has a duty to treat the patient and not base treatment decisions on the patient's insurance plan coverage. This often entails challenging, in writing, the denial of payment by the plan administrators for the recommended course of treatment by appealing on behalf of the patient for medically appropriate dental care. A letter addressing this situation should include the following elements:

1. A statement that the patient has been under the dentist's care for a specific condition (diagnosis) and the dentist's recommended course of treatment.
2. The clinical indications for the recommended treatment.
3. The risks and complications involved in failing to undergo the recommended treatment.
4. A statement that the dentist believes that the previous denial of authorization by plan administrators is inappropriate. It may be helpful to use key language from the court decision stating, "It is essential that cost limitation programs not be permitted to interfere with decisions based on medical/dental judgment."

Two other documents are needed to close the loop on the communications aspect of a managed care denial: (1) a form for patients to sign that advises them of their diagnosis, recommended treatment, and risks of not undergoing the treatment and indicates acknowledgment that alternative forms of treatment may create less desirable results than those of the recommended treatment and that they understand that they can pay for the recommended treatment from their own funds; (2) a letter to the patient who refuses recommended treatment that has been denied payment under the patient's insurance plan, asking the patient to reconsider the decision, expressing the dentist's concern for the consequences, and urging the patient to appeal the decision directly to the insurance plan administrators.

The Affordable Care Act (or "Obamacare") requires that all Americans obtain medical insurance coverage.[6] Initially there was a requirement that all Affordable Care Act plans include dental coverage for pediatric patients. However, this requirement has been relaxed or eliminated in most states. Adults have no requirement to obtain dental insurance; but if this is available, the same decision-making situations as described in other managed care plans will be applicable.

Telemedicine and the Internet

Technologic developments have induced significant changes in medical and dental practices. Computers and the Internet created new potential duties and liability concerns. Digital imaging—combined with the Internet capabilities for communication and even videoconferencing—has created situations in which patients may receive advice without the traditional doctor-patient interaction.

The Internet access to health care information has changed the dynamics of traditional dentist-patient interaction. A dentist's legal duty to a patient is currently linked to the existence of a doctor-patient relationship. Determining whether this relationship exists, however, is no longer a simple task. The advent of Internet marketing, telemedicine, and other modes of providing information or advice through electronic media—without direct examination, diagnosis, and recommendation for treatment—has clouded the issue of whether a doctor-patient relationship (and a legal duty owed to a particular patient) exists. Courts make decisions that may provide some guidance related to these evolving issues, although disagreement among jurisdictions still exists. One court decision has determined that a physician who consults with a treating physician over the telephone owes no legal duty to the treating physician's patient when treatment options were relayed through a telephone call.[7] However, another court ruled that a doctor-patient relationship could be implied when an on-call physician is consulted by telephone by an emergency department physician who relied on the consulting physician's advice.[7]

Defining clear rules that can be relied on by practicing dentists who provide direct or indirect advice over the telephone, Internet, or through websites will not be an easy task. Many questions remain unanswered. Do the laws of the state in which the patient lives or those in which the dentist practices actually apply in this issue? Is the dentist practicing dentistry in another state without

a license? In general, courts have found that practitioners must be licensed in the state from which the patient initiates the consultation and that the laws of that jurisdiction apply. Other questions remain. Is the advice offered by electronic means intended for general information and not intended to be relied upon by patients or the treating dentist for specific care? If so, then a prominent disclaimer should be posted and acknowledged before proceeding with the interaction. Will the electronic transfer of the information such as the patient's chart or billing information violate state or federal privacy laws? Under the Health Insurance Portability and Accountability Act (HIPAA) Security and Privacy regulations, duties are clearly defined, as described later. Can the dentist protect the information sent electronically from manipulation or misuse? In the coming years, it will be important for practitioners to monitor trends in dental care as the Internet, information storage and transfer, and doctor-patient relationships are all affected by advancing technology.

Rules and Regulations Affecting Practice

Health Insurance Portability and Accountability Act Privacy and Security

The HIPAA of 1996 has made major impacts on how patient health information is handled by health care organizations and professionals.[8] In recent years the public has grown increasingly concerned about disclosures of confidential health information by virtually all parts of the health care industry, including hospitals, pharmacies, managed care organizations, laboratories, and health care providers.

The HIPAA was enacted to protect such information. Although originally intended to codify an employee's right to continue to receive health insurance should he or she change jobs, resign, or be terminated, Congress used this legislation as a springboard to address several additional health care issues such as health care fraud and abuse and the security and confidentiality of electronically stored or transmitted health information.

The privacy regulations apply to "covered entities," which include health plans, health care clearinghouses, and health care providers who transmit health information in writing or electronically. This also includes practices that employ third parties to process and transmit electronic claims on their behalf. The regulations require covered entities to protect "individually identifiable health information." It is important to state that practices are permitted by the privacy laws to use or disclose a patient's health information for purposes of treatment, payment, and health care operations. In other words, a consent form completed by the patient will allow the practice to use protected patient information in its regular business. Additional uses and disclosures of protected information require separate consent. Compliance with these regulations includes the following:

1. Each practice must maintain a confidentiality statement, known as a "notice of privacy practices," posted in a prominent place in the office and on the website of the practice, if applicable.
2. Each patient must sign a consent form that allows the release of his or her health information, as necessary, to conduct the business of the practice.
3. All staff must be educated and periodically updated about the privacy and confidentiality rules and regulations.

The HIPAA security regulations cover protected health information as well as information that is maintained or transmitted in electronic form. The security regulations require that a covered entity protect the confidentiality, integrity, and availability of electronic protected health information (e-PHI) that it creates, stores, maintains, or transmits. By "confidentiality," the regulations mean ensuring the privacy of the information; by "integrity," ensuring that the information is not improperly altered or destroyed; and by "availability," ensuring that the information is accessible and usable to authorized persons.

Health Information Technology for Economic and Clinical Health Act Regulations

The HITECH Act of 2009[9] is intended to advance health information technology by creating incentives for increased use of electronic health records (EHRs). This legislation also increased the protection of electronically transmitted health information by strengthening HIPAA protection.[10] The HITECH Act applies to all covered entities (as defined in the HIPAA) that transmit health information electronically.

The Affordable Care Act includes requirements and incentives for practices to convert to exclusive use of EHRs.[6] The initial deadline for implementation of the EHR was set at 2015. However, due to the inability of many practices and medical institutions to comply by the deadline, this requirement has not been fully implemented, and multiple extensions of the deadline have been required, with a final date still unknown at the time of this writing.

The major provisions of the HITECH Act are aimed at prevention and management of breaches in transmitted electronic health information with increased penalties for violation. HIPAA has strict requirements related to the electronic transmission of any portion of the EHR or any other protected health information. These requirements are contained in the HIPAA Security Rule and are designed to maintain reasonable and appropriate administrative, technical, and physical safeguards for protection of the e-PHI and include the following[11]:

1. Ensuring the confidentiality, integrity, and availability of all e-PHI created, received, maintained, or transmitted
2. Identifying and protecting against reasonably anticipated threats to the security or integrity of the information
3. Protecting against reasonably anticipated, impermissible uses or disclosures
4. Ensuring compliance by their workforce.

Risk Analysis and Management

The Administrative Safeguards provisions in the Security Rule require all covered entities to perform risk analysis as part of their security management processes. Risk analysis affects the implementation of all of the safeguards contained in the Security Rule.

A risk analysis should include the following activities[12]:

1. Implement appropriate security measures to address the risks identified in the risk analysis.
2. Document the chosen security measures and, where required, the rationale for adopting those measures.
3. Maintain continuous, reasonable, and appropriate security protections.

Risk analysis should be an ongoing process in which a covered entity regularly reviews its records to track access to e-PHI and detect security incidents, periodically evaluates the effectiveness of security measures put in place, and regularly reevaluates potential risks to e-PHI. The important aspects of ongoing risk assessment should incorporate designating a security official who is responsible for developing and implementing its security policies and procedures;

providing for appropriate authorization and supervision of workforce members who work with e-PHI; limiting physical access to its facilities while ensuring that authorized access is allowed; putting in place policies and procedures regarding the transfer, removal, disposal, and reuse of electronic media to ensure appropriate protection of e-PHI; and implementing technical security measures that guard against unauthorized access to e-PHI that is being transmitted over an electronic network.

When health information is transmitted electronically, the information should be secured through encryption, a mechanism for destruction after use, or both. The security or privacy of health information is considered compromised if a breach poses potential harm to the affected individual or there is reputational or financial compromise. In cases where access to health information has been breached, the covered entity is required to notify the affected individual of the breach.

HIPAA violations are expensive.[13] The penalties for noncompliance are based on the level of negligence and can range from $100 to $50,000 per violation (or per record), with a maximum penalty of $1.5 million per year for violations of an identical provision. Violations can also carry criminal charges that can result in jail time.

Fines increase with the number of patients involved and the amount of neglect. The lowest level of penalty involves a situation where a doctor or other practice personnel did not know and, with reasonable diligence, would not have known that he or she had violated a provision. Penalty at the other end of the spectrum occurs when a breach is due to negligence and is not corrected in 30 days.

The fines and charges are broken down into several categories ranging from $10,000 to $50,000 for each incident and can result in criminal charges. HIPAA violation categories and their respective penalty amounts are shown in Table 12.1.

Almost half of all data breaches are the result of theft. When laptops, smartphones, and other electronic devices are unencrypted, the risk of a breach increases considerably. For this reason it is recommended that all data be safely stored off premises so that a stolen laptop, smartphone, or similar device has no e-PHI stored on the device that can result in possible compromise.

Title VI, Limited English Proficiency

Title VI of the Civil Rights Act of 1964 prohibits discrimination based on race, color, or national origin by any entity that receives federal financial assistance.[14] Individuals with limited English proficiency (LEP) have also been determined to be protected under this law. Dentists who treat such patients are required to take necessary steps to ensure that LEP persons can meaningfully access programs and services. The key to meaningful access for LEP persons is effective communication. These requirements apply to practices that treat patients who receive financial assistance. Medicaid and Medicare patients are those most commonly assisted by the Department of Health and Human Services. There are varying levels of requirements based on the number of LEP persons served by a practice:

1. For practices in which the LEP language group consists of fewer than 100 persons, all such persons must be provided with written notice in the primary language of the LEP language group of the right to receive competent oral translation of written materials.
2. For practices in which an eligible LEP language group constitutes 5% of the practice or 1000 persons, whichever is less, the practice must provide translations for vital documents for patient interactions.
3. For practices in which an eligible LEP language group constitutes 10% of the practice or 3000 persons, whichever is less, the practice must provide translated written materials, which includes vital documents for patient interactions in the primary language of the LEP language group.

If a practice falls under these boundaries, certain rules apply to serve LEP persons. To ensure compliance with these rules, a provider should develop and implement a comprehensive written language assistance program. This program should include the following:

- An assessment of the language needs of the patient population by identifying the non-English languages likely to be encountered, estimating the number of LEP persons eligible for services and their language needs, and identifying the resources needed to provide effective language assistance.
- The development of a policy on language access for providing oral language interpretation such as bilingual staff, staff interpreters, or outside interpreters, as well as translation of written materials (e.g., health history forms, consent forms, and privacy notices). The practice should post signs in regularly encountered languages about the available services and right to free language assistance services.
- Ensuring that the staff is trained in LEP policies and procedures and in how to work effectively with in-person and telephone interpreters and including such training in orientation for new employees.

It is illegal for a practice to encourage patients from language minority groups to provide their own interpreters as an alternative to maintaining bilingual employees or interpreters. Confidentiality issues aside, patients may naturally be reluctant to disclose or discuss intimate details of their personal and family lives in front of family members or complete strangers who have no formal training or obligation to observe confidentiality.

TABLE 12.1 HIPAA Violation Categories and Penalties

	Amount Per Violation	Violations of an Identical Provision in a Calendar Year
Did not know	$100–$50,000	$1,500,000
Reasonable cause	$1000–$50,000	$1,500,000
Willful neglect corrected	$10,000–$50,000	$1,500,000
Willful neglect not corrected	$50,000	$1,500,000

HIPAA, Health Insurance Portability and Accountability Act.

Americans With Disabilities Act

The ADA, enacted in 1990, is one of the nation's most comprehensive civil rights statutes.[2] Many doctors have heard of the act but do not realize the significant implications the ADA can have for the provision of dental care by even the smallest office practice.

The basic requirements of the law mandate that private practitioners accept patients with disabilities for treatment, provide "auxiliary aids" when necessary for effective communication with patients with disabilities, and make health care facilities physically

accessible and usable by patients with disabilities if this is "readily achievable."

The ADA provisions apply to "places of public accommodation." "The professional office of a health care professional" is specifically included in this category. The law applies to health care offices irrespective of their size.

Under Title III of the ADA, a health care provider may not discriminate in providing services to individuals with disabilities. A dentist may not refuse to treat a patient or refuse to accept a new patient because of the patient's disability. The ADA also imposes obligations on health care providers to provide "auxiliary aids and services" to enable a patient with a disability to benefit from the services of the office. The obligation can be as uncomplicated as the provision of additional assistance to a patient who has difficulty getting into an examination chair and as extensive as the provision of qualified signers for patients with hearing impairment.

In selecting an auxiliary aid, a doctor must take into account the specific abilities or limitations of the patient. For instance, the National Center for Law and Deafness points out a number of misconceptions regarding the abilities of patients with hearing impairment; these may lead to ineffective communication. As an example, lip-reading is effective for only a few of these patients. The vast majority of adults with hearing impairment rate themselves as having poor ability or complete inability to lip-read. The center also notes that the average hearing-impaired high school graduate reads and writes on a third-grade level; therefore the exchange of written communication may also not be effective for many such patients. Some patients may ask the doctor to provide a signer for them. Under the ADA laws, hearing-impaired patients have the right to ask for a signer. If asked, a dental office must provide a signer for the patient. If the office refuses to provide a signer, the office may be subject to a claim for discrimination. The cost of the signer must be borne by the office and may not be passed on to the patient.

In some situations, such as obtaining informed consent before surgery, it may be necessary to use a qualified interpreter. A qualified interpreter is defined by the ADA as someone "who is able to interpret effectively, accurately, and impartially, both receptively and expressively, using any necessary specialized vocabulary." Interpreters need not be specially accredited or affiliated with a particular group. In some instances, a family member or friend may be qualified to interpret. It is wise to have the interpreter complete a Translator's Statement form before performing interpretation services.

Dentists and office staff members must be aware that there may be some instances when a family member may not be able to render the necessary interpretation because of emotional or personal involvement or the family member's age. Confidentiality considerations may also adversely affect the ability to interpret "effectively, accurately, and impartially." If there are concerns that a family member or friend may not be able to interpret for the reasons cited, it is best to obtain an impartial interpreter.

Emergency Medical Treatment and Active Labor Act

The Emergency Medical Treatment and Active Labor Act (EMTALA) was enacted to prevent hospitals from refusing to treat patients who were unable to pay or from transferring such patients to other health care facilities before the emergency condition was identified and stabilized.[15] The EMTALA imposes four main duties on hospitals:

1. To provide a medical screening to any patient who presents to a hospital emergency department
2. To determine whether an emergency medical condition exists
3. To stabilize the condition so that transfer or discharge does not threaten a deterioration of the patient's condition
4. To transfer the patient to another facility if warranted, but only if the benefits outweigh the risks of the transfer

The courts have been clear that the EMTALA is intended only to prevent hospitals from purposefully withholding treatment from nonpaying patients in an emergency condition or from dumping patients onto other health care providers or facilities. Dentists become involved with EMTALA issues when patients are referred to the practice by the hospital emergency room and the hospital administrators tell the practitioner that the dentist will be in violation of the antidumping statute, the EMTALA, unless he or she treats the nonpaying patient. This kind of threat is unfounded and should be challenged by asking for the statutory authority of the hospital in making such statements.

Liability under the EMTALA may extend to practitioners in two situations: (1) If the dentist is on call with the hospital and the hospital sends a patient to the dentist's office (for the convenience of using an appropriately equipped facility), then the dentist most likely has an obligation to examine and stabilize the patient. If the dentist decides that he or she cannot treat the patient, another practitioner who *will* treat the patient must be found. (2) If the dentist has agreed to be bound by EMTALA duties through a specific contract or under the bylaws of the hospital where he or she holds privileges, these regulations will apply.

Summary

In addition to providing sound technical care, the dentist must address several other aspects of patient care to minimize unnecessary legal liability. The dentist should develop the best possible rapport with patients through excellent communication and by providing any information that may enhance patients' understanding of their treatments. Adequate documentation of all aspects of patient care is also necessary. Clinicians face a constant struggle to document quality care and their advice to patients. The law requires only that such efforts be reasonable—not perfect.

This chapter is intended to provide suggestions to be considered by individual dentists and is not intended to establish, influence, or modify the standard of care. Medical and dental malpractice laws vary from state to state. When confronted by medicolegal issues, all health care providers should consult local counsel familiar with the laws and regulations that apply in their jurisdictions.

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PART III

Preprosthetic and Implant Surgery

Despite the improved ability of dentistry to maintain the dentition, many individuals continue to require replacement of some or all of their teeth. Surgical improvement of the denture-bearing area and surrounding tissue (preprosthetic surgery) offers an interesting and demanding challenge to the dental practice.

Many minor modifications of the alveolar ridge and vestibular areas can greatly improve denture stability and retention. In some cases, patients have severe bone changes or soft tissue abnormalities that require extensive surgical preparation before the prosthetic appliance can be properly constructed and worn. Procedures that improve prosthesis retention and stability are discussed and illustrated in Chapter 13.

One of the most exciting frontiers in dentistry is implantology. Proper bony and soft tissue reconstruction followed by placement of implants and subsequent prosthetic reconstruction can provide patients with a more natural and efficient substitute for their lost dentition. Depending on the circumstances, several types of implant systems may be used. Chapter 14 discusses the various types of implant systems currently in use and their advantages, disadvantages, and indications for use. It goes on to show the basic procedures used to place dental implants into the jaws. Chapter 15 gives more information about implant dentistry but covers more complex situations and how they can be successfully managed.

13

Preprosthetic Surgery

MYRON R. TUCKER AND RICHARD E. BAUER

CHAPTER OUTLINE

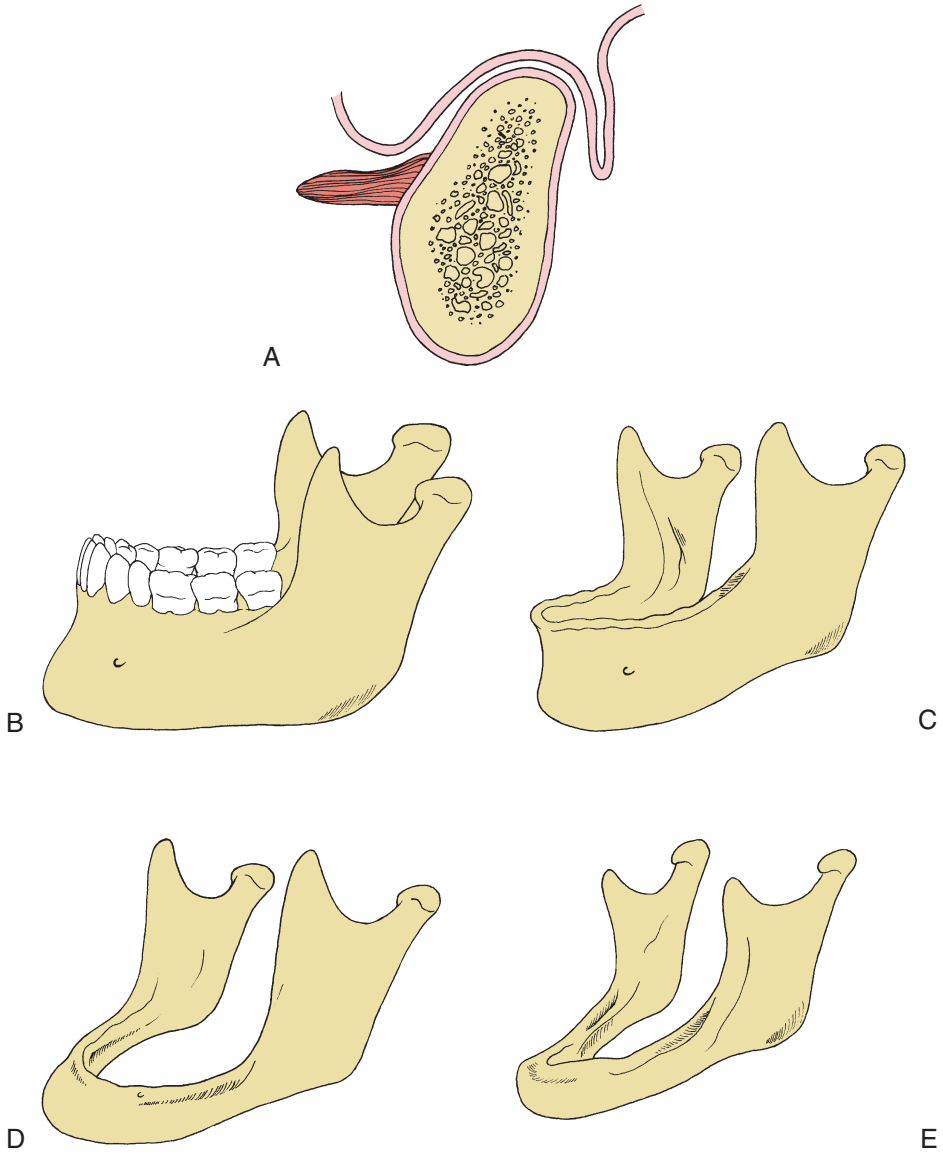
After the loss of natural teeth, bony changes in the jaws begin to take place immediately. Because the alveolar bone no longer responds to stresses placed in this area by teeth and the periodontal ligament, bone begins to resorb. The specific pattern of resorption is unpredictable in a given patient because great variation exists among individuals. In many patients, this resorption process tends to stabilize after a period, whereas in others a continuation of the process eventually results in total loss of alveolar bone and underlying basal bone (Fig. 13.1). The results of this resorption are accelerated by wearing dentures and tend to affect the mandible more severely than the maxilla because of the decreased surface area and less favorable distribution of occlusal forces.[1]

The increasing use of implants for the restoration of missing dentition has changed the treatment planning paradigm. The practitioner must identify, prior to the extraction of teeth, if the patient is going to have implant placement immediately or in the future. The planned or immediate placement of implants following the extraction of teeth necessitates different treatment planning in regard to preprosthetic surgical procedures. The focus of the practitioner still remains maximal preservation of hard and soft tissue to maintain alveolar and jaw height and width. Traditional preprosthetic surgery focuses on maintaining alveolar ridge form in addition to maintaining ideal edentulous jaw relationships, palatal and vestibular depth, tuberosity form, and keratinized gingiva and avoiding damage or compression of the neurovascular bundle.

The practitioner must address the treatment option regarding the placement of implants prior to the surgical procedure. The maximal preservation of alveolar ridge form for implant placement, especially with the use of grafting procedures, is ideally performed at the time of the initial surgery. The surgical planning for the immediate or delayed placement of implants is addressed in the corresponding chapter on contemporary implant dentistry. Despite the increasing use of implants, many of the preprosthetic surgical techniques or variations of these techniques remain applicable to achieve an ideal bony ridge form for successful implant placement or if the patient has medical or financial limitations and will be treated with removable partial or complete dentures.

Objectives of Preprosthetic Surgery

Despite the enormous progress in the technology available to preserve the dentition, prosthetic restoration and rehabilitation of the masticatory system are still needed in patients who are edentulous or partially edentulous. General systemic and local factors are responsible for the variation in the amount and pattern of alveolar bone resorption.[2] Systemic factors include the presence of nutritional abnormalities and systemic bone diseases such as osteoporosis,



• **Fig. 13.1** (A) Ideal shape of the alveolar process in the denture-bearing area. (B–E) Progression of bone resorption in the mandible after tooth extraction.

endocrine dysfunction, or any other systemic condition that may affect bone metabolism. Local factors affecting alveolar ridge resorption include alveoloplasty techniques used at the time of tooth removal and localized trauma associated with loss of alveolar bone. Denture wearing also may contribute to alveolar ridge resorption because of improper ridge adaptation of the denture or inadequate distribution of occlusal forces. Variations in facial structure may contribute to resorption patterns in two ways: (1) The actual volume of bone present in the alveolar ridges varies with facial form[3]; and (2) individuals with low mandibular plane angles and more acute gonial angles are capable of generating higher bite force, thereby placing greater pressure on the alveolar ridge areas. The long-term result of combined general and local factors is the loss of the bony alveolar ridge, increased interarch space, increased influence of surrounding soft tissue, decreased stability and retention of the prosthesis, and increased discomfort from improper prosthesis adaptation. In the most severe cases of resorption, a significant increase in the risk of spontaneous mandibular fracture exists.

The prosthetic replacement of lost or congenitally absent teeth frequently involves surgical preparation of the remaining oral tissues to support the best possible prosthetic replacement. Often, oral structures such as frenal attachments and exostoses have no significance when teeth are present but become obstacles to proper prosthetic appliance construction after tooth loss. The challenge of prosthetic rehabilitation of the patient includes restoration of the best masticatory function possible, combined with restoration or improvement of dental and facial esthetics. Maximal preservation of hard and soft tissue during preprosthetic surgical preparation is also mandatory. The oral tissues are difficult to replace after they are lost.

The objective of preprosthetic surgery is to create proper supporting structures for subsequent placement of prosthetic appliances. The best denture support has the following 11 characteristics[4]:

1. No evidence of intraoral or extraoral pathologic conditions
2. Proper interarch jaw relationship in the anteroposterior, transverse, and vertical dimensions
3. Alveolar processes that are as large as possible and of the proper configuration (The ideal shape of the alveolar process is a broad U-shaped ridge, with the vertical components as parallel as possible; see Fig. 13.1.)
4. No bony or soft tissue protuberances or undercuts
5. Adequate palatal vault form
6. Proper posterior tuberosity notching
7. Adequate attached keratinized mucosa in the primary denture-bearing area
8. Adequate vestibular depth for prosthesis extension
9. Added strength where mandibular fracture may occur
10. Protection of the neurovascular bundle
11. Adequate bony support and attached soft tissue covering to facilitate implant placement when necessary

Principles of Patient Evaluation and Treatment Planning

Before any surgical or prosthetic treatment, a thorough evaluation outlining the problems to be solved and a detailed treatment plan should be developed for each patient. It is imperative that no preparatory surgical procedure be undertaken without a clear understanding of the desired design of the final prosthesis.

Preprosthetic surgical treatment must begin with a thorough history and physical examination of the patient. An important aspect of the history is to obtain a clear idea of the patient's chief complaint and expectations of surgical and prosthetic treatment. Esthetic and functional goals of the patient must be assessed carefully and a determination made as to whether these expectations can be met. A thorough assessment of overall general health is especially important when considering more advanced preprosthetic surgical techniques because many of the approaches described require general anesthesia, donor site surgery to harvest autogenous graft material, and multiple surgical procedures. Specific attention should also be given to possible systemic diseases that may be responsible for the severe degree of bone resorption. Laboratory tests such as serum levels of calcium, phosphate, parathyroid hormone, and alkaline phosphatase may be useful in pinpointing potential metabolic problems that may affect bone resorption. Psychological factors and the adaptability of patients are important determinants of their ability to function adequately with full or partial dentures. Information on success or failure with previous prosthetic appliances may be helpful in determining the patient's attitude toward and adaptability to prosthetic treatment. The history should include important information such as the patient's risk status for surgery, with particular emphasis on systemic diseases that may affect bone or soft tissue healing.

An intraoral and extraoral examination of the patient should include an assessment of the existing occlusal relationships (if any remain), the amount and contour of remaining bone, the quality of overlying soft tissue, the vestibular depth, location of muscle attachments, the jaw relationships, and the presence of soft tissue or bony pathologic condition.

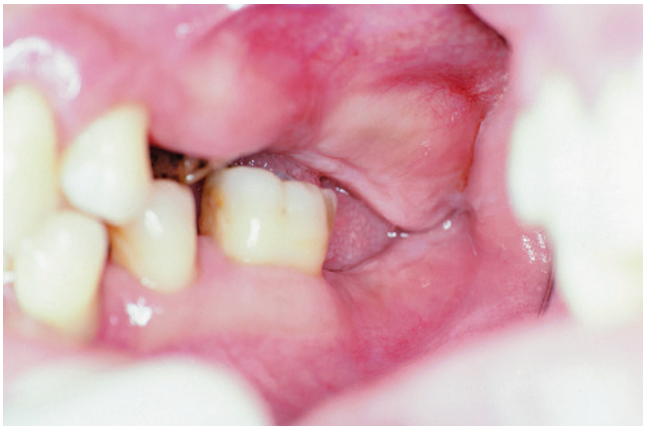
Evaluation of Supporting Bony Tissue

Examination of the supporting bone should include visual inspection, palpation, radiographic examination, and, in some cases, evaluation of models. Abnormalities of the remaining bone can often be assessed during the visual inspection; however, because of bony resorption and location of muscle or soft tissue attachments, many bony abnormalities may be obscured. Palpation of all areas of the maxilla and mandible, including the primary denture-bearing area and vestibular area, is necessary.

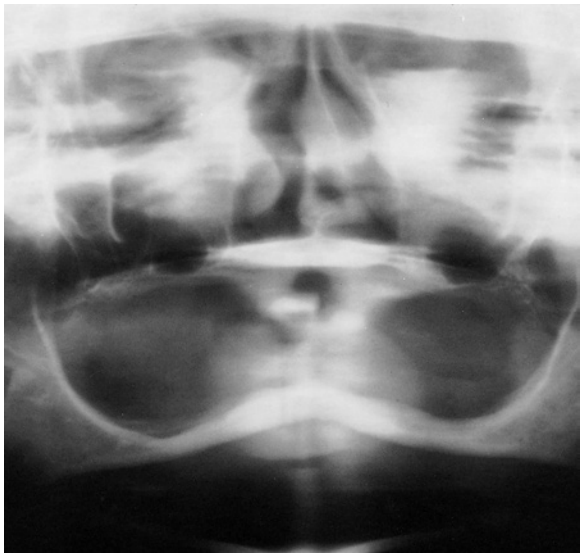
Evaluation of the denture-bearing area of the maxilla includes an overall evaluation of the bony ridge form. No bony undercuts or gross bony protuberances that block the path of denture insertion should be allowed to remain in the area of the alveolar ridge, buccal vestibule, or palatal vault. Palatal tori that require modification should be noted. Adequate posttuberosity notching is necessary for stabilization of the posterior denture and peripheral seal.

The remaining mandibular ridge should be evaluated visually for overall ridge form and contour, gross ridge irregularities, tori, and buccal exostosis. In cases of moderate to severe resorption of alveolar bone, ridge contour cannot be adequately assessed by visual inspection alone. Muscular and mucosal attachments near the crest of the ridge may obscure underlying bony anatomy, particularly in the area of the posterior mandible, where a depression can frequently be palpated between the external oblique line and mylohyoid ridge areas. The location of the mental foramen and mental neurovascular bundle can be palpated in relation to the superior aspect of the mandible, and neurosensory disturbances can be noted.

Evaluation of the interarch relationship of the maxilla and the mandible is important and includes an examination of the anteroposterior and vertical relationships, as well as any possible skeletal asymmetries that may exist between the maxilla and the mandible. In partially edentulous patients, the presence of supraerupted or malpositioned teeth should also be noted. The anteroposterior relationship must be evaluated with the patient in the proper vertical dimension. Overclosure of the mandible may result in a class III skeletal relationship but may appear normal if evaluated with the mandible in the proper postural position. Lateral and posteroanterior cephalometric radiographs with the jaws in proper postural position may be helpful in confirming a skeletal discrepancy. Careful attention must be paid to the interarch distance, particularly in the posterior areas, where vertical excess of the tuberosity, either bony tissue or soft tissue, may impinge on space necessary for placement of a prosthesis that is properly constructed (Fig. 13.2).



• **Fig. 13.2** Examination of interarch relationships in proper vertical dimension often reveals lack of adequate space for prosthetic reconstruction. In this case, bony and fibrous tissue excess in the tuberosity area must be reduced to provide adequate space for partial denture construction.



• **Fig. 13.3** Radiograph demonstrating atrophic mandibular and maxillary alveolar ridges. Pneumatization of the maxillary sinus is demonstrated.

Proper radiographs are an important part of the initial diagnosis and treatment plan. Panoramic radiographic techniques provide an excellent overview assessment of underlying bony structure and pathologic conditions.[5] Radiographs should disclose bony pathologic lesions, impacted teeth or portions of remaining roots, the bony pattern of the alveolar ridge, and pneumatization of the maxillary sinus (Fig. 13.3).

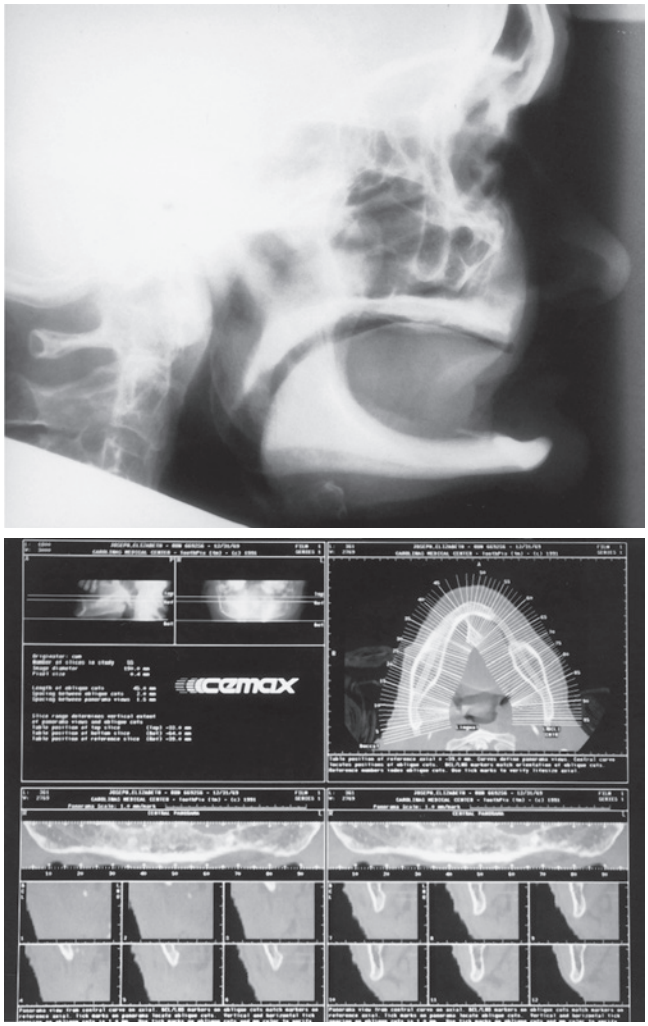
Cephalometric radiographs may also be helpful in evaluating the cross-sectional configuration of the anterior mandibular ridge area and ridge relationships (Fig. 13.4). To evaluate the ridge relationship in the vertical and anteroposterior dimensions, it may be necessary to obtain the cephalometric radiograph in the appropriate vertical dimension. This often requires adjusting or reconstructing dentures to this position or making properly adjusted bite rims to be used for positioning at the time the radiograph is taken.

More sophisticated radiographic studies, such as computed tomography scans, may provide further information. Computed tomography scans are particularly helpful in evaluating the cross-sectional anatomy of the maxilla, including ridge form and sinus anatomy. The cross-sectional anatomy of the mandible, including the configuration of basal bone, the alveolar ridge, and the location of the inferior alveolar nerve, can be evaluated more precisely.

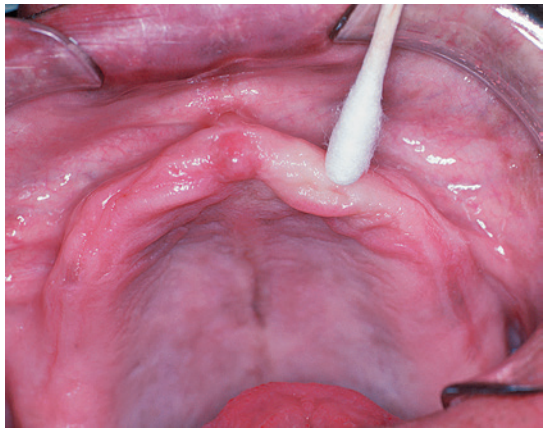
Evaluation of Supporting Soft Tissue

Assessment of the quality of tissue of the primary denture-bearing area overlying the alveolar ridge is of utmost importance. The amount of keratinized tissue firmly attached to the underlying bone in the denture-bearing area should be distinguished from poorly keratinized or freely movable tissue. Palpation discloses hypermobile fibrous tissue that is inadequate for a stable denture base (Fig. 13.5).

The vestibular areas should be free of inflammatory changes such as scarred or ulcerated areas caused by denture pressure or hyperplastic tissue resulting from an ill-fitting denture. Tissue at the depth of the vestibule should be supple and without irregularities



• **Fig. 13.4** (A) Cephalometric radiograph illustrating cross-sectional anatomy of the anterior mandible (patient is overclosed, giving the relative appearance of a class III jaw relationship). (B) Computed tomography scan showing detailed cross-sectional anatomy of the mandible.



• **Fig. 13.5** Palpation reveals hypermobile tissue that will not provide an adequate base in the denture-bearing area.

for maximal peripheral seal of the denture. Assessment of vestibular depth should include manual manipulation of the adjacent muscle attachments. By tensing the soft tissue adjacent to the area of the alveolar ridge, the dentist can note muscle or soft tissue attachments (including frena) that approximate the crest of the alveolar ridge and are often responsible for the loss of peripheral seal of the denture during speech and mastication.

The lingual aspect of the mandible should be inspected to determine the level of attachment of the mylohyoid muscle in relation to the crest of the mandibular ridge and the attachment of the genioglossus muscle in the anterior mandible. The linguovestibular depth should be evaluated with the tongue in several positions because movement of the tongue accompanied by elevation of the mylohyoid and genioglossus muscles is a common cause of movement and displacement of the lower denture.

Treatment Planning

Before any surgical intervention, a treatment plan addressing the patient's identified oral problems should be formulated. The dentist responsible for prosthesis construction should assume responsibility for seeking surgical consultation, when necessary. Long-term maintenance of the underlying bone, soft tissue, and prosthetic appliances should be kept in mind at all times. When severe bony atrophy exists, treatment must be directed at correction of the bony deficiency and alteration of the associated soft tissue. When some degree of bony support remains despite alveolar atrophy, improvement of the denture-bearing area may be accomplished by directly treating the bony deficiency or by compensating for it with soft tissue surgery. The most appropriate treatment plan should consider ridge height, width, and contour. Several other factors should also be considered: in an older patient in whom moderate bony resorption has taken place, soft tissue surgery alone may be sufficient for improved prosthesis function. In an extremely young patient who has undergone the same degree of atrophy, bony augmentation procedures may be indicated. The role of implants may alter the need for surgical modification of bone or soft tissue.

Hasty treatment planning, without consideration for long-term results, can often result in unnecessary loss of bone or soft tissue and improper functioning of the prosthetic appliance. For example, when there appears to be redundant or loose soft tissue over the alveolar ridge area, the most appropriate long-term treatment plan may involve grafting bone to improve the contour of the alveolar ridge or support endosteal implants. Maintenance of the redundant soft tissue may be necessary to improve the results of the grafting procedure. If this tissue were removed without any consideration of the possible long-term benefits of a grafting procedure, the opportunity for improved immediate function and the opportunity for long-term maintenance of bony tissue and soft tissue would be lost. If bony augmentation is indicated, maximum augmentation frequently depends on availability of adjacent soft tissue to provide tension-free coverage of the graft. Soft tissue surgery should be delayed until hard tissue grafting and appropriate healing have occurred. This is especially true for conservation of gingiva and keratinized soft tissues, which provide a better implant environment. Therefore it is usually desirable to delay definitive soft tissue procedures until underlying bony problems have been adequately resolved. However, when extensive grafting or other more complex treatment of bony abnormalities is not required, bony and soft tissue preparation sometimes can be completed simultaneously.

Recontouring of Alveolar Ridges

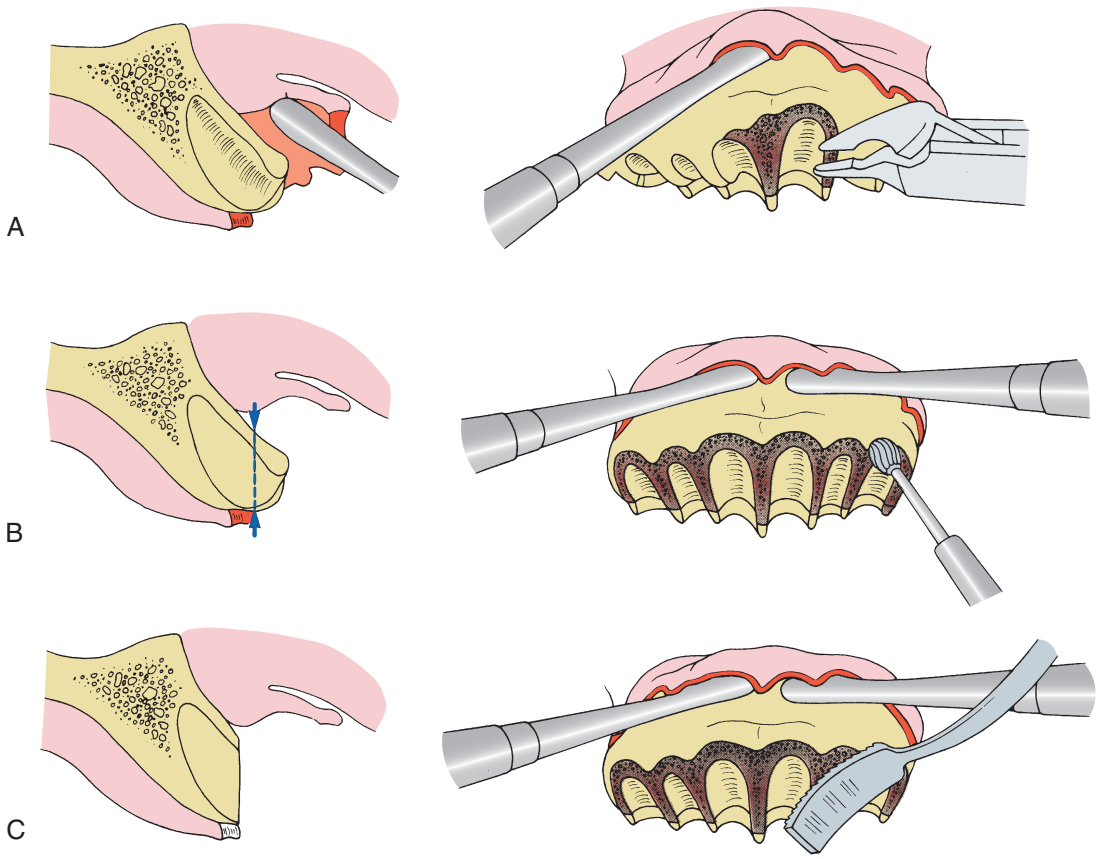
Irregularities of the alveolar bone found at the time of tooth extraction or after a period of initial healing require recontouring before final prosthetic construction. This chapter focuses primarily on preparation of ridges for removable prostheses, but some emphasis is placed on the possibility of future implant placement and the obvious need to conserve as much bone and soft tissue as possible.

Simple Alveoloplasty Associated With Removal of Multiple Teeth

The simplest form of alveoloplasty consists of the compression of the lateral walls of the extraction socket after simple tooth removal. In many cases of single tooth extraction, digital compression of the extraction site adequately contours the underlying bone, provided no gross irregularities of bone contour are found in the area after extraction. When multiple irregularities exist, more extensive recontouring often is necessary. A conservative alveoloplasty in combination with multiple extractions is carried out after all of the teeth in the arch have been removed (see Chapter 8). The specific areas requiring alveolar recontouring are obvious if this sequence is followed. Whether alveolar ridge recontouring is performed at the time of tooth extraction or after a period of healing, the technique is essentially the same. Bony areas requiring recontouring should be exposed using an envelope type of flap. A mucoperiosteal incision along the crest of the ridge, with adequate extension anteroposterior to the area to be exposed, and flap reflection allow adequate visualization and access to the alveolar ridge. Where adequate exposure is not possible, small vertical-releasing incisions may be necessary.

The primary objectives of mucoperiosteal flap reflection are to allow for adequate visualization and access to the bony structures that require recontouring and to protect soft tissue adjacent to this area during the procedure. Although releasing incisions often create more discomfort during the healing period, this technique is certainly preferred to the possibility of an unanticipated tear in the edges of a flap when inadequate exposure could not be achieved with an envelope flap. Regardless of flap design, the mucoperiosteum should be reflected only to the extent that adequate exposure to the area of bony irregularity can be achieved. Excessive flap reflection may result in devitalized areas of bone, which will resorb more rapidly after surgery, and a diminished soft tissue adaptation to the alveolar ridge area.

Depending on the degree of irregularity of the alveolar ridge area, recontouring can be accomplished with a rongeur, a bone file, or a bone burr in a handpiece, alone or in combination (Fig. 13.6). Copious saline irrigation should be used throughout the recontouring procedure to avoid overheating and bone necrosis. After recontouring, the flap should be reapproximated by digital pressure and the ridge palpated to ensure that all irregularities have been removed (Fig. 13.7). After copious irrigation to ensure removal of debris, the tissue margins can be reapproximated with interrupted or continuous sutures. Resorbable sutures are usually used to approximate tissue and add tensile strength across the wound margins. The resorbable material is broken down by salivary proteolytic enzymes or hydrolysis over several days to weeks, eliminating the need for removal.[6] If an extensive incision has been made, continuous suturing tends to be less annoying to the patient and provides for easier postoperative hygiene because of the elimination of knots and loose suture ends along the incision



• **Fig. 13.6** Simple alveoloplasty eliminates buccal irregularities and undercut areas by removing labiocortical bone. (A) Elevation of mucoperiosteal flap, exposure of irregularities of the alveolar ridge, and removal of gross irregularity with a rongeur. (B) Bone burr in a rotating handpiece can also be used to remove bone and smooth labiocortical surface. (C) Use of a bone file to smooth irregularities and achieve the final desired contour.

line. The initial soft tissue redundancy created with reduction of the bony irregularities often shrinks and readapts over the alveolus, allowing preservation of attached gingiva.

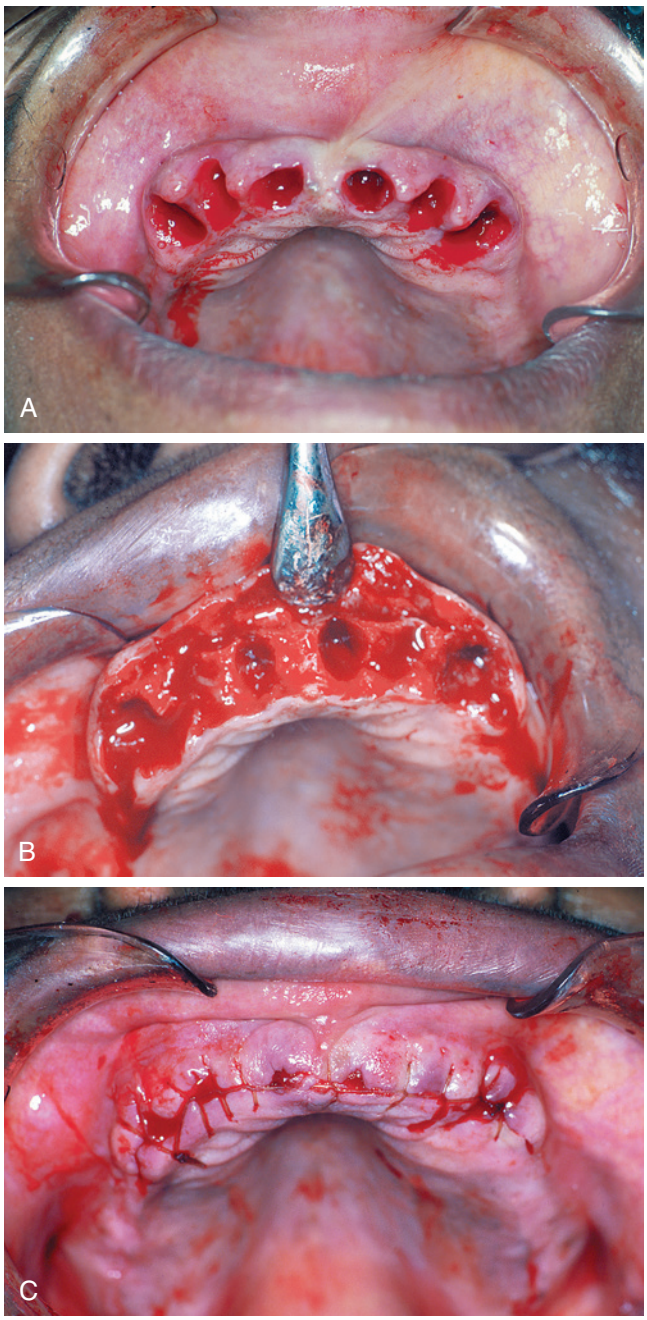
When a sharp knife-edge ridge exists in the mandible, the sharp superior portion of the alveolus can be removed in a manner similar to that described for simple alveoloplasty. After local anesthesia is obtained, a crestal incision is made, extending along the alveolar ridge approximately 1 cm beyond either end of the area requiring recontouring (Fig. 13.8). After minimal reflection of the mucoperiosteum, a rongeur can be used to remove the major portion of the sharp area of the superior aspect of the mandible. A bone file is used to smooth the superior aspect of the mandible. After copious irrigation, this area is closed with continuous or interrupted sutures. Before removal of any bone, strong consideration should be given to reconstruction of proper ridge form using grafting procedures (discussed later in this chapter).

Intraseptal Alveoloplasty

An alternative to the removal of alveolar ridge irregularities by the simple alveoloplasty technique is the use of an intraseptal alveoloplasty, or Dean technique, involving the removal of intraseptal bone and the repositioning of the labial cortical bone, rather than removal of excessive or irregular areas of the labial cortex.[7] This technique is best used in an area where the ridge is of relatively regular contour and adequate height but presents an undercut to the depth of the labial vestibule because of the configuration of the alveolar ridge. The technique can be accomplished at the time of tooth removal or in the early initial postoperative healing period.

After exposure of the crest of the alveolar ridge by reflection of the mucoperiosteum, a small rongeur can be used to remove the intraseptal portion of the alveolar bone (Fig. 13.9). After adequate bone removal has been accomplished, digital pressure should be sufficient to fracture the labiocortical plate of the alveolar ridge inward to approximate the palatal plate area more closely. Occasionally, small vertical cuts at either end of the labiocortical plate facilitate repositioning of the fractured segment. By using a burr or osteotome inserted through the distal extraction area, the labial cortex is scored without perforation of the labial mucosa. Digital pressure on the labial aspect of the ridge is necessary to determine when the bony cut is complete and to ensure that the mucosa is not damaged. After positioning of the labiocortical plate, any slight areas of bony irregularity can be contoured with a bone file, and the alveolar mucosa can be reapproximated with interrupted or continuous suture techniques. A splint or an immediate denture lined with a soft lining material can then be inserted to maintain the bony position until initial healing has taken place.

This type of technique has several advantages: the labial prominence of the alveolar ridge can be reduced without significantly reducing the height of the ridge in this area. The periosteal attachment to the underlying bone can also be maintained, thereby



• **Fig. 13.7** (A) Clinical appearance of the maxillary ridge after removal of teeth. (B) Minimal flap reflection for recontouring. (C) Proper alveolar ridge form free of irregularities and bony undercuts after recontouring.

reducing postoperative bone resorption and remodeling. Finally, the muscle attachments to the area of the alveolar ridge can be left undisturbed in this type of procedure. Michael and Barsoum reported the results of a study comparing the effects of postoperative bone resorption after three alveoloplasty techniques.[8] In their study, nonsurgical extraction, labial alveoloplasty, and an intraseptal alveoloplasty technique were compared with evaluate postoperative bony resorption. The initial postoperative results were similar, but the best long-term maintenance of alveolar ridge height was achieved with nonsurgical extractions, and the intraseptal alveoloplasty technique resulted in less resorption than did removal of labiocortical bone for reduction of ridge irregularities.

The main disadvantage of this technique is the decrease in ridge thickness that obviously occurs with this procedure. If the ridge form remaining after this type of alveoloplasty is excessively thin, it may preclude placement of implants in the future. For this reason the intraseptal alveoloplasty should reduce the thickness of the ridge in an amount sufficient only to reduce or eliminate undercuts in areas where a plan to place endosteal implants does not exist. Methods for preservation of alveolar width with simultaneous grafting into the extraction site are addressed later in the chapter.

Maxillary Tuberosity Reduction (Hard Tissue)

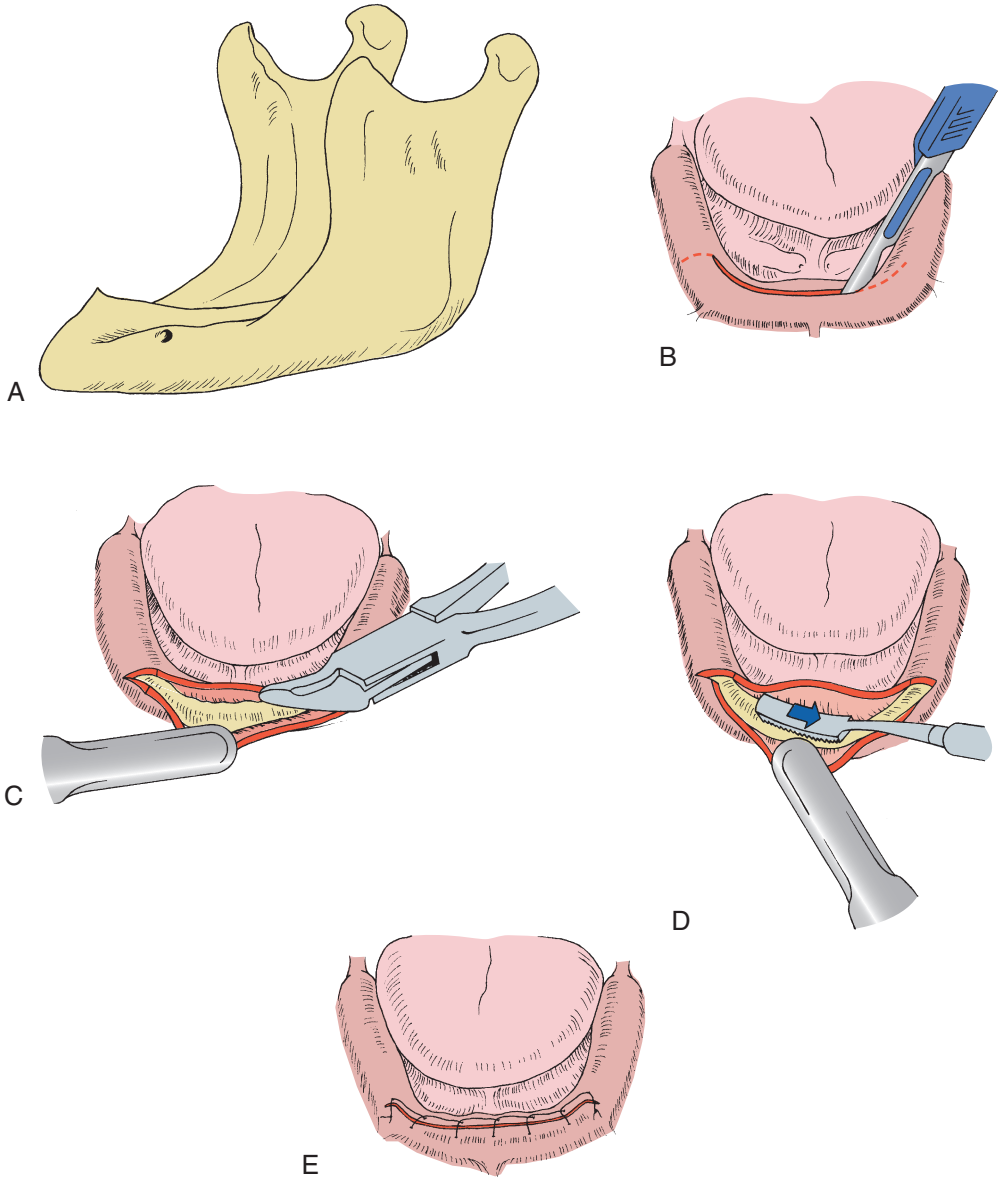
Horizontal or vertical excess of the maxillary tuberosity area may be a result of excess bone, an increase in the thickness of soft tissue overlying the bone, or both. A preoperative radiograph or selective probing with a local anesthetic needle is often useful to determine the extent to which bone and soft tissue contribute to this excess and to locate the floor of the maxillary sinus. Recontouring of the maxillary tuberosity area may be necessary to remove bony ridge irregularities or to create adequate interarch space, which allows proper construction of prosthetic appliances in the posterior areas. Surgery can be accomplished using local anesthetic infiltration or posterosuperior alveolar and greater palatine blocks. Access to the tuberosity for bone removal is accomplished by making a crestal incision that extends up the posterior aspect of the tuberosity area. The most posterior aspect of this incision is often best made with a No. 12 scalpel blade. Reflection of a full-thickness mucoperiosteal flap is completed in the buccal and palatal directions to allow adequate access to the entire tuberosity area (Fig. 13.10). Bone can be removed using a side-cutting rongeur or rotary instruments, with care taken to avoid perforation of the floor of the maxillary sinus. If the maxillary sinus is inadvertently perforated, no specific treatment is required, provided that the sinus membrane has not been violated. After the appropriate amount of bone has been removed, the area should be smoothed with a bone file and copiously irrigated with saline. The mucoperiosteal flaps can then be readapted.

Excess, overlapping soft tissue resulting from the bone removal is excised in an elliptical fashion. A tension-free closure over this area is important, particularly if the floor of the sinus has been perforated. Sutures should remain in place for approximately 7 days. Initial denture impressions can be completed approximately 4 weeks after surgery.

In the event of a gross sinus perforation involving an opening in the sinus membrane, the use of postoperative antibiotics and sinus decongestants is recommended. Amoxicillin is usually the antibiotic of choice, unless contraindicated by allergy. Sinus decongestants such as pseudoephedrine, with or without an antihistamine, are adequate. The antibiotic and the decongestant should be given for 7 to 10 days postoperatively. The patient is informed of the potential complications and cautioned against creating excessive sinus pressure such as nose blowing or sucking with a straw for 10 to 14 days.

Buccal Exostosis and Excessive Undercuts

Excessive bony protuberances and resulting undercut areas are more common in the maxilla than in the mandible. A local anesthetic should be infiltrated around the area requiring bony reduction. For mandibular buccal exostosis, inferior alveolar blocks may also be required to anesthetize bony areas. A crestal incision extends 1 to 1.5 cm beyond each end of the area requiring contouring,

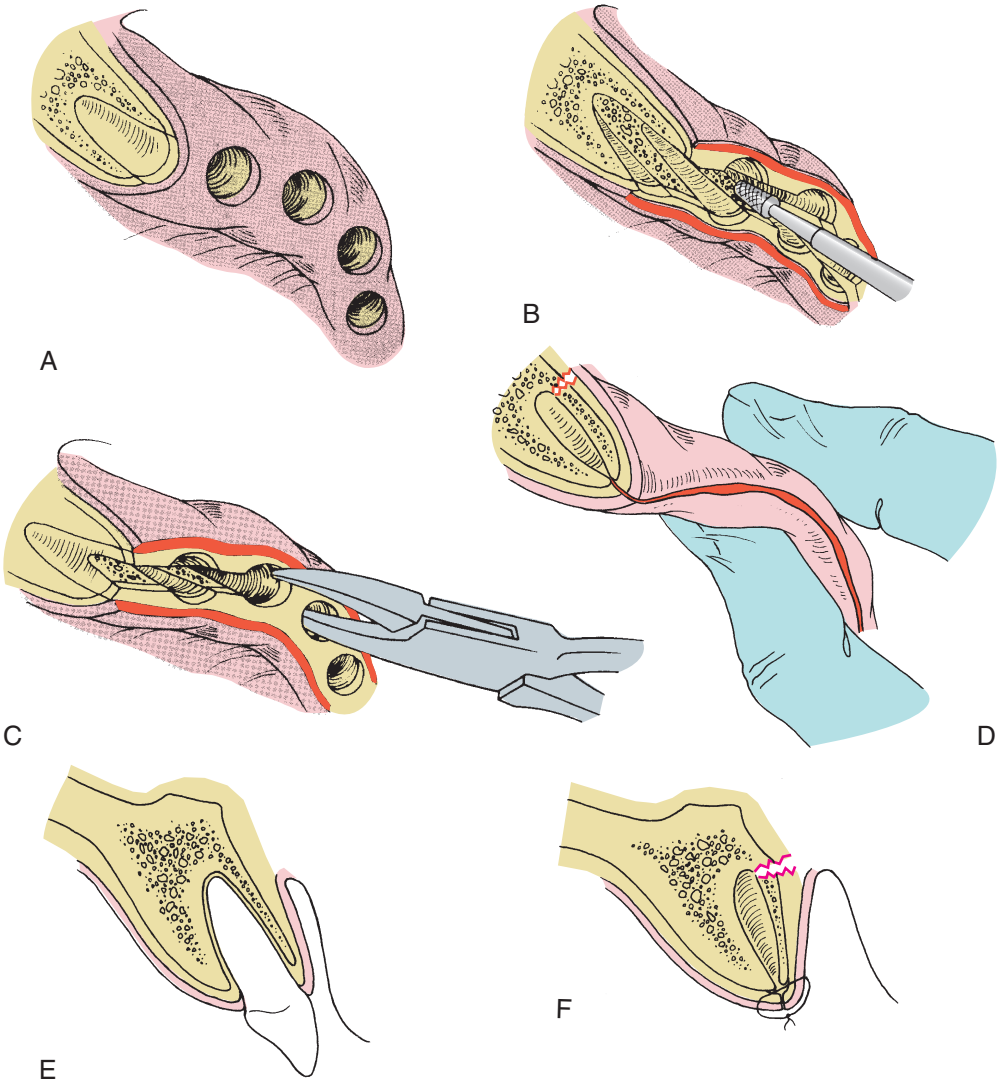


• **Fig. 13.8** Recontouring of a knife-edge ridge. (A) Lateral view of the mandible, with resorption resulting in a knife-edge alveolar ridge. (B) Crestal incision extends 1 cm beyond each end of area to be recontoured (vertical-releasing incisions are occasionally necessary at the posterior ends of the initial incision). (C) Rongeur used to eliminate bulk of a sharp bony projection. (D) Bone file used to eliminate any minor irregularities (bone burr and handpiece can also be used for this purpose). (E) Continuous suture technique for mucosal closure.

and a full-thickness mucoperiosteal flap is reflected to expose the areas of bony exostosis. If adequate exposure cannot be obtained, vertical-releasing incisions are necessary to provide access and prevent trauma to the soft tissue flap. If the areas of irregularity are small, recontouring with a bone file may be all that is required; larger areas may necessitate use of a rongeur or rotary instrument (Fig. 13.11). After completion of the bone recontouring, soft tissue is readapted, and visual inspection and palpation ensure that no irregularities or bony undercuts exist. Interrupted or continuous suturing techniques are used to close the soft tissue incision. Denture impressions can be completed 4 weeks postoperatively.

Although extremely large areas of bony exostosis generally require removal, small undercut areas are often best treated by being filled with autogenous or allogeneic bone material. Such a situation might occur in the anterior maxilla or mandible, where removal of the bony buccal protuberance results in a narrowed crest in the alveolar ridge area and a less desirable area of support for the denture, as well as an area that may resorb more rapidly.

Local anesthetic infiltration is generally sufficient when filling in buccal undercut areas. The undercut portion of the ridge is exposed with a crestal incision and standard dissection, or the undercut area can be accessed with a vertical incision made in the anterior maxillary or mandibular areas (Fig. 13.12). A small periosteal elevator is then used to create a subperiosteal tunnel extending the length of the area to be filled in with bone graft. Autogenous or allogeneic material can then be placed in the



• **Fig. 13.9** Intraseptal alveoloplasty. (A) Oblique view of the alveolar ridge, demonstrating a slight facial undercut. (B) Minimal elevation of the mucoperiosteal flap followed by removal of intraseptal bone using a fissure burr and handpiece. (C) Rongeur used to remove intraseptal bone. (D) Digital pressure used to fracture the labiocortex in a palatal direction. (E) Cross-sectional view of alveolar process. (F) Cross-sectional view of alveolar process after tooth removal and intraseptal alveoloplasty. By fracturing the labiocortex of the alveolar process in a palatal direction, labial undercut can be eliminated without reducing vertical height of the alveolar ridge.

defect and covered with a resorbable membrane. Impressions for denture fabrication can be taken after tissue healing 3 to 4 weeks after surgery. A modification of this technique is also discussed in Chapter 15.

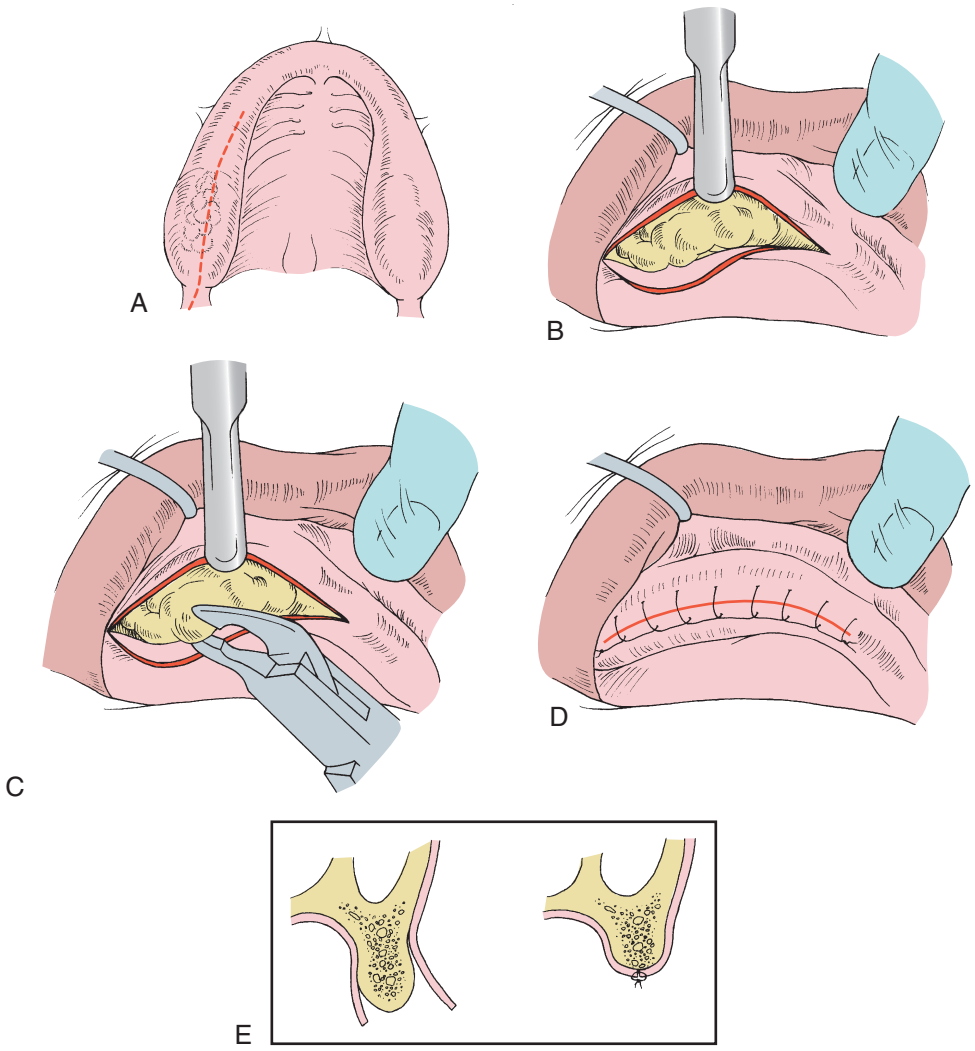
Lateral Palatal Exostosis

The lateral aspect of the palatal vault may be irregular because of the presence of lateral palatal exostosis. This presents problems in denture construction because of the undercut created by the exostosis and the narrowing of the palatal vault. Occasionally these exostoses are large enough that the mucosa covering the area becomes ulcerated.

Local anesthetic in the area of the greater palatine foramen and infiltration in the area of the incision are necessary. A crestal incision is made from the posterior aspect of the tuberosity, extending slightly beyond the anterior area of the exostosis, which requires recontouring (Fig. 13.13). Reflection of the mucoperiosteum in the palatal direction should be accomplished with careful attention to the area of the palatine foramen to avoid damage to the blood vessels as they leave the foramen and extend forward. After adequate exposure, a rotary instrument or bone file can be used to remove the excess bony projection in this area. The area is irrigated with sterile saline and closed with continuous or interrupted sutures. No surgical splint or packing is generally required, and the apparent redundant soft tissues will adapt after this procedure.

Mylohyoid Ridge Reduction

One of the more common areas interfering with proper denture construction in the mandible is the mylohyoid ridge area. In addition to the actual bony ridge, with its easily damaged thin covering of mucosa, the muscular attachment to this area often is responsible for dislodging the denture. When this ridge is extremely sharp,



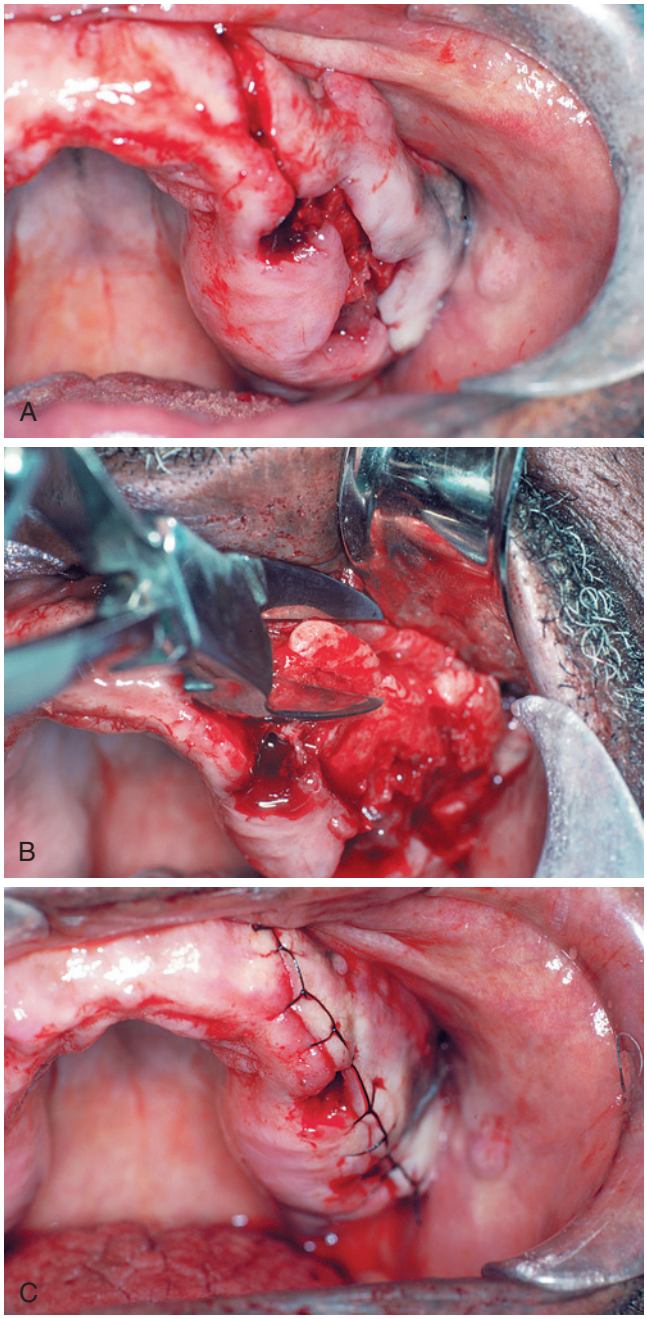
• **Fig. 13.10** Bony tuberosity reduction. (A) Incision extended along the crest of the alveolar ridge distally to the superior extent of the tuberosity area. (B) Elevated mucoperiosteal flap provides adequate exposure to all areas of bony excess. (C) Rongeur used to eliminate bony excess. (D) Tissue reapproximated with a continuous suture technique. (E) Cross-sectional view of the posterior tuberosity area, showing vertical reduction of bone and reapposition of the mucoperiosteal flap. (In some cases removal of large amounts of bone produces excessive soft tissue, which can be excised before closure to prevent overlapping.)

denture pressure may produce significant pain in this area. (Relocation of the mylohyoid muscle to improve this condition is discussed later in this chapter.) In cases of severe resorption, the external oblique line and the mylohyoid ridge area may actually form the most prominent areas of the posterior mandible, with the midportion of the mandibular ridge existing as a concave structure. In such cases, augmentation of the posterior aspect of the mandible, rather than removal of the mylohyoid ridge, may be beneficial. However, some cases can be improved by reduction of the mylohyoid ridge area.

Inferior alveolar, buccal, and lingual nerve blocks are required for mylohyoid ridge reduction. A linear incision is made over the crest of the ridge in the posterior aspect of the mandible. Extension of the incision too far to the lingual aspect should be avoided because this may cause potential trauma to the lingual nerve. A full-thickness mucoperiosteal flap is reflected, which exposes the mylohyoid ridge area and mylohyoid muscle attachments (Fig. 13.14). The mylohyoid muscle fibers are removed from the ridge by sharply incising the muscle attachment at the area of bony origin. When the muscle is released, the underlying fat is visible in the surgical field. After reflection of the muscle, a rotary instrument with careful soft tissue protection or bone file can be used to remove the sharp prominence of the mylohyoid ridge. Immediate replacement of the denture is desirable because it may help to facilitate a more inferior relocation of the muscular attachment; however, this is unpredictable and may actually be best managed by a procedure to lower the floor of the mouth.

Genial Tubercle Reduction

As the mandible begins to undergo resorption, the area of the attachment of the genioglossus muscle in the anterior portion of the mandible may become increasingly prominent. In some cases the tubercle may actually function as a shelf against which the denture can be constructed, but it usually requires reduction to construct the prosthesis properly. Before a decision to remove this



• **Fig. 13.11** Removal of buccal exostosis. (A) Gross irregularities of the buccal aspect of the alveolar ridge. After tooth removal, incision is completed over the crest of the alveolar ridge. (Vertical-releasing incision in the cuspid area is demonstrated.) (B) Exposure and removal of buccal exostosis with a rongeur. (C) Soft tissue closure using a continuous suture technique.

prominence is made, consideration should be given to possible augmentation of the anterior portion of the mandible rather than reduction of the genial tubercle. If augmentation is the preferred treatment, the tubercle should be left to add support to the graft in this area. Local anesthetic infiltration and bilateral lingual nerve blocks should provide adequate anesthesia. A crestal incision is made from each premolar area to the midline of the mandible. A full-thickness mucoperiosteal flap is dissected lingually to expose the genial tubercle. The genioglossus muscle attachment can be removed by a sharp incision.

Smoothing with a burr or a rongeur followed by a bone file removes the genial tubercle. The genioglossus muscle is left to reattach in a random fashion. As with the mylohyoid muscle and mylohyoid ridge reduction, a procedure to lower the floor of the mouth may also benefit the anterior mandible.

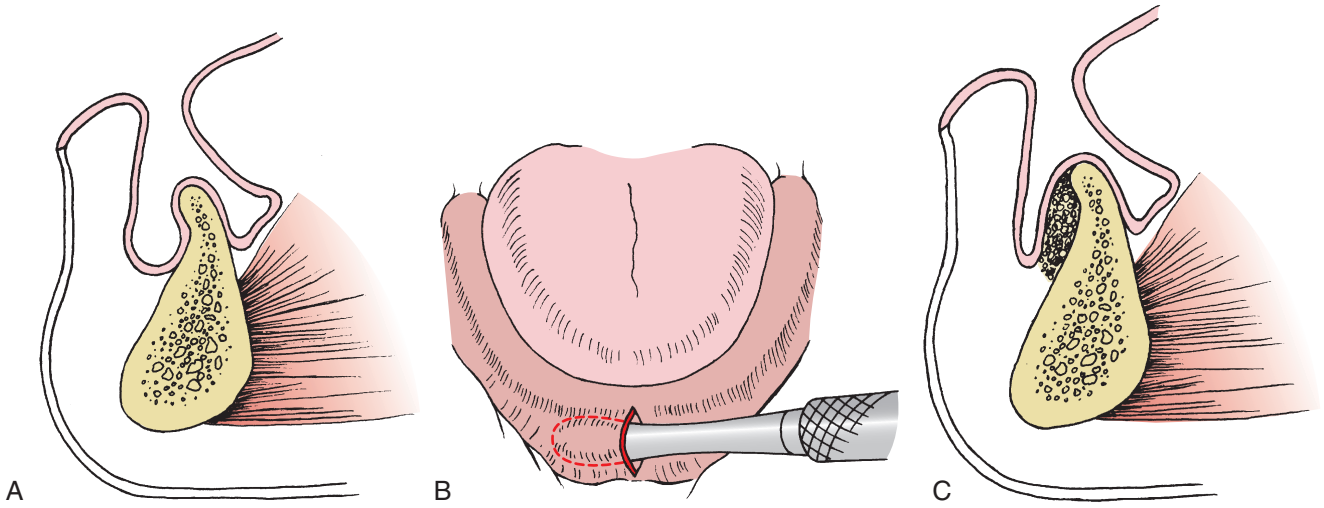
Tori Removal

Maxillary Tori

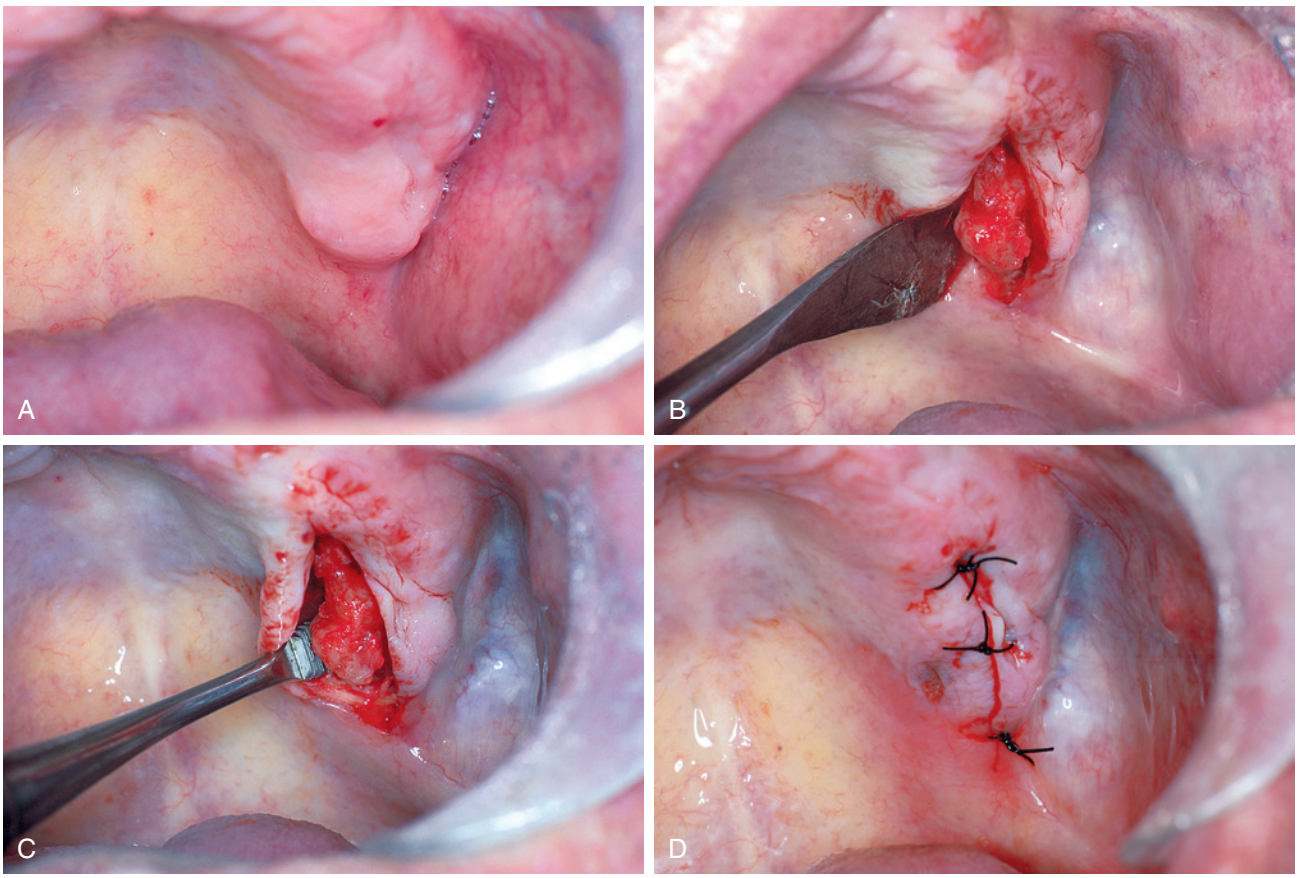
Maxillary tori consist of bony exostosis formation in the area of the palate. The origin of maxillary tori is unclear. Tori are found in 20% of the female population, which is approximately twice the prevalence rate in males.[9] Tori may have multiple shapes and configurations, ranging from a single smooth elevation to a multiloculated pedunculated bony mass. Tori present few problems when the maxillary dentition is present and only occasionally interfere with speech or become ulcerated from frequent trauma to the palate. However, when the loss of teeth necessitates full or partial denture construction, tori often interfere with proper design and function of the prosthesis. Nearly all large maxillary tori should be removed before full or partial denture construction. Smaller tori may often be left because they do not interfere with prosthetic construction or function. Even small tori necessitate removal when they are irregular, extremely undercut, or in the area where a posterior palatal seal would be expected.

Bilateral greater palatine and incisive blocks and local infiltration provide the necessary anesthesia for tori removal. A linear incision in the midline of the torus with oblique vertical-releasing incisions at one or both ends is generally necessary (Fig. 13.15). Because the mucosa over this area is extremely thin, care must be taken in reflecting the tissue from underlying bone, a particularly difficult task when the tori are multiloculated. A full palatal flap can sometimes be used for exposure of the tori. An incision is made along the crest of the ridge when the patient is edentulous or a palatal sulcular incision is used when teeth are present. Tissue reflection with this type of incision is often difficult if the tori have large undercuts where the bony exostosis is fused with the palate. When tori with a small pedunculated base are present, an osteotome and mallet may be used to remove the bony mass. For larger tori, it is usually best to section the tori into multiple fragments with a burr in a rotary handpiece. Careful attention must be paid to the depth of the cuts to avoid perforation of the floor of the nose. After sectioning, individual portions of the tori can be removed with a mallet and osteotome or a rongeur; then the area can be smoothed with a large bone burr. The entire bony projection does not necessarily require removal, but a smooth regular area without undercuts should be created, without extension into the area where a posterior palatal seal would be placed. Tissue is readapted by finger pressure and is inspected to determine the amount of excess mucosa that may require removal. Retention of enough tissue to allow a tension-free closure over the entire area of exposed bone is important. The mucosa is reapproximated and sutured; an interrupted suture technique is often required because the thin mucosa may not retain sutures well. To prevent hematoma formation, some form of pressure dressing must be placed over the area of the palatal vault. A temporary denture or prefabricated splint with a soft liner placed in the center of the palate to prevent pressure necrosis can also be used to support the thin mucosa and prevent hematoma formation.

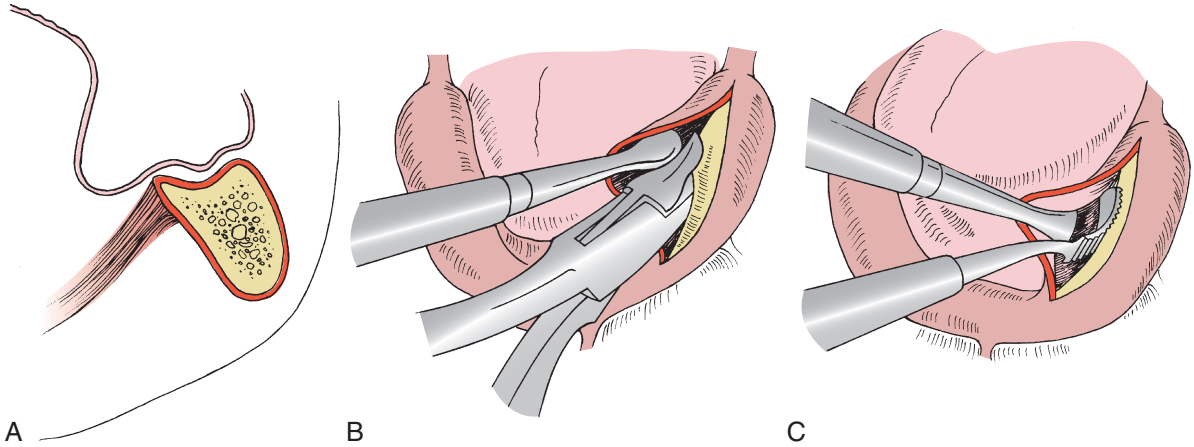
The major complications of maxillary tori removal include postoperative hematoma formation, fracture or perforation of the



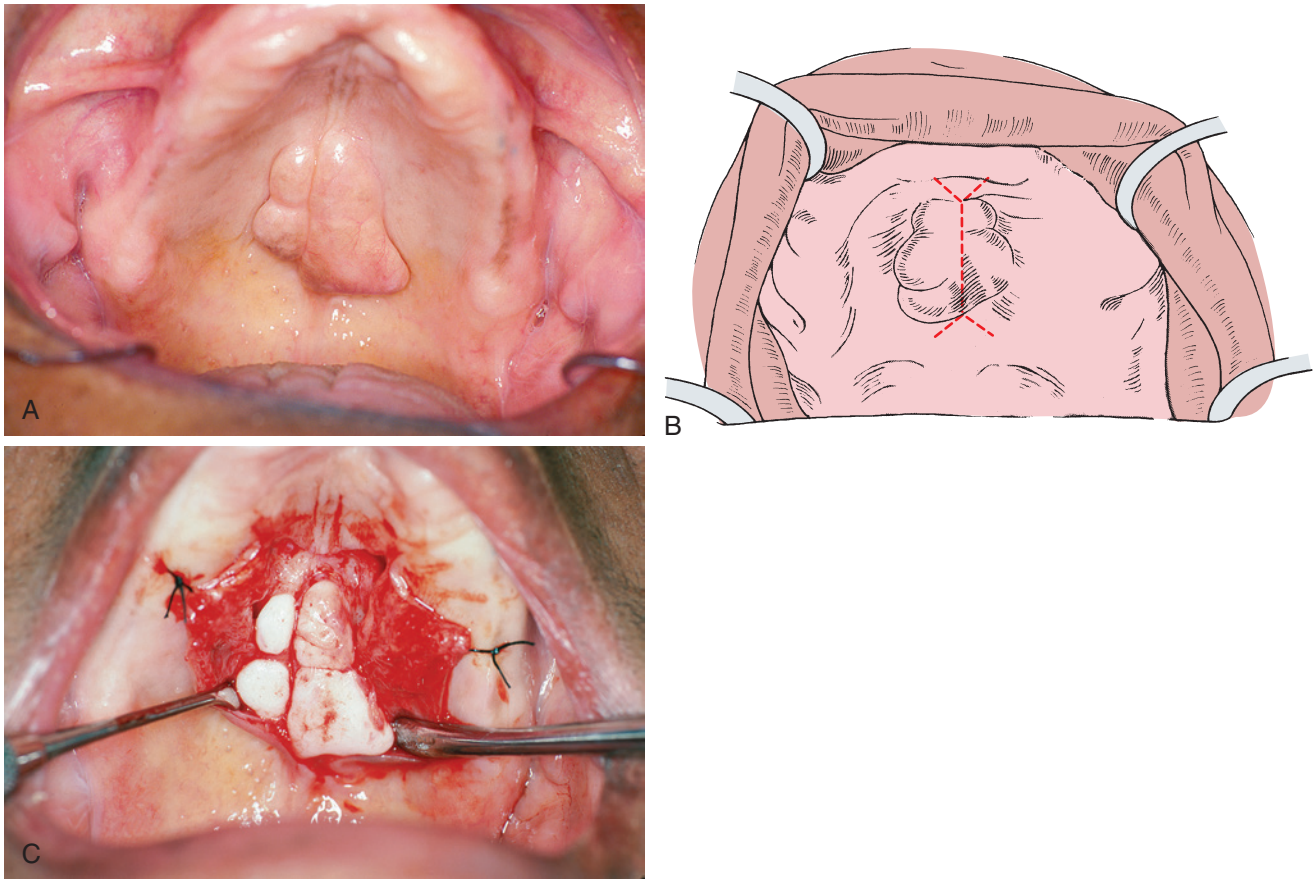
• **Fig. 13.12** Removal of mandibular buccal undercut. (A) Cross-sectional view of the anterior portion of the mandible, which, if corrected by removal of labiocortical bone, would result in knife-edge ridge. (B) Vertical incision is made and a subperiosteal tunnel developed in the depth of the undercut area. (C) Cross-sectional view after filling the defect with graft material. The material is contained within the boundaries of the subperiosteal tunnel.



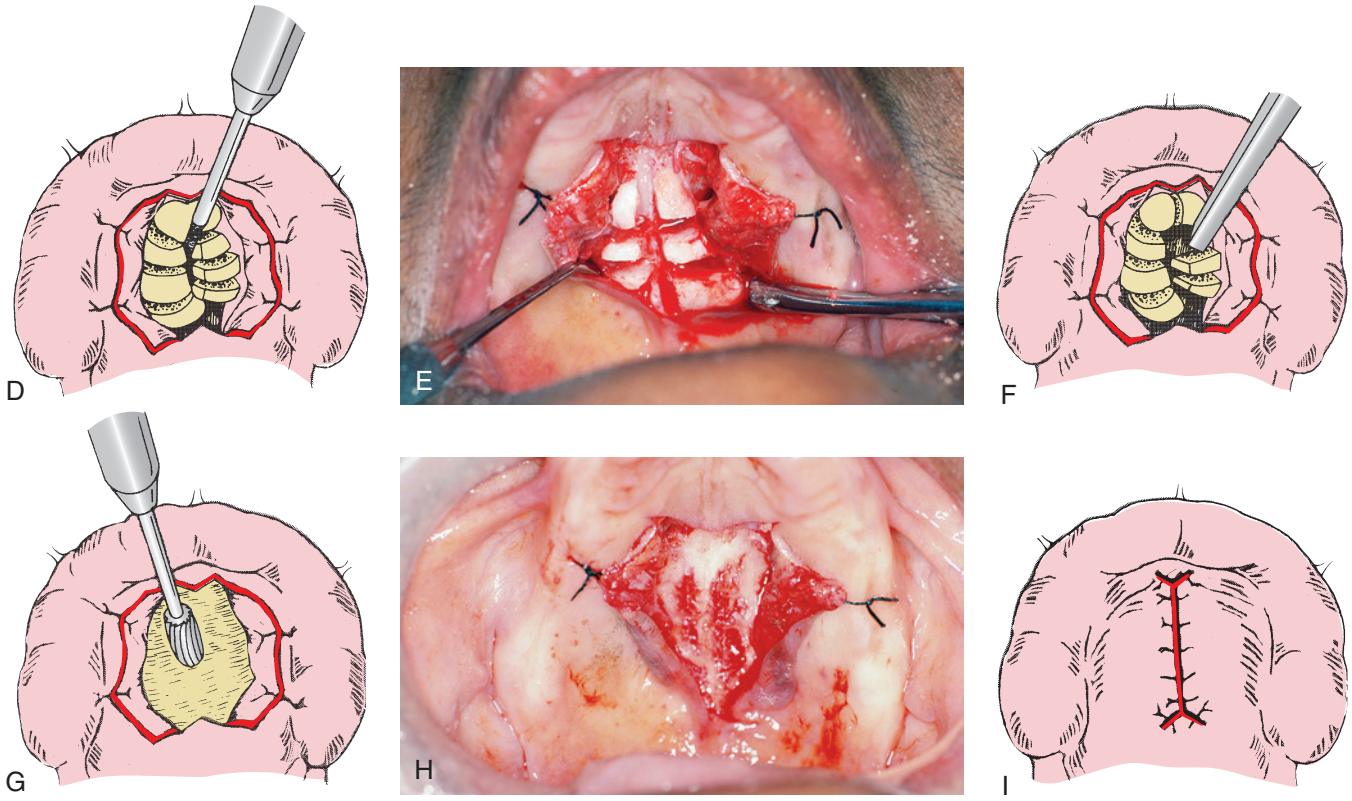
• **Fig. 13.13** Removal of palatal bony exostosis. (A) Small palatal exostosis that interferes with proper denture construction in this area. (B) Crestal incision and mucoperiosteal flap reflection to expose palatal exostosis. (C) Use of a bone file to remove bony excess. (D) Soft tissue closure.



• **Fig. 13.14** Mylohyoid ridge reduction. (A) Cross-sectional view of the posterior aspect of the mandible, showing concave contour of the superior aspect of the ridge from resorption. Mylohyoid ridge and external oblique lines form the highest portions of the ridge. (This can generally best be treated by alloplastic augmentation of the mandible but, in rare cases, may also require mylohyoid ridge reduction.) (B) Crestal incision and exposure of the lingual aspect of the mandible for removal of sharp bone in the mylohyoid ridge area. Rongeur or burr in a rotating handpiece can be used to remove bone. (C) Bone file used to complete recontouring of the mylohyoid ridge.



• **Fig. 13.15** Removal of a palatal torus. (A) Typical appearance of a maxillary torus. (B) Midline incision with the anteroposterior oblique releasing incisions. (C) Mucoperiosteal flaps retracted with silk sutures to improve access to all areas of the torus. Removal of palatal torus. *Continued*



• **Fig. 13.15, cont'd** (D–E) Sectioning of the torus using a fissure burr. (F) Small osteotome used to remove sections of the torus. (G–H) Large bone burr used to produce the final desired contour. (I) Soft tissue closure.

floor of the nose, and necrosis of the flap. Local care, including vigorous irrigation, good hygiene, and support with soft tissue conditioners in the splint or denture, usually provides adequate treatment.

Mandibular Tori

Mandibular tori are bony protuberances on the lingual aspect of the mandible that usually occur in the premolar area. The origins of this bony exostosis are uncertain, and the growths may slowly increase in size. Occasionally, extremely large tori interfere with normal speech or tongue function during eating, but these tori rarely require removal when teeth are present. After the removal of lower teeth and before the construction of partial or complete dentures, it may be necessary to remove mandibular tori to facilitate denture construction.

Bilateral lingual and inferior alveolar injections provide adequate anesthesia for tori removal. A crest of the ridge incision should be made, extending 1 to 1.5 cm beyond each end of the tori to be reduced. When bilateral tori are to be removed simultaneously, it is best to leave a small band of tissue attached at the midline between the anterior extent of the two incisions. Leaving this tissue attached helps to eliminate potential hematoma formation in the anterior floor of the mouth and maintains as much of the lingual vestibule as possible in the anterior mandibular area. As with maxillary tori, the mucosa over the lingual tori is generally very thin and should be reflected carefully to expose the entire area of bone to be recontoured (Fig. 13.16).

When the torus has a small pedunculated base, a mallet and osteotome may be used to cleave the tori from the medial aspect of the mandible. The line of cleavage can be directed by creating a small trough with a burr and a handpiece before using an osteotome. It is important to ensure that the direction of the initial burr trough (or the osteotome, if it is used alone) is parallel with the medial aspect of the mandible to avoid an unfavorable fracture of the lingual or inferior cortex. The use of a burr and handpiece can be a more controlled technique versus the use of a mallet and osteotome, due to potential trauma to anatomic structures within the floor of the mouth. This is especially so when the practitioner has little experience with an osteotome. The tongue and mucosa of the floor of the mouth must be retracted and protected with a smaller contoured retractor such as a Seldin retractor. The burr can also be used to deepen the trough so that a small instrument, such as a #81 straight dental elevator, can be levered against the mandible to fracture the lingual tori to allow its removal. A bone burr or file can then be used to smooth the lingual cortex. The tissue should be readapted and palpated to evaluate contour and elimination of undercuts. An interrupted or continuous suture technique is used to close the incisions. Gauze packs placed in the floor of the mouth and retained for several hours are generally helpful in reducing postoperative edema and hematoma formation. In the event of wound dehiscence or exposed bone in the area of a mucosal perforation, treatment with local care, including frequent vigorous saline irrigation, is usually sufficient.

Soft Tissue Abnormalities

Abnormalities of the soft tissue in the denture-bearing and peripheral tissue areas include excessive fibrous or hypermobile tissue, inflammatory lesions such as inflammatory fibrous hyperplasia of the

vestibule and inflammatory papillary hyperplasia of the palate, and abnormal muscular and frenal attachments. With the exception of pathologic and inflammatory lesions, many of the other conditions do not present problems when the patient has a full dentition. However, when loss of teeth necessitates prosthetic reconstruction, alteration of the soft tissue is often necessary. Immediately after tooth removal, muscular and frenal attachments initially do not present problems but may eventually interfere with proper denture construction as bony resorption takes place.

Long-term treatment planning before any soft tissue surgery is mandatory. Soft tissue that initially appears to be flabby and excessive may be useful if future ridge augmentation or grafting procedures are necessary. Oral mucosa is difficult to replace once it is removed. The only exception to this usefulness of excess tissue is when pathologic soft tissue lesions require removal.

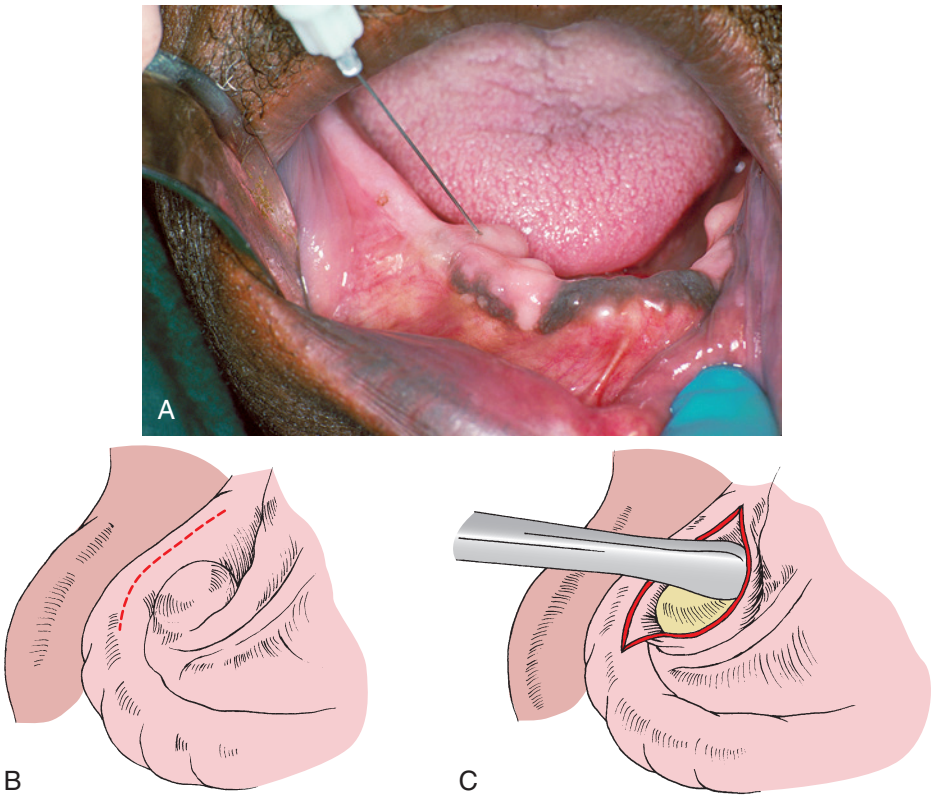
Maxillary Tuberosity Reduction (Soft Tissue)

The primary objective of soft tissue maxillary tuberosity reduction is to provide adequate interarch space for proper denture construction in the posterior area and a firm mucosal base of consistent thickness over the alveolar ridge denture-bearing area. Maxillary tuberosity reduction may require the removal of soft tissue and bone to achieve the desired result. The amount of soft tissue available for reduction can often be determined by evaluating a presurgical panoramic radiograph. If a radiograph is not of the quality necessary to determine soft tissue thickness, this depth can be measured with a sharp probe after local anesthesia is obtained at the time of surgery.

Local anesthetic infiltration in the posterior maxillary area is sufficient for a tuberosity reduction. An initial elliptical incision is made over the tuberosity in the area requiring reduction, and this section of tissue is removed (Fig. 13.17). After tissue removal, the medial and lateral margins of the excision must be thinned to remove excess soft tissue, which allows further soft tissue reduction and provides a tension-free soft tissue closure. This can be accomplished by digital pressure on the mucosal surface of the adjacent tissue while sharply excising tissue tangential to the mucosal surface (Fig. 13.18). After the flaps are thinned, digital pressure can be used to approximate the tissue to evaluate the vertical reduction that has been accomplished. If adequate tissue has been removed, the area is sutured with interrupted or continuous suturing techniques. If too much tissue has been removed, no attempt should be made to close the wound primarily. A tension-free approximation of the tissue to bone should be accomplished, which allows the open wound area to heal by secondary intention.

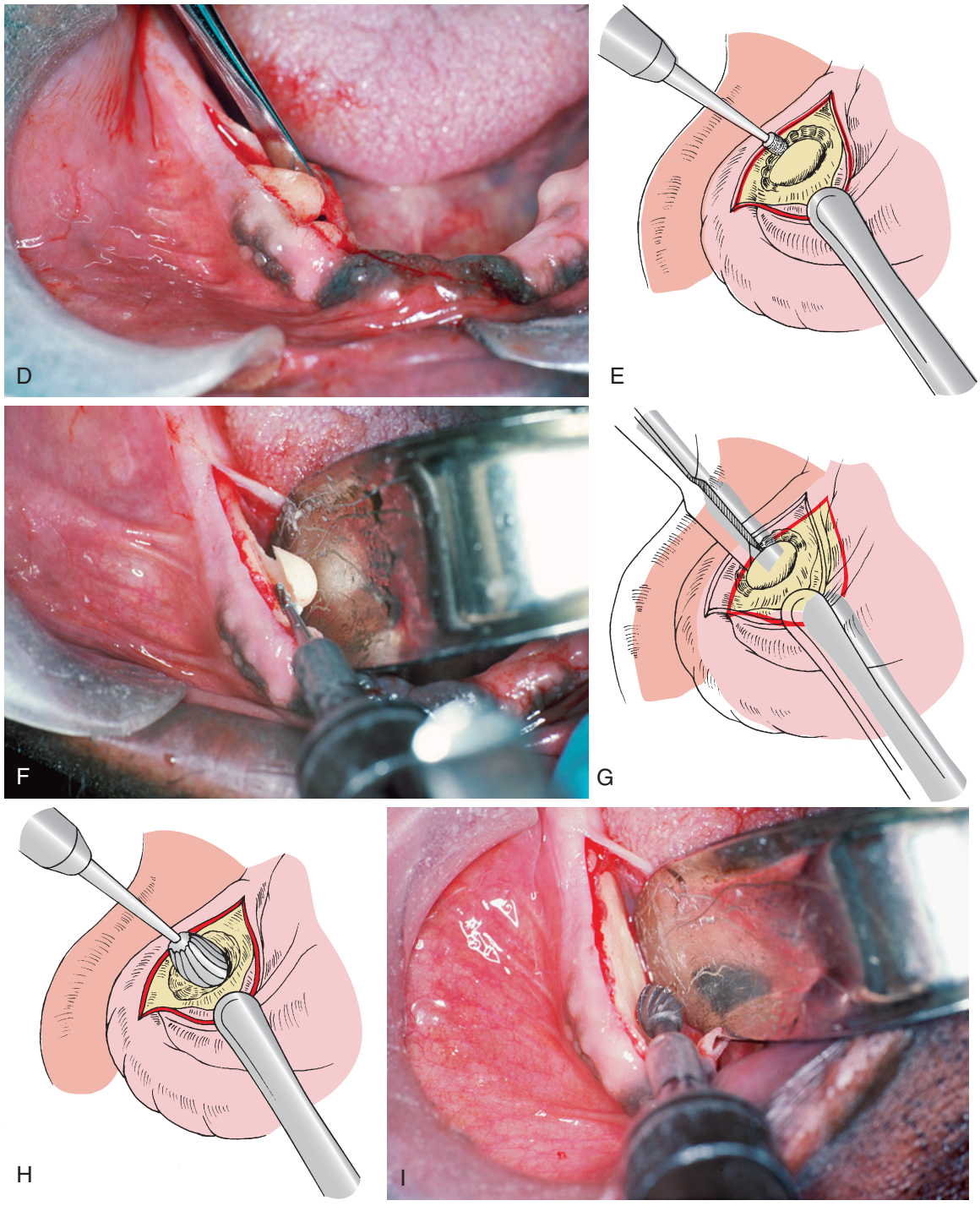
Mandibular Retromolar Pad Reduction

The need for removal of mandibular retromolar hypertrophic tissue is rare. It is important to verify that the patient is not posturing the mandible forward or vertically overclosed during clinical evaluation and with treatment records and mounted casts. Local

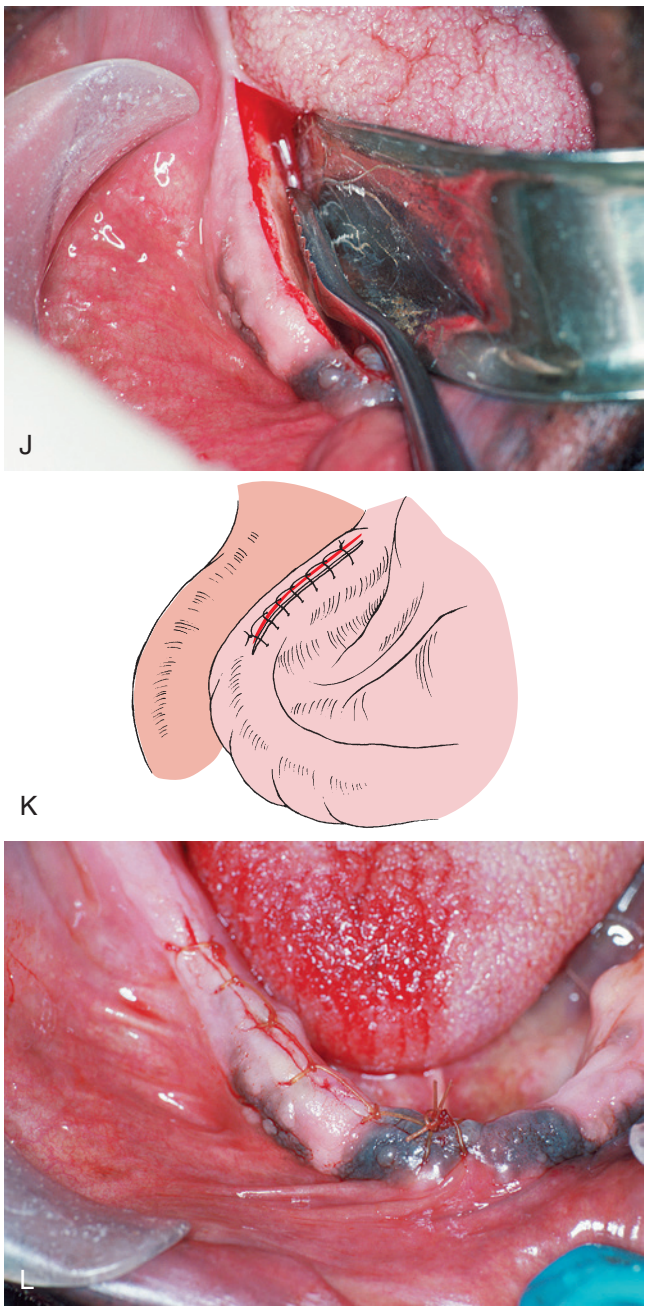


• **Fig. 13.16** Removal of mandibular tori. (A) After block, local anesthetic is administered; ballooning of thin mucoperiosteum over the area of the tori can be accomplished by placing the bevel of a local anesthetic needle against the torus and injecting local anesthetic subperiosteally. (This greatly facilitates reflection of the mucoperiosteal flap.) (B) Outline of crestal incision. (C) Exposure of torus. Removal of mandibular tori.

anesthetic infiltration in the area requiring excision is sufficient. An elliptical incision is made to excise the greatest area of tissue thickness in the posterior mandibular area. Slight thinning of the adjacent areas is carried out with the majority of the tissue reduction on the labial aspect. Excess removal of tissue in the submucosal area of the lingual flap may result in damage to the lingual nerve and artery. The tissue is approximated with continuous or interrupted sutures. Another option for tissue removal in this area is with the use of a laser. Laser-assisted recontouring of the retromolar area allows reduction of the tissue excess without incisions and limits the postoperative healing period.[10] The most common laser used in oral surgery is the carbon dioxide laser.[11] Tissue ablation allows for controlled removal of tissue in layers based on intensity and depth of penetration.[12]



• **Fig. 13.16, cont'd** (D) Exposure of torus. (E) and (F) Fissure burr and handpiece used to create a small trough between the mandibular ridge and torus. (G) Use of a small osteotome to complete removal of torus from the mandible. (H–I) Use of a bone burr and a bone file to eliminate minor irregularities. Removal of mandibular tori.



• **Fig. 13.16, cont'd** (J) Use of a bone burr and bone file to eliminate minor irregularities. (K–L) Tissue closure.

Lateral Palatal Soft Tissue Excess

Soft tissue excess on the lateral aspect of the palatal vault often interferes with proper construction of the denture. As with bony abnormalities of this area, soft tissue hypertrophy often narrows the palatal vault and creates slight undercuts, which interfere with denture construction and insertion.

One technique suggested for removal of lateral palatal soft tissue involves submucosal resection of the excess tissue in a manner similar to the previously described soft tissue tuberosity reduction. However, the amount and extension of soft tissue removal under the mucosa are much more extensive and creates the risk of damage to the greater palatine vessels, with possible hemorrhaging or sloughing of the lateral palatal soft tissue area.

The preferred technique requires superficial excision of the soft tissue excess. Local anesthetic infiltrated in the greater palatine area and anterior to the soft tissue mass is sufficient. With a sharp scalpel blade in the tangential fashion, the superficial layers of mucosa and underlying fibrous tissue can be removed to the extent necessary to eliminate undercuts in soft tissue bulk (Fig. 13.19). After removal of this tissue, a surgical splint lined with a tissue conditioner can be inserted for 5 to 7 days to aid in healing.

Unsupported Hypermobile Tissue

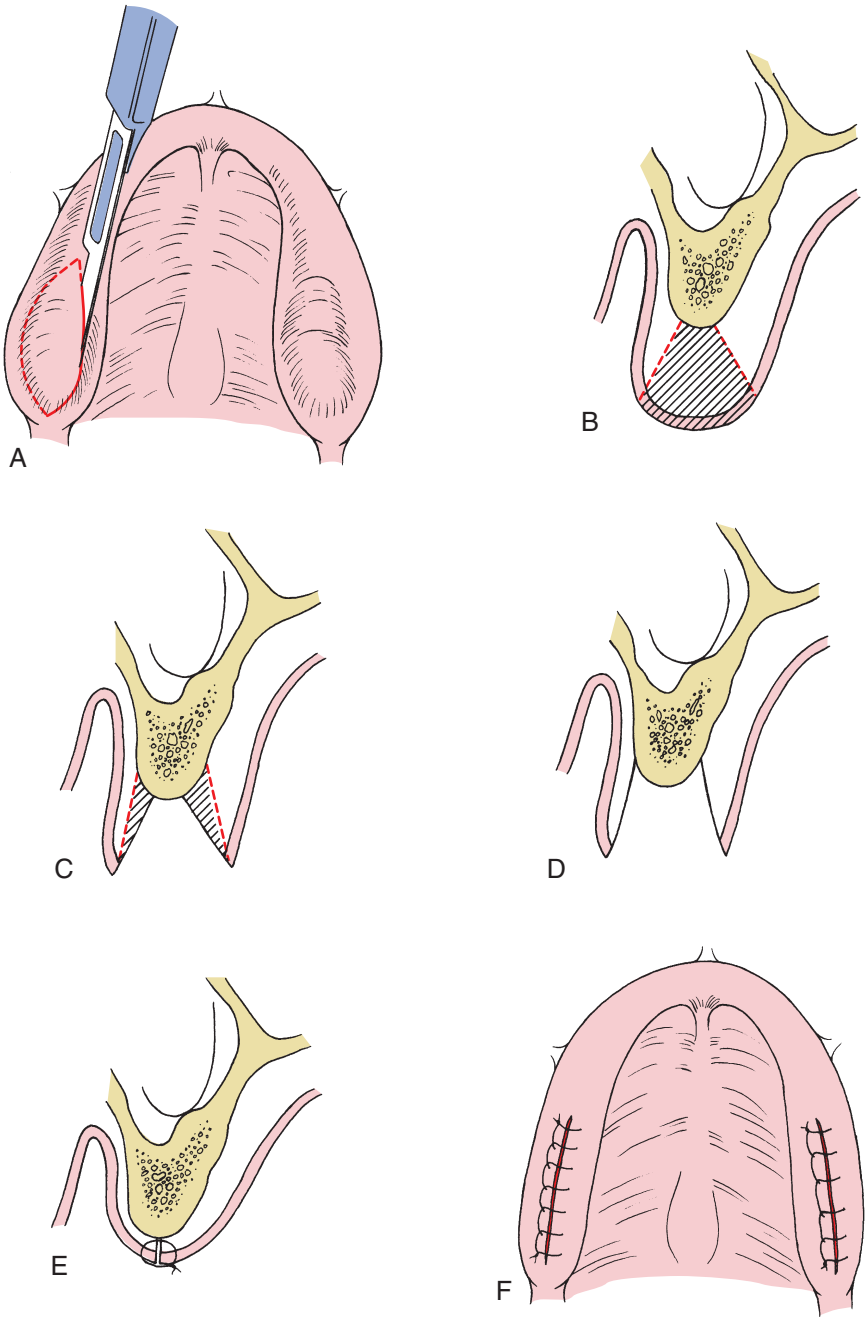
Excessive hypermobile tissue without inflammation on the alveolar ridge is generally the result of resorption of the underlying bone, ill-fitting dentures, or both. Before the excision of this tissue, a determination must be made whether the underlying bone should be augmented with a graft. If a bony deficiency is the primary cause of soft tissue excess, then augmentation of the underlying bone is the treatment of choice. If adequate alveolar height remains after reduction of the hypermobile soft tissue, then excision may be indicated.

A local anesthetic is injected adjacent to the area requiring tissue excision. Removal of hypermobile tissue in the alveolar ridge area consists of two parallel full-thickness incisions on the buccal and lingual aspects of the tissue to be excised (Fig. 13.20). A periosteal elevator is used to remove excess soft tissue from underlying bone. A tangential excision of small amounts of tissue in the adjacent areas may be necessary to allow for adequate soft tissue adaptation during closure. These additional excisions should be kept to a minimum whenever possible to avoid removing too much soft tissue and to prevent detachment of periosteum from underlying bone. Continuous or interrupted sutures are used to approximate the remaining tissue. Denture impressions can usually be taken 3 to 4 weeks after surgery. One possible complication of this type of procedure is the obliteration of the buccal vestibule as a result of tissue undermining necessary-to-obtain tissue closure.

Hypermobile tissue in the crestal area of the mandibular alveolar ridge frequently consists of a small cordlike band of tissue. If no underlying sharp bony projection is present, this tissue can best be removed by a supraperiosteal soft tissue excision. Local anesthetic is injected adjacent to the area requiring tissue removal. The cordlike band of fibrous connective tissue can be elevated by using pickups and scissors, and the scissors can be used to excise the fibrous tissue at the attachment to the alveolar ridge (Fig. 13.21). In general, no suturing is necessary for this technique, and a denture with a soft liner can be reinserted immediately.

Inflammatory Fibrous Hyperplasia

Inflammatory fibrous hyperplasia, also called *epulis fissurata* or *denture fibrosis*, is a generalized hyperplastic enlargement of mucosa and fibrous tissue in the alveolar ridge and vestibular area, which most often results from ill-fitting dentures. In the early stages of fibrous hyperplasia, when fibrosis is minimal, nonsurgical treatment with a denture in combination with a soft liner is frequently sufficient for reduction or elimination of this tissue. When the condition has been present for some time, significant fibrosis exists within the hyperplastic tissue. This tissue does not respond to nonsurgical treatment (Fig. 13.22); excision of the hyperplastic tissue is the treatment of choice.

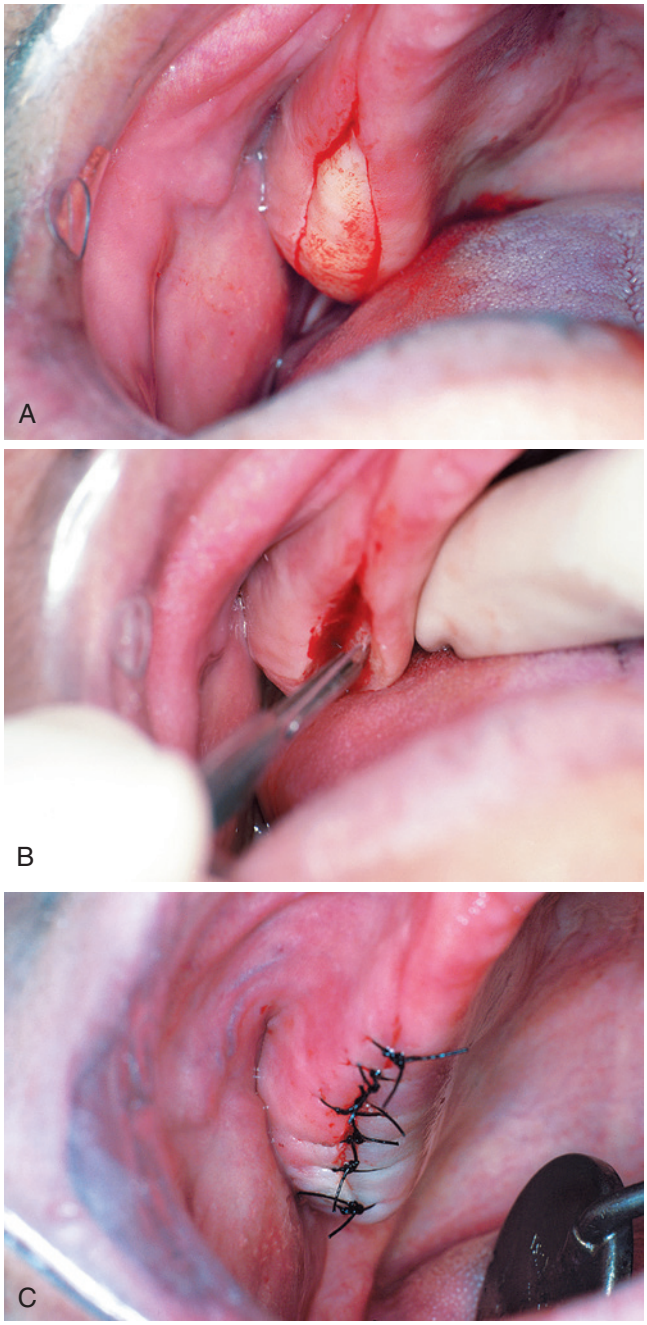


• **Fig. 13.17** Maxillary soft tissue tuberosity reduction. (A) Elliptical incision around soft tissue to be excised in the tuberosity area. (B) Soft tissue area excised with the initial incision. (C) Undermining of buccal and palatal flaps to provide adequate soft tissue contour and tension-free closure. (D) View of final tissue removal. (E–F) Soft tissue closure.

Three techniques can be used for successful treatment of inflammatory fibrous hyperplasia. Local anesthetic infiltration in the area of the redundant tissue is sufficient for anesthesia. When the area to be excised is minimally enlarged, electrosurgical or laser techniques provide good results for tissue excision. If the tissue mass is extensive, large areas of excision using electrosurgical techniques may result in excessive vestibular scarring. Simple excision and reapproximation of the remaining tissue is preferred. The redundant areas of tissue are grasped with tissue pickups, a sharp incision is made at the base of the excessive fibrous tissue down to the periosteum, and the hyperplastic tissue is removed (Fig. 13.23). The adjacent tissue is gently undermined and reapproximated using interrupted or continuous sutures.

When areas of gross tissue redundancy are found, excision frequently results in total elimination of the vestibule. In such cases excision of the epulides, with peripheral mucosal repositioning and secondary epithelialization, is preferable.

In this procedure the hyperplastic soft tissue is excised superficial to the periosteum from the alveolar ridge area. A clean supraperiosteal bed is created over the alveolar ridge area, and the unaffected



• **Fig. 13.18** Maxillary soft tissue tuberosity reduction. (A) Elliptical incision. (B) Thinning of mucosal flaps by removal of underlying soft tissue. Digital pressure used to stabilize the tissue flaps during submucosal excision. (C) Tension-free readaptation of flaps.

margin of the tissue excision is sutured to the most superior aspect of the vestibular periosteum with an interrupted suture technique. A surgical splint or denture lined with soft tissue conditioner is inserted and worn continuously for the first 5 to 7 days, with removal only for oral saline rinses. Secondary epithelialization usually takes place, and denture impressions can be made within 4 weeks. Laser excision of large epulis allows complete removal without excessive scarring or bleeding. A soft relined denture can provide for additional postoperative comfort from a procedure that initially creates minimal pain but with pain that peaks several days later.

The hyperplastic tissue usually represents only the result of an inflammatory process; however, other pathologic conditions may exist. Therefore it is imperative that representative tissue samples always be submitted for pathologic examination after removal.

Labial Frenectomy

Labial frenal attachments consist of thin bands of fibrous tissue covered with mucosa, extending from the lip and cheek to the alveolar periosteum. The level of frenal attachments may vary from the height of the vestibule to the crest of the alveolar ridge and even to the incisal papilla area in the anterior maxilla. With the exception of the midline labial frenum in association with a diastema, frenal attachments generally do not present problems when the dentition is intact. In cases of frenal attachment in the area of a diastema in a patient undergoing orthodontic treatment, there is some debate about the timing of frenum removal. Many surgeons and orthodontists prefer to remove or reposition the frenum prior to closure of the diastema, believing the elimination of the soft tissue barrier will facilitate alignment of the teeth. There are some practitioners who advocate removing the frenal attachment after the space closure because they believe surgery first will create dense scar tissue in the area of the diastema, making space closure more difficult.[13]

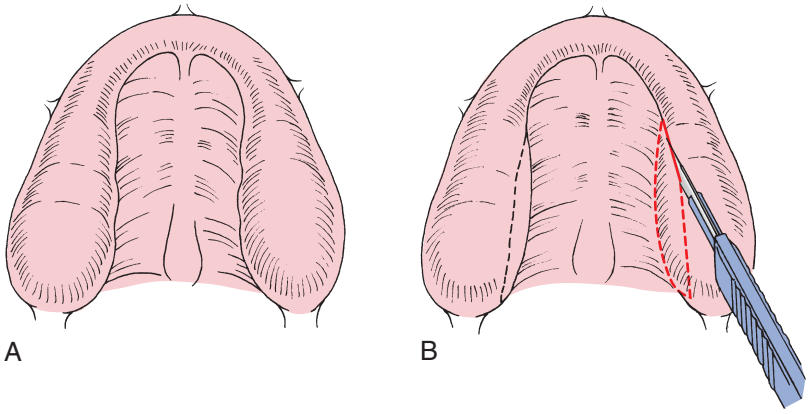
The construction of a denture may be complicated when it is necessary to accommodate a frenal attachment. Movement of the soft tissue adjacent to the frenum may create discomfort and ulceration and may interfere with the peripheral seal and dislodge the denture.

Multiple surgical techniques are effective in removal of frenal attachments: (1) the simple excision technique, (2) the Z-plasty technique, (3) localized vestibuloplasty with secondary epithelialization, and (4) the laser-assisted frenectomy. The simple excision and Z-plasty are effective when the mucosal and fibrous tissue band is relatively narrow.

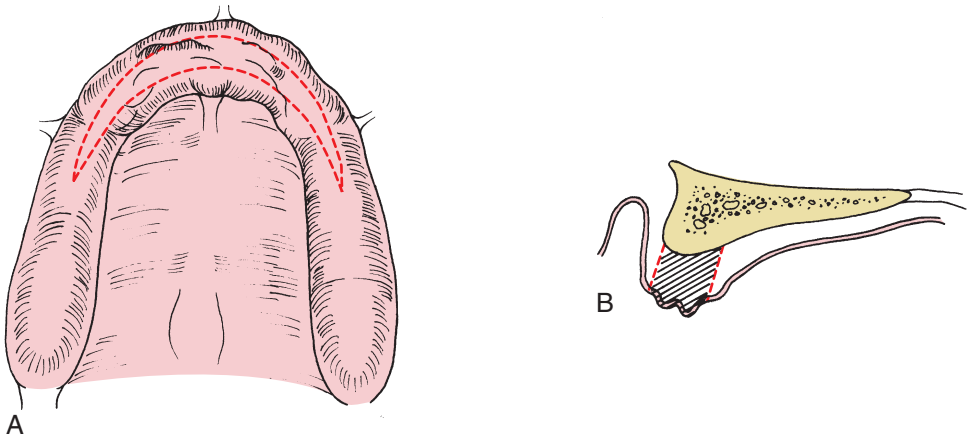
A localized vestibuloplasty with secondary epithelialization is often preferred when the frenal attachment has a wide base. Laser-assisted techniques are versatile in creating local excision and ablation of excessive mucosal tissue and fibrous tissue attachments, allowing secondary epithelialization.

Local anesthetic infiltration is often sufficient for surgical treatment of frenal attachments. Care must be taken to avoid excessive anesthetic infiltration directly in the frenum area because it may obscure the anatomy that must be visualized at the time of excision. In all cases it is helpful to have the surgical assistant elevate and evert the lip during this procedure. For the simple excision technique, a narrow elliptical incision around the frenal area down to the periosteum is completed (Fig. 13.24). The fibrous frenum is then sharply dissected from the underlying periosteum and soft tissue, and the margins of the wound are gently undermined and reapproximated. Placement of the first suture should be at the maximal depth of the vestibule and should include both edges of mucosa and underlying periosteum at the height of the vestibule beneath the anterior nasal spine. This technique reduces hematoma formation and allows for adaptation of the tissue to the maximal height of the vestibule. The remainder of the incision should then be closed with interrupted sutures. Occasionally it is not possible to approximate the portion of the excision closest to the alveolar ridge crest; this will undergo secondary epithelialization without difficulty.

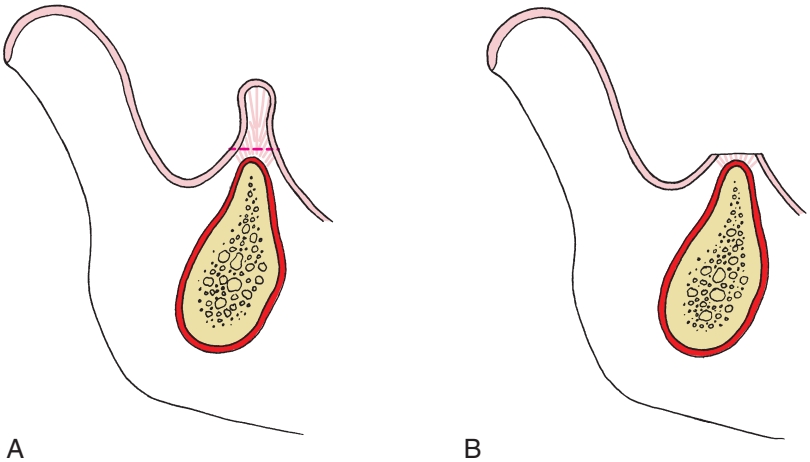
In the Z-plasty technique, an excision of the fibrous connective tissue is performed similarly to that in the simple excision procedure.



• **Fig. 13.19** Removal of lateral palatal soft tissue. (A) View of excessive palatal tissue creating a narrow palatal vault and undercut areas. (B) Tangential excision of excess soft tissue.

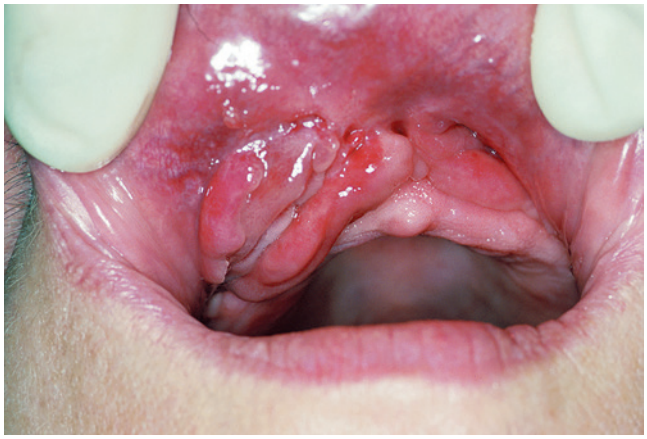


• **Fig. 13.20** Removal of hypermobile unsupported tissue. (A) Outline of incisions for removal of the crestal area of hypermobile tissue. (B) Cross-sectional area demonstrating the amount of tissue to be excised. (This type of tissue excision should be considered only if adequate ridge height will remain after removal of tissue. If excision of this tissue will result in inadequate ridge height and obliteration of vestibular depth, some type of augmentation procedure should be considered.)



• **Fig. 13.21** Supraperiosteal removal of hypermobile tissue on the mandibular alveolar ridge. (A) Hypermobile tissue on the superior aspect of the ridge. (B) Pickups and scissors are used to excise the cordlike mobile fibrous tissue without perforating the periosteum.

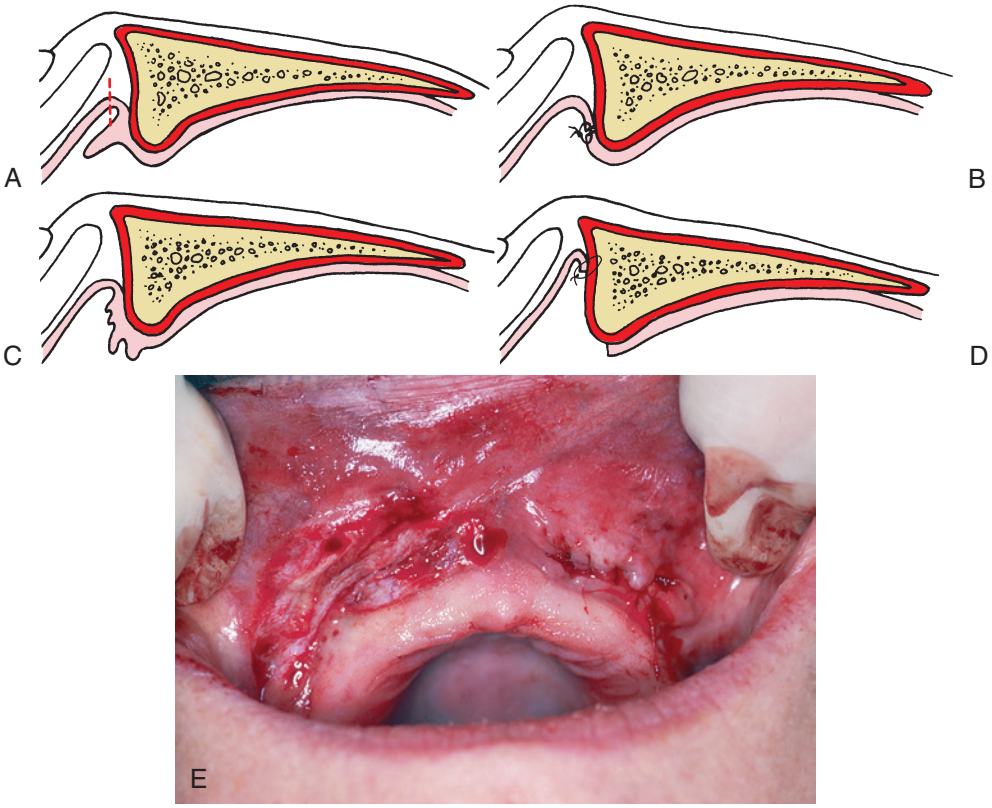
After excision of the fibrous tissue, two oblique incisions are made in a Z fashion, one at each end of the previous area of excision (Fig. 13.25). The two pointed flaps are then gently undermined and rotated to close the initial vertical incision horizontally. The two small oblique extensions also require closure. This technique may decrease the amount of vestibular ablation sometimes seen after linear excision of a frenum.



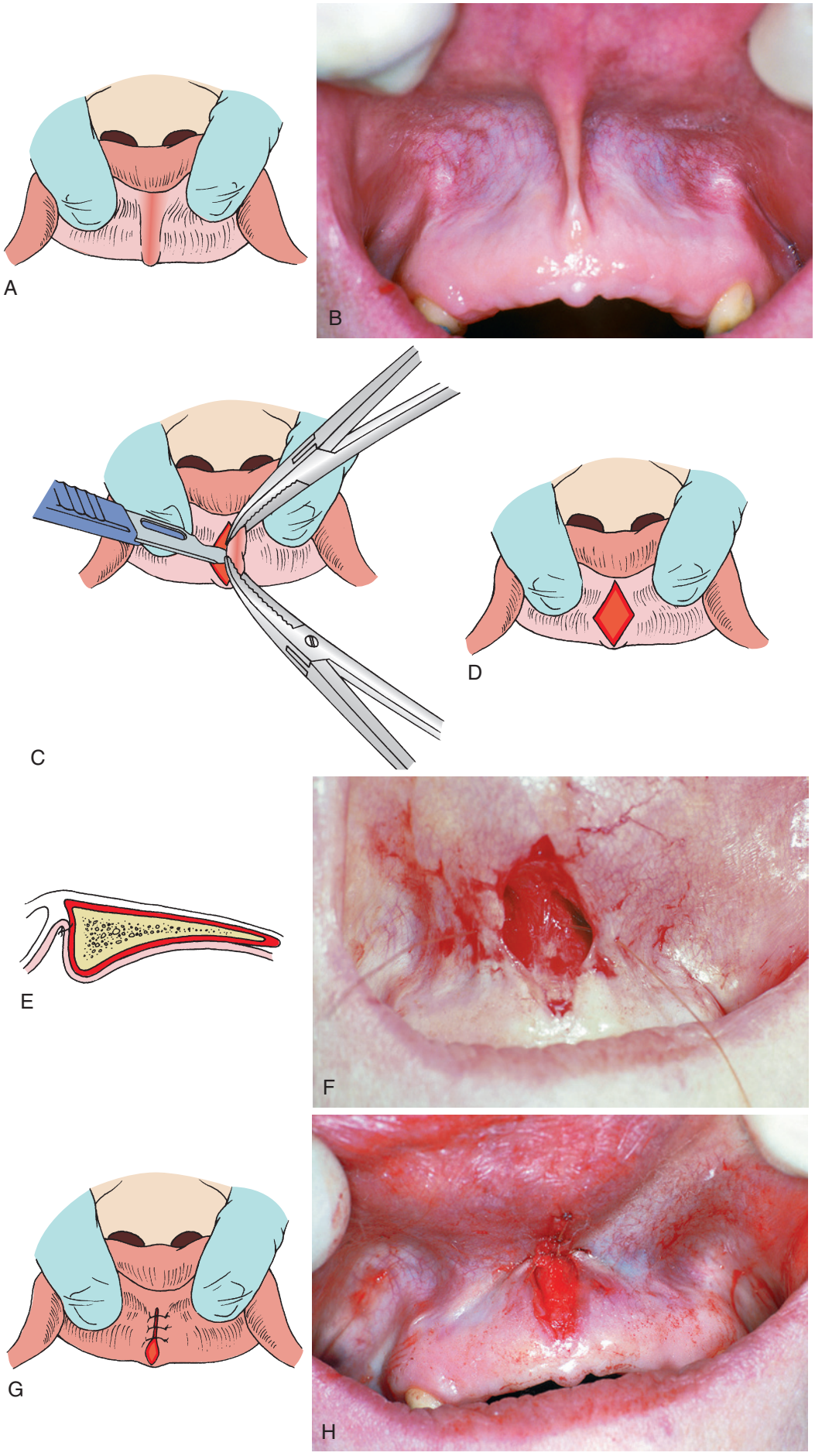
• **Fig. 13.22** Inflammatory fibrous hyperplasia of the vestibule.

A third technique for elimination of the frenum involves a localized vestibuloplasty with secondary epithelialization. This procedure is especially advantageous when the base of the frenal attachment is extremely wide, as in many mandibular anterior frenal attachments. Local anesthetic is infiltrated primarily in the supraperiosteal areas along the margins of the frenal attachments. An incision is made through mucosal tissue and underlying submucosal tissue, without perforating the periosteum. A supraperiosteal dissection is completed by undermining the mucosal and submucosal tissue with scissors or by digital pressure on a sponge placed against the periosteum. After a clean periosteal layer is identified, the edge of the mucosal flap is sutured to the periosteum at the maximal depth of the vestibule and the exposed periosteum is allowed to heal by secondary epithelialization (Fig. 13.26). A surgical splint or denture containing a soft tissue liner is often useful in the initial healing period to minimize pain and to maintain the vestibular depth by minimizing soft tissue relapse. This technique is also useful in localized broad-based muscle attachments, such as those frequently seen in the lateral maxillary areas.

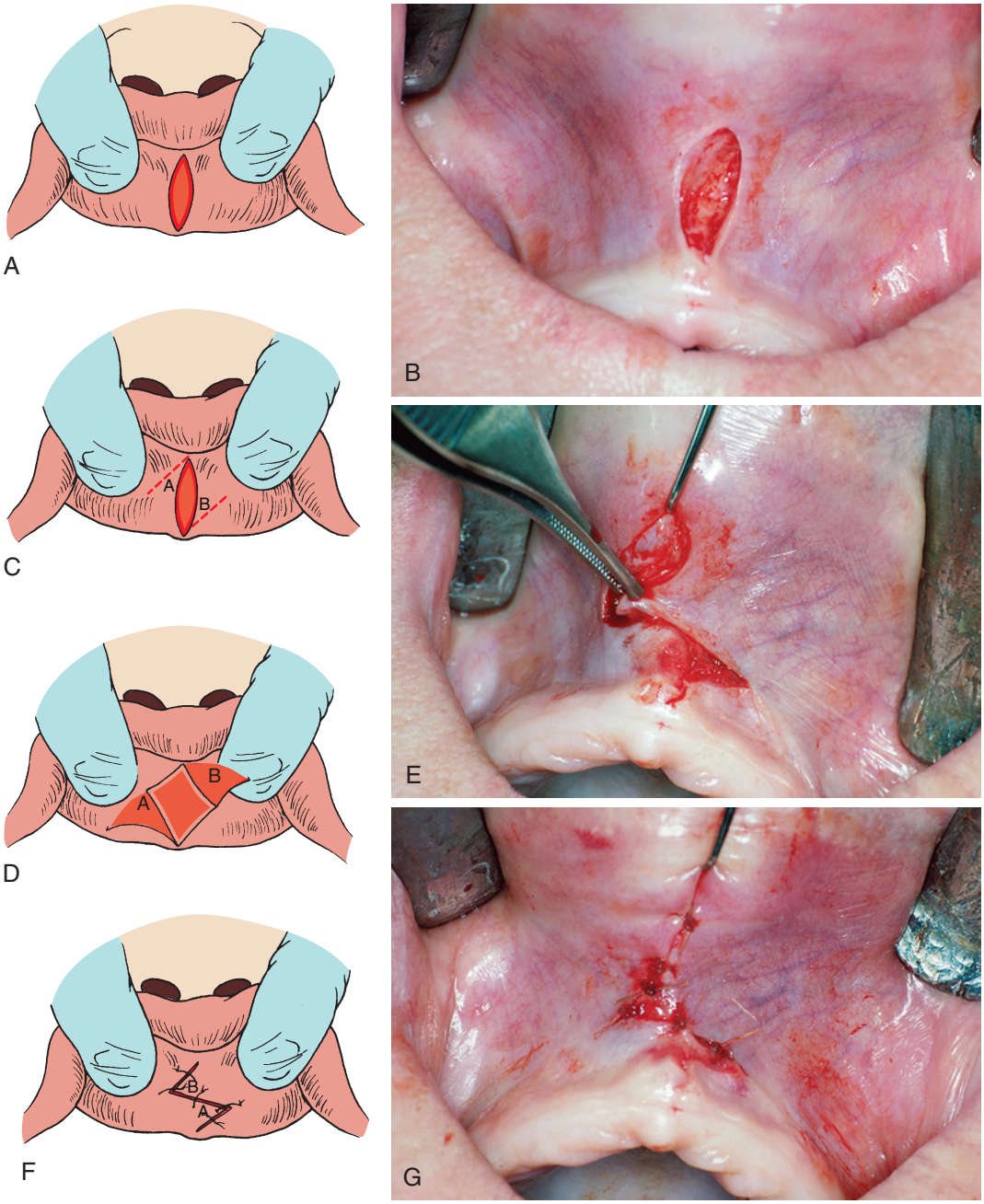
The excision of frenum attachments can also be accomplished through a laser. The tendinous frenum attachment is ablated with the laser and often does not require suture reapproximation of the tissue because reepithelialization occurs from the wound margins (Fig. 13.27). Frenectomies completed with the laser often respond well, with fewer postoperative patient complaints of swelling and pain.



• **Fig. 13.23** (A) Small, well-localized area of fibrous hyperplasia. This area can be removed with simple excision. (B) Closure of wound margins. (C) Large area of inflammatory fibrous hyperplasia. Removal and primary closure would result in elimination of the labial vestibule. (D) After supraperiosteal removal of excess tissue, the mucosal edge is sutured to the periosteum at the depth of the vestibule. (E) Postoperative view of patient in Fig. 13.22. The smaller well-localized area on the patient's left has been removed and closed primarily. The larger area of excessive tissue on the right has been removed, and the wound margin has been sutured to the periosteum at the depth of the vestibule, which leaves exposed periosteum.



• **Fig. 13.24** Simple excision of the maxillary labial frenum. (A–B) Eversion and exposure of the frenal attachment area. (C–D) Excision along the lateral margins of the frenum. Tissue is removed, exposing underlying periosteum. (E–F) Placement of the suture through mucosal margins and periosteum, which closes the mucosal margin and sutures mucosa to the periosteum at the depth of the vestibule. (G–H) Wound closure. Removal of tissue in areas adjacent to attached mucosa sometimes prevents complete primary closure at the most inferior aspect of wound margin.

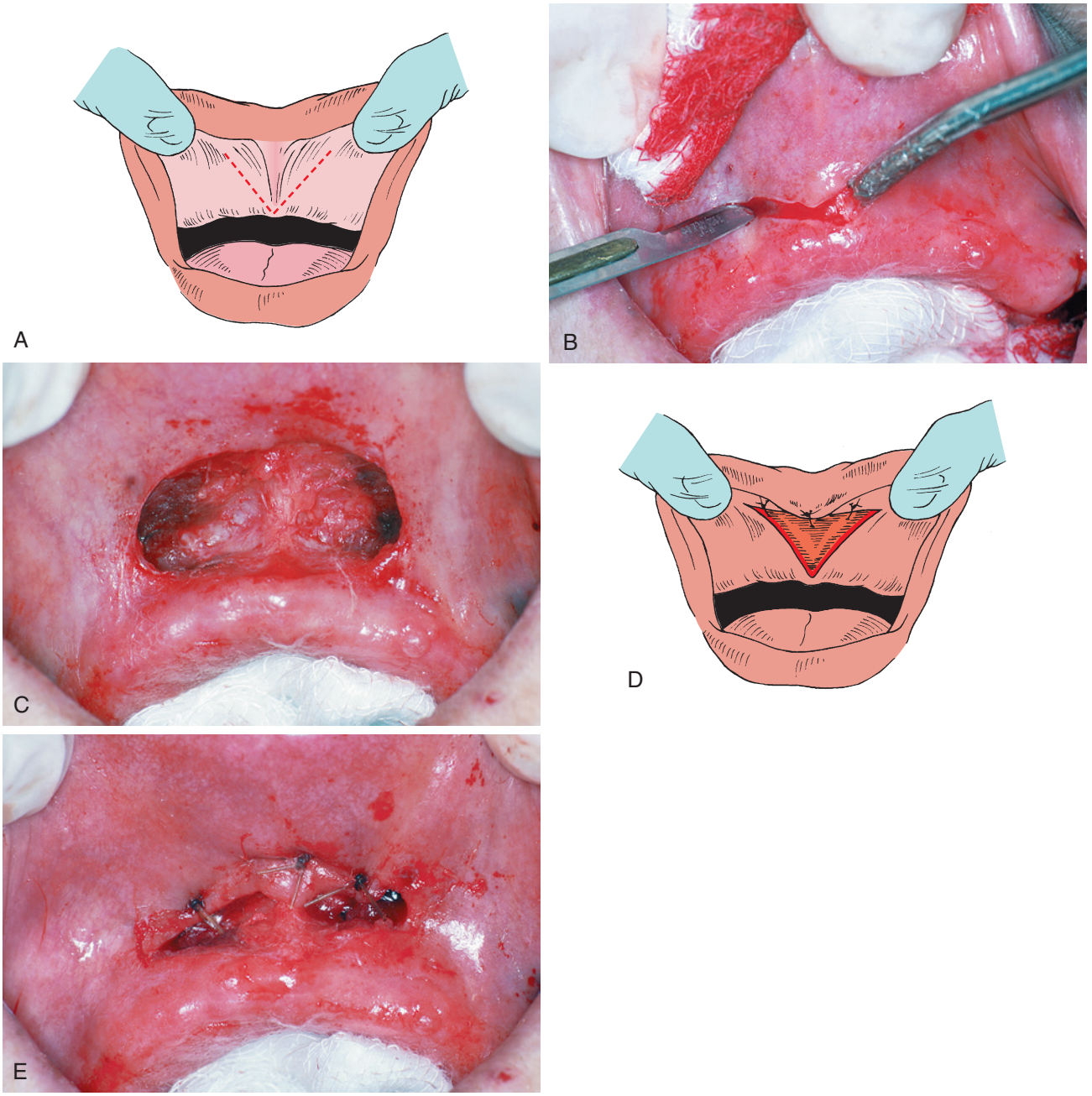


• **Fig. 13.25** Z-plasty technique for elimination of the labial frenum. (A–B) Small elliptical excision of mucosa and underlying loose connective tissue. (C–E) Flaps are undermined and rotated to the desired position. (F–G) Closure with interrupted sutures.

Lingual Frenectomy

An abnormal lingual frenal attachment usually consists of mucosa, dense fibrous connective tissue, and, occasionally, superior fibers of the genioglossus muscle. This attachment binds the tip of the tongue to the posterior surface of the mandibular alveolar ridge. Even when no prosthesis is required, such attachments can affect speech. After loss of teeth, this frenal attachment interferes with denture stability, because each time the tongue is moved, the frenal attachment is tensed and the denture is dislodged.

Bilateral lingual blocks and local infiltration in the anterior area provide adequate anesthesia for a lingual frenectomy. The tip of the tongue is best controlled with a traction suture. Surgical release of the lingual frenum requires incising the attachment of the mucosa and fibrous connective tissue at the base of tongue in a transverse fashion to prevent dissection into the floor of the mouth and damage to adjacent anatomic structures such as the lingual vessels, nerve, and submandibular ducts. This is followed by closure in a linear direction, which completely releases the anterior portion of the tongue (Fig. 13.28). Placement of a hemostat across the frenal attachment at the base of the tongue for approximately 3 minutes provides vasoconstriction and a nearly bloodless field during the surgical procedure. After removal of the hemostat, an incision is created through the area previously closed within



• **Fig. 13.26** Release of the labial frenum with a wide base. (A–B) Wide V-type of incision made at the most inferior portion of frenal attachments in the area of the alveolar ridge. (C) Supraperiosteal dissection completed, releasing mucosa and fibrous frenal attachments. (D) Diagram of mucosal margins sutured to periosteum. (E) Mucosal margins sutured to periosteum at the depth of the vestibule.

the hemostat. The tongue is retracted superiorly, and the margins of the wound are carefully undermined and closed parallel to the midline of the tongue. Careful attention must be given to blood vessels at the inferior aspect of the tongue and floor of the mouth and to the submandibular duct openings. Trauma to these vital structures during the incision or closure may result in postoperative hemostatic concerns and obstruction of salivary flow.

Occasionally, a lingual frenum release must also be accompanied by a small soft tissue–releasing procedure performed between the opening of the submandibular duct and the lingual aspect of the mandible. If access is available, this can be done in a fashion similar to the release above the submandibular ducts. However, if only a short tissue band exists in this area, a localized supraperiosteal dissection removing the fibrous attachment from the lingual aspect of the alveolar ridge is sufficient.

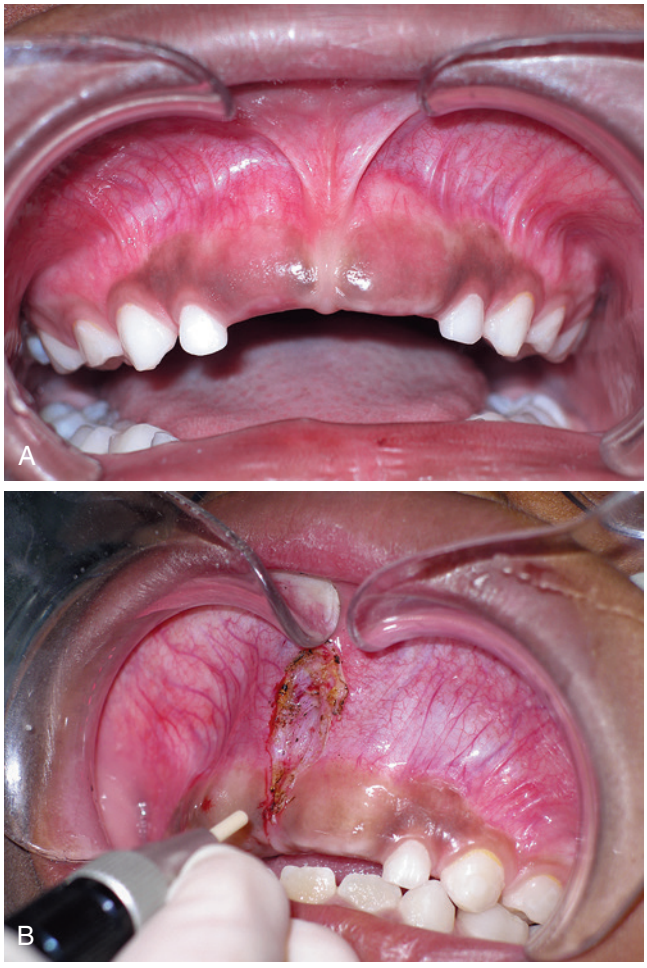
Immediate Dentures

The decision to insert dentures may be made at the time of tooth removal and bony recontouring. Hartwell cited several advantages

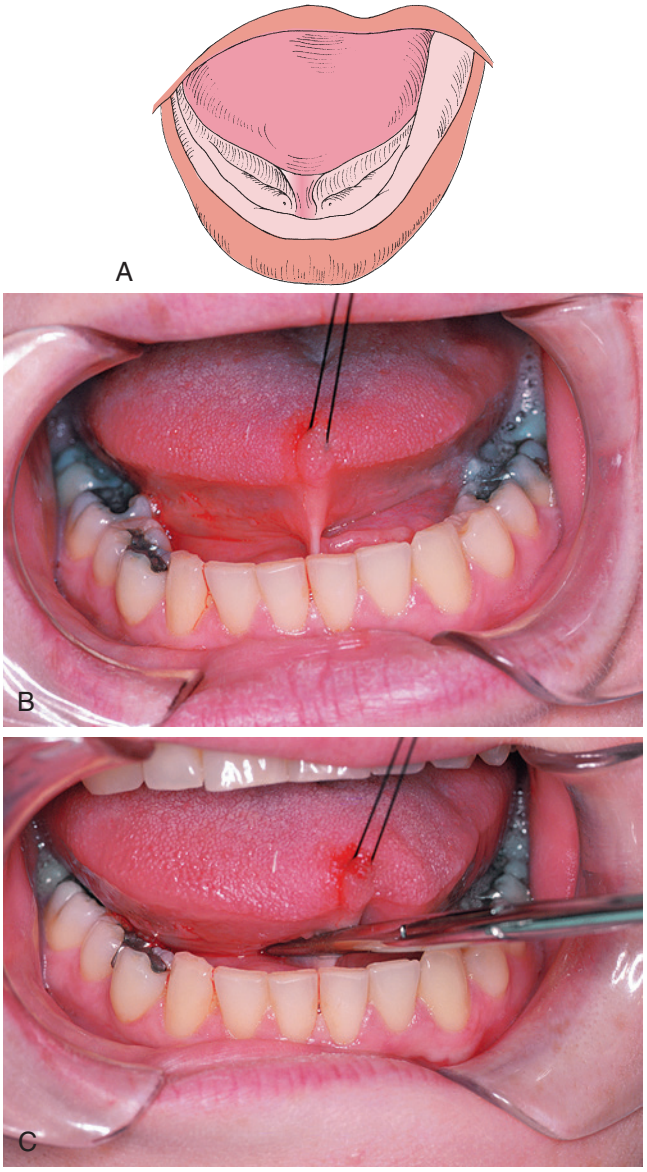
of an immediate denture technique.[14] The insertion of dentures after extraction offers immediate psychological and esthetic benefits to patients, as otherwise they may be edentulous for some time. The immediate insertion of dentures after surgery also functions to splint the surgical site, which results in the reduction of postoperative bleeding and edema and improved tissue adaptation to the alveolar ridge. Another advantage is that the vertical dimension can be most easily reproduced with an immediate denture technique. Disadvantages include the need for frequent alteration of the dentures postoperatively and the construction of new dentures after initial healing has taken place.

Anterior and posterior teeth can be extracted and dentures inserted in a single stage, although this requires meticulous planning and construction of the prosthesis. Surgical treatment for immediate denture insertion can also be accomplished in stages, with extraction of the posterior dentition in the maxilla and the mandible done before anterior extraction. This allows for initial healing of the posterior areas and facilitates improved adaptation of the dentures over the alveolus and tuberosity. Before extraction of the remaining anterior teeth, new records are taken and models are mounted on a semiadjustable articulator. The models allow for fabrication of dentures maintaining proper vertical height and esthetics. The cast of the alveolar ridge area is then carefully recontoured in anticipation of the extraction of the remaining anterior teeth and recontouring of the bony alveolus (Fig. 13.29). A clear acrylic splint is fabricated from the recontoured presurgical casts to replicate the desired alveolar ridge form. Dentures are also constructed on these casts.

Immediate denture surgery involves the most conservative technique possible in removal of the remaining teeth. Simple minimal recontouring or an intraseptal alveoloplasty, preserving as much vertical height and cortical bone as possible, is generally indicated (Fig. 13.30). After the bony recontouring and elimination of gross irregularities is completed, the tissue is approximated with digital pressure, and the clear acrylic surgical guide is inserted. Any areas of tissue blanching or gross irregularities are then reduced until the clear surgical guide is adapted to the alveolar ridge in all areas. Incisions are closed with continuous or interrupted sutures. The immediate denture with a soft liner is inserted. Care should



• **Fig. 13.27** Laser excision of the frenum. (A) Broad-based frenum in the anterior maxilla. (B) Supraperiosteal ablation of mucosal and dense fibrous frenal attachments. Healing occurs by secondary epithelialization.



• **Fig. 13.28** Lingual frenum release. (A) Frenal attachment connecting the tip of the tongue to the lingual aspect of the mandible. In edentulous patients, movement of the tongue will dislodge the dentures. (B) Traction suture placed in the tip of the tongue. (C) Hemostat used to compress the frenum area for 2 to 3 minutes allows improved hemostasis. Lingual frenum release.

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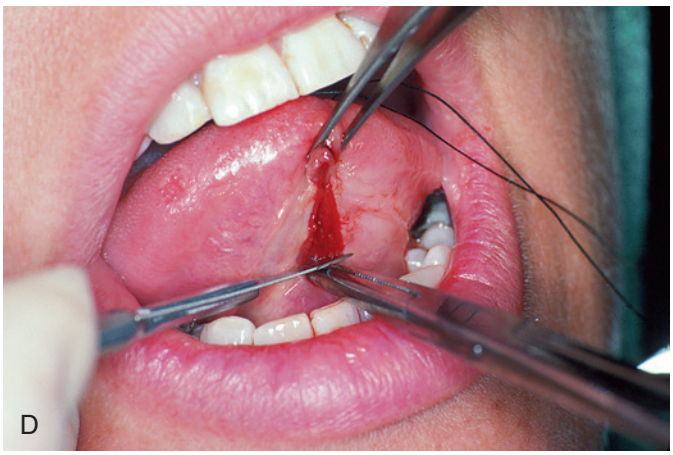
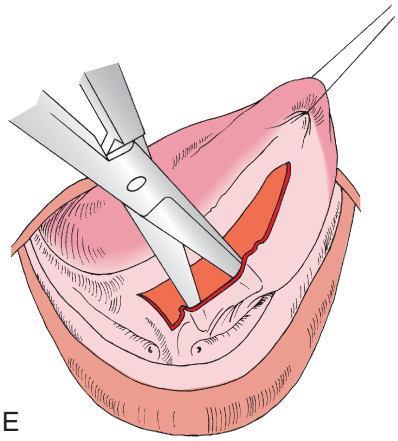
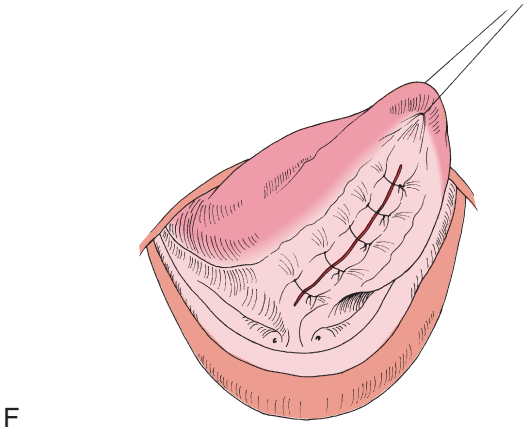
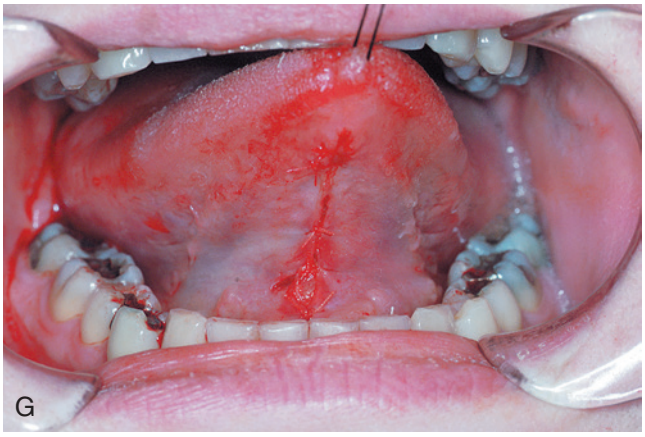








• **Fig. 13.28, cont'd** (D) Incision made at the superior portion of frenal attachment through the serrations created by the hemostat to the inferior surface of the tongue. (E) Lateral borders of wound margin are undermined. (F–G) Soft tissue closure.

be taken not to extrude any reline material into the fresh wound. The occlusal relationships are checked and adjusted as necessary. The patient is instructed to wear the dentures continuously for 24 hours and to return the next day for a postoperative check. Bupivacaine or another similar long-acting local anesthetic injected at the conclusion of the surgical procedure greatly improves comfort in the first 24-hour postoperative period. At that time, the dentures are gently removed, and the underlying mucosa and alveolar ridge areas are inspected for any areas of excessive pressure. The dentures are cleaned and reinserted, and the patient is instructed to wear the dentures for 5 to 7 days and to remove them only for oral saline rinses.

Alveolar Ridge Preservation

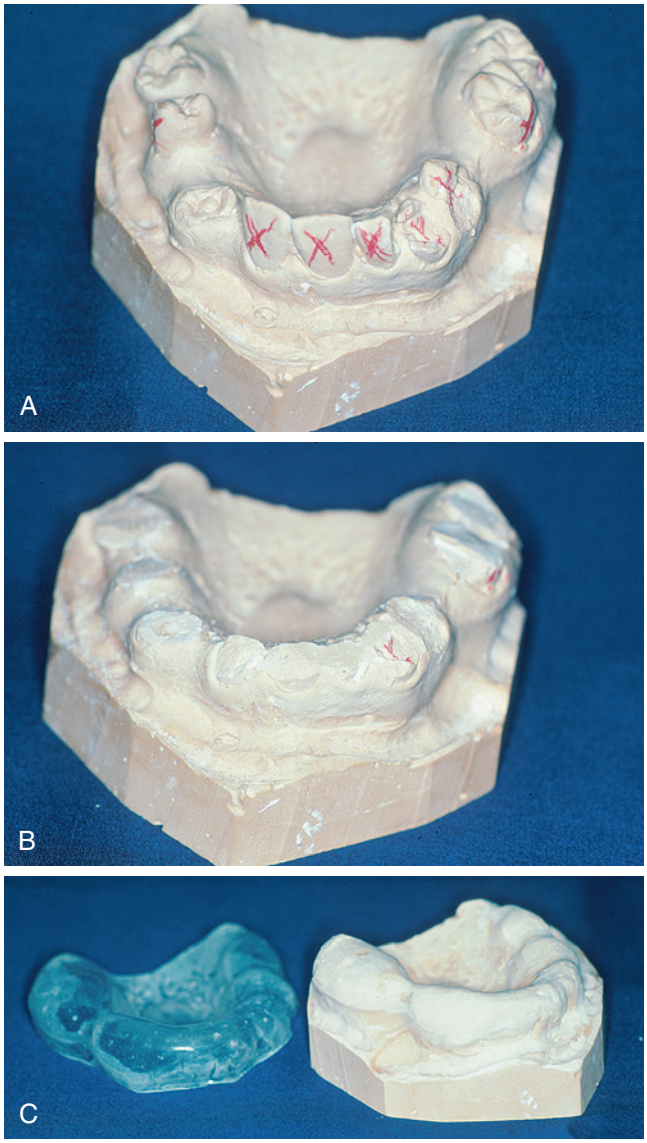
The majority of this chapter is devoted to management of the dentoalveolar area following extraction and subsequent bony and soft tissue changes. An important aspect of preprosthetic surgery can actually be accomplished at the time of tooth extraction by attempting to maintain and regain as much bone in the extraction area as possible. If a tooth is deemed nonrestorable and planned for extraction, simultaneous preservation of the socket using a variety of bone materials can aid in the maintenance of alveolar height and width.[15] The adjunctive measures maintain ridge form as the alloplastic materials are slowly resorbed through bony remodeling. Several allogeneic and xenogeneic bone materials have been used to maintain the bony architecture, limiting the morbidity of harvesting autogenous bone from an adjacent intraoral site.[16] These inorganic materials are derived from a bovine source (xenograft) or processed cadaveric bone.[17,18]

Atraumatic extraction with maintenance of the buccal and lingual cortical walls is essential to preservation of alveolar bone.[19] The site is curetted and irrigated after removal of the tooth in entirety. The graft material is placed into the extraction site and compressed to the level of the alveolar crest (Fig. 13.31). The extraction site usually is not closed primarily. In most cases the graft material is covered with some type of collagen material that is held in place with resorbable sutures. The use of a resorbable membrane requires limited soft tissue reflection of the adjacent margins to place the membrane under the attached gingiva. Mucosal reepithelialization occurs over the grafted site within a few weeks.

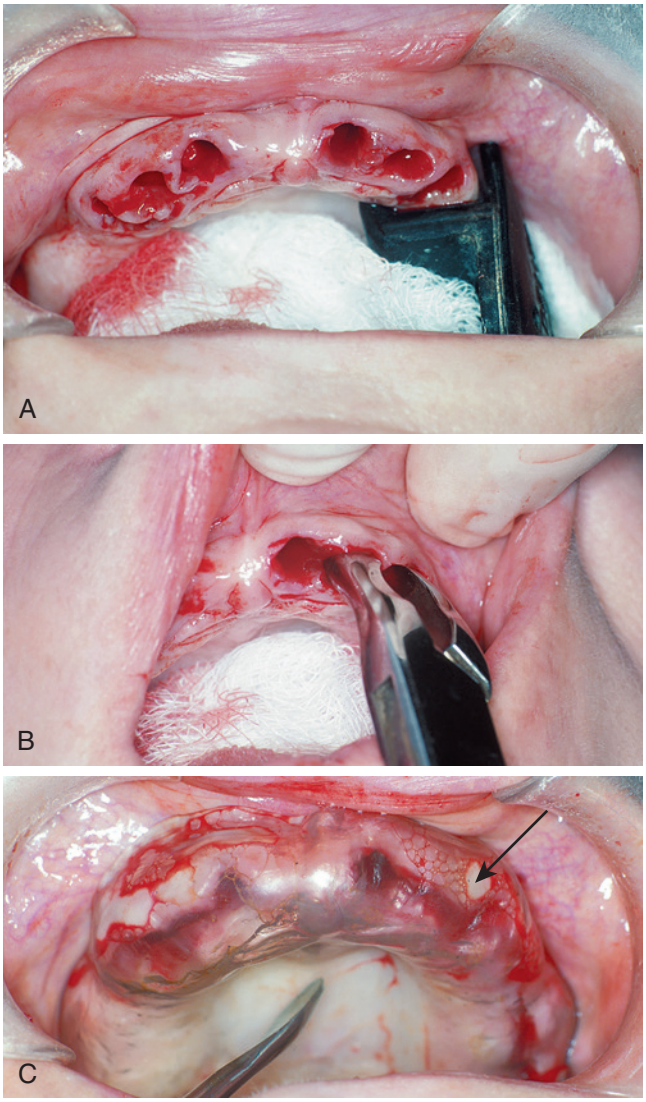
Implant placement in a site preserved with grafted bone material usually proceeds in 2 to 6 months.

Overdenture Surgery

Alveolar bone is maintained primarily in response to stresses transferred to the bone through the teeth and periodontal ligament during mastication. By maintaining teeth wherever possible, resorption of bone under a prosthetic appliance may be minimized.



• **Fig. 13.29** Construction of a clear acrylic surgical guide for immediate denture surgery. (A) Presurgical cast. (B) Cast after removal of teeth exhibiting bony irregularity. (C) Recontoured maxillary cast and surgical guide.



• **Fig. 13.30** (A) Appearance of the maxillary alveolar ridge after removal of teeth. (B) Intraseptal removal of bone with a rongeur. (C) Clear acrylic surgical guide in place. Any areas that interfere with seating of the template or cause blanching of tissue from excess bone or underlying soft tissue should be removed *(arrow)*.

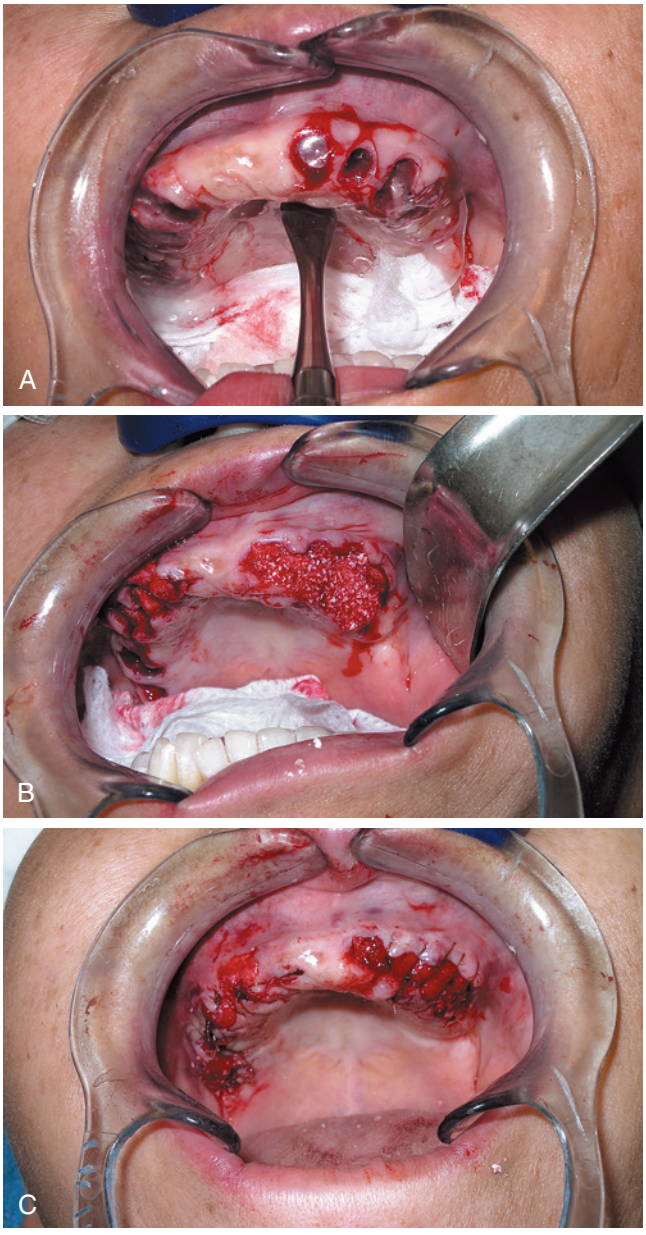
An overdenture technique attempts to maintain teeth in the alveolus by transferring force directly to bone and improving masticatory function with prosthetic restoration. The presence of teeth may also improve proprioception during function, and special retentive attachments can be incorporated into the retained teeth to improve denture retention and stability. Overdentures should be considered wherever several teeth exist with adequate bone support and when good periodontal health can be maintained and the teeth can be properly restored. Bilateral canines are generally best suited for this type of treatment. Because this technique also requires endodontic and prosthetic treatment of retained teeth, financial considerations must also be taken into account.

A complete discussion of periodontal considerations is not within the scope of this chapter; however, it is important to evaluate any potentially retained teeth before preparing the patient for overdentures. Adequate clinical and radiographic evaluation of these teeth should be completed, including a clinical examination, evaluation of pocket depth around the teeth, and evaluation of the attached gingiva.

ADVANCED PREPROSTHETIC SURGICAL PROCEDURES

Soft Tissue Surgery for Ridge Extension of the Mandible

As alveolar ridge resorption takes place, the attachment of mucosa and muscles near the denture-bearing area exerts a greater influence on the retention and stability of dentures. In addition, the amount and quality of fixed tissue over the denture-bearing area may be decreased. Soft tissue surgery performed to improve denture stability may be carried out alone or may be done after bony augmentation.



• **Fig. 13.31** Alveolar ridge preservation. (A) Extraction of teeth maintaining alveolar height. (B) Allogeneic material is placed in the extraction site to the height of the alveolar crest. (C) Resorbable membrane placed over the graft and stabilized with bolster stitches to allow secondary intention over the crest.

In either case the primary goals of soft tissue preprosthetic surgery are to provide an enlarged area of fixed tissue in the primary denture-bearing or implant area and to improve extension in the area of the denture flanges by removing the dislodging effects of muscle attachments in the denture-bearing or vestibular areas.

Transpositional Flap Vestibuloplasty (Lip Switch)

A lingually based flap vestibuloplasty was first described by Kazanjian.[20] In this procedure a mucosal flap pedicled from the alveolar ridge is elevated from the underlying tissue and sutured to the depth of the vestibule (Fig. 13.32). The inner portion of the lip is allowed to heal by secondary epithelialization. This procedure has been modified, and the use of a technique transposing a lingually based mucosal flap and a labially based periosteal flap (transpositional flap) has become popular.[21]

When adequate mandibular height exists, this procedure increases the anterior vestibular area, which improves denture retention and stability. The primary indications for the procedure include adequate anterior mandibular height (at least 15 mm), inadequate facial vestibular depth from mucosal and muscular attachments in the anterior mandible, and the presence of an adequate vestibular depth on the lingual aspect of the mandible.

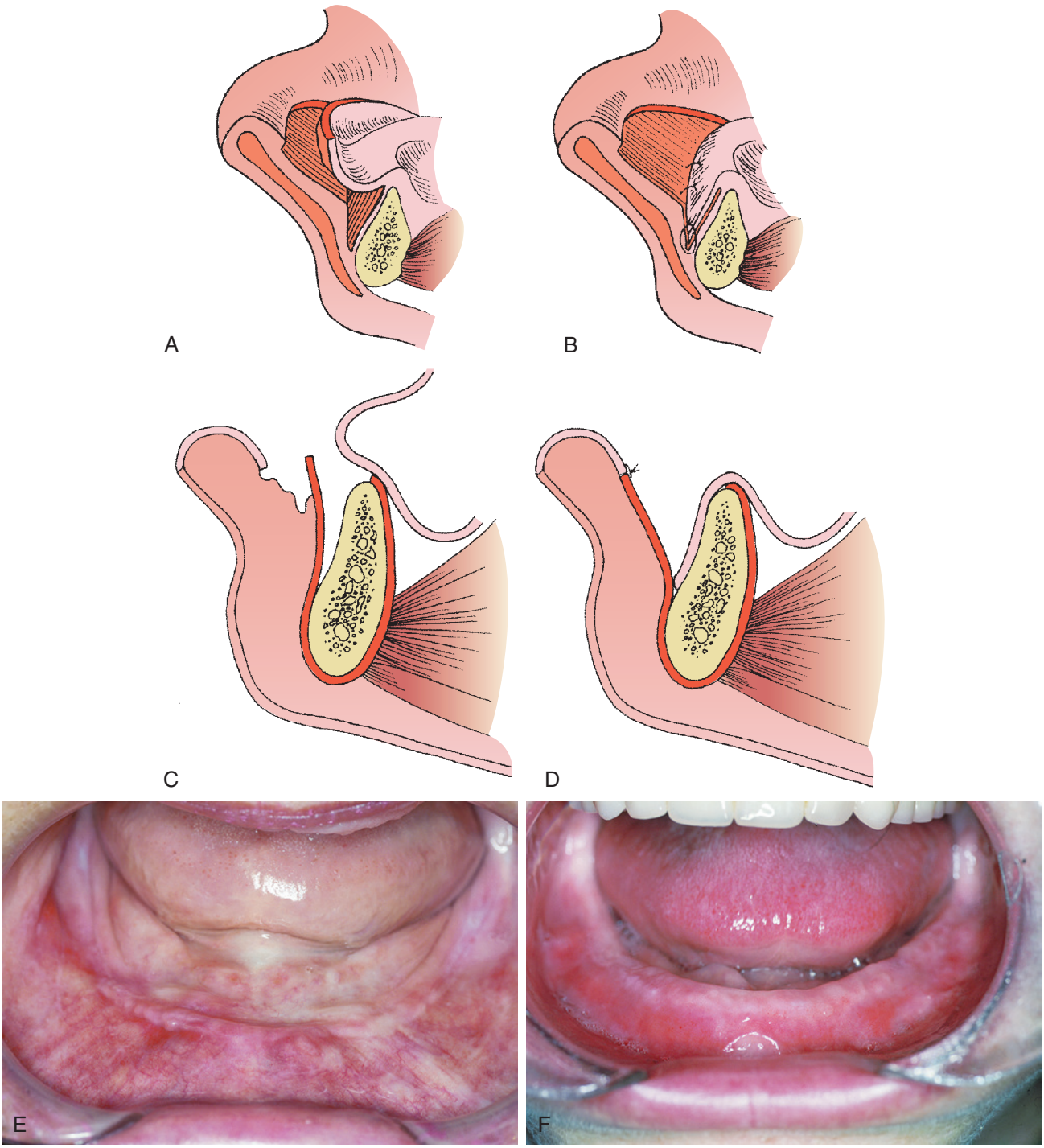
These techniques provide adequate results in many cases and generally do not require hospitalization, donor site surgery, or prolonged periods without dentures. Disadvantages of these techniques include unpredictability of the amount of relapse of the vestibular depth, scarring in the depth of the vestibule, and problems with adaptation of the peripheral flange area of the denture to the depth of the vestibule.[22,23]

Vestibule and Floor-of-Mouth Extension Procedures

In addition to the attachment of labial muscles and soft tissues to the denture-bearing area, the mylohyoid and genioglossus muscles in the floor of the mouth present similar problems on the lingual aspect of the mandible. Trauner described detaching the mylohyoid muscles from the mylohyoid ridge area and repositioning them inferiorly, effectively deepening the floor of the mouth area and relieving the influence of the mylohyoid muscle on the denture.[24] MacIntosh and Obwegeser later described the effective use of a labial extension procedure combined with the Trauner procedure to provide maximal vestibular extension to the buccal and lingual aspects of the mandible.[25] The technique for extension of the labial vestibule is a modification of a labially pedicled supraperiosteal flap described by Clark.[26] After the two vestibular extension techniques have been performed, a skin graft can be used to cover the area of denuded periosteum (Fig. 13.33). The combination procedure effectively eliminates the dislodging forces of the mucosa and muscle attachments and provides a broad base of fixed keratinized tissue on the primary denture-bearing area (Fig. 13.34). Soft tissue grafting with the buccal vestibuloplasty and the floor-of-mouth procedure is indicated when adequate alveolar ridge for a denture-bearing area is lost but at least 15 mm of mandibular bone height remains. The remaining bone must have adequate contour so that the form of the alveolar ridge exposed after the procedure is adequate for denture construction. Endosteal implants are generally a much more suitable treatment, and therefore vestibuloplasty with grafting is not commonly performed. If gross bony irregularities such as large concavities in the superior aspect of the posterior mandible exist, they should be corrected through grafting or minor alveoloplasty procedures before the soft tissue procedure is performed.

The technique has the advantage of early covering of the exposed periosteal bed, which improves patient comfort and allows earlier denture construction. In addition, the long-term results of vestibular extension are predictable. The need for hospitalization and donor site surgery, combined with the moderate swelling and discomfort experienced by the patient postoperatively, are the primary disadvantages. Patients rarely complain about the appearance or function of skin in the oral cavity. If the skin graft is too thick at the time of harvesting, hair follicles may not totally degenerate, and hair growth may occasionally be seen in isolated areas of the graft.

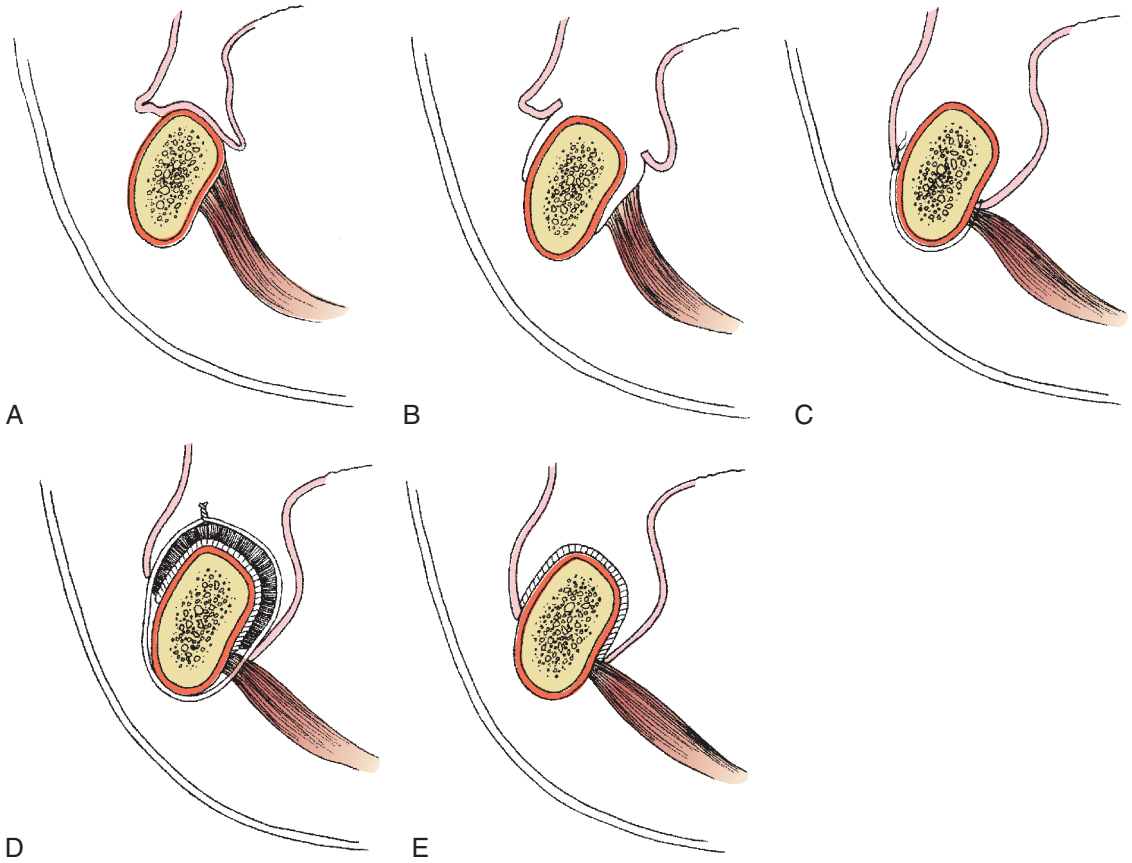
Tissue other than skin has been used effectively for grafting over the alveolar ridge. Palatal tissue offers the potential advantages of providing a firm, resilient tissue, with minimal contraction of



• **Fig. 13.32** Transpositional flap vestibuloplasty (i.e., lip switch). (A) Incision is made in the labial mucosa, and a thin mucosal flap is dissected from underlying tissue. Supraperiosteal dissection is also performed on the anterior aspect of the mandible. (B) The flap of the labial mucosa is sutured to the depth of the vestibule. Exposed labial tissue heals by secondary intention. (C) Modification of technique by incising periosteum at crest of alveolar ridge and suturing free periosteal edge to denuded area of labial mucosa. (D) The mucosal flap is then sutured over denuded bone to the periosteal junction at the depth of the vestibule. (E) Preoperative photograph. (F) Result of surgery 6 months later.

the grafted area.[27] Although palatal tissue is relatively easy to obtain at the time of surgery, the limited amount of tissue and the discomfort associated with donor site harvesting are the primary drawbacks. In areas where only a small localized graft is required, palatal tissue is usually adequate.

Full-thickness buccal mucosa harvested from the inner aspect of the cheek provides advantages similar to those of palatal tissue. However, the need for specialized mucotomes to harvest buccal mucosa and extensive buccal mucosa scarring after harvesting of a full-thickness graft are disadvantages. This mucosa does not



• **Fig. 13.33** Labial vestibuloplasty, floor-of-mouth lowering procedure, and skin grafting (i.e., Obwegeser technique). (A) Preoperative muscle and soft tissue attachments near the crest of the remaining mandible. (B) A crestal incision is made. Buccal and lingual flaps are created by a supraperiosteal dissection. (C) Sutures are passed under the inferior border of the mandible, tethering the labial and lingual flaps near the inferior border of the mandible. (D) Graft held over the supraperiosteal dissection with a stent stabilized with circummandibular wires. (E) Postoperative view of newly created vestibular depth and floor-of-mouth area.

become keratinized, is generally mobile, and often results in an inadequate denture-bearing surface.

Soft Tissue Surgery for Maxillary Ridge Extension

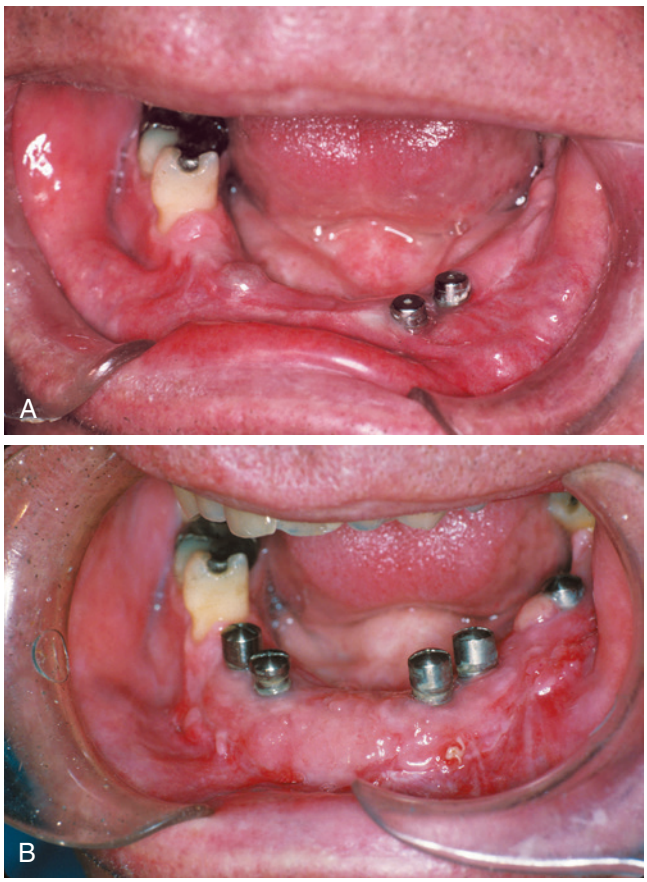
Maxillary alveolar bone resorption frequently results in mucosal and muscle attachments that interfere with denture construction, stability, and retention. Because of the large denture-bearing area of the maxilla, adequate denture construction and stability can often be achieved after extensive bone loss. However, excess soft tissue may accompany bony resorption, or soft tissue may require modification as an adjunct to previous augmentation surgery. Several techniques provide additional fixed mucosa and vestibular depth in the maxillary denture-bearing area.

Submucosal Vestibuloplasty

The submucosal vestibuloplasty, as described by Obwegeser, may be the procedure of choice for correction of soft tissue attachment on or near the crest of the alveolar ridge of the maxilla.[28] This technique is particularly useful when maxillary alveolar ridge resorption has occurred but the residual bony maxilla is adequate for proper denture support. In this technique, underlying submucosal tissue is excised or repositioned to allow direct apposition of the labiovestibular mucosa to the periosteum of the remaining maxilla.

To provide adequate vestibular depth without producing an abnormal appearance of the upper lip, adequate mucosal length must be available in this area. A simple test to determine whether adequate labiovestibular mucosa is present is performed by placing a dental mouth mirror under the upper lip and elevating the superior aspect of the vestibule to the desired postoperative depth (Fig. 13.35). If no inversion or shortening of the lip occurs, adequate mucosa is present to perform a proper submucosal vestibuloplasty.

The submucosal vestibuloplasty can generally be performed with local anesthetic and intravenous sedation in an outpatient setting. A midline incision is made in the anterior maxilla, and the mucosa is undermined and separated from the underlying submucosal tissue. A supraperiosteal tunnel is then developed by dissecting the muscular and submucosal attachments from the periosteum. The intermediate layer of tissue created by the two tunneling dissections is incised at its attachment area near the crest of the alveolar ridge. This submucosal and muscular tissue can be repositioned superiorly or excised. After closure of the midline incision, a preexisting denture or prefabricated splint is modified to extend into the vestibular areas and is secured with palatal



• **Fig. 13.34** Vestibuloplasty, floor-of-mouth lowering, and palatal soft tissue grafting. (A) Preoperative photograph showing lack of facial and lingual vestibular depth and absent keratinized tissue adjacent to implant abutments. (B) Improved vestibular depth with sound attached tissue over the alveolar ridge.

screws for 7 to 10 days to hold the mucosa over the ridge in close apposition to the periosteum. When healing takes place, usually within 3 weeks, the mucosa is closely adapted to the anterior and lateral walls of the maxilla at the required depth of the vestibule.

These techniques provide a predictable increase in vestibular depth and attachment of mucosa over the denture-bearing area. A properly relined denture can often be worn immediately after the surgery or after removal of the splint, and impressions for final denture relining or construction can be completed 2 to 3 weeks after surgery.

Maxillary Vestibuloplasty With Tissue Grafting

When insufficient labiovestibular mucosa exists and lip shortening would result from a submucosal vestibuloplasty technique, other vestibular extension techniques must be used. In such cases a modification of the Clark vestibuloplasty technique using mucosa pedicled from the upper lip and sutured at the depth of the maxillary vestibule after a supraperiosteal dissection can be used.[29] The denuded periosteum over the alveolar ridge heals by secondary epithelialization. Moderate discomfort may be experienced by the patient in the postoperative period, and a longer healing time is required (6 to 8 weeks) before denture construction. Maintenance of the maxillary vestibular depth is unpredictable. The use of a labially pedicled mucosal flap combined with tissue grafting over the exposed periosteum of the maxilla provides the added benefits of more rapid healing over the area of previously exposed periosteum and more predictable long-term maintenance of vestibular depth (Fig. 13.36).

Correction of Abnormal Ridge Relationships

Approximately 5% of the population has a severe skeletal discrepancy between their upper and lower jaws, which results in a severe malocclusion. When teeth are lost, an abnormal ridge relationship can result that complicates construction of prosthetic appliances. When a preexisting class III ridge relationship exists, loss of teeth and the pattern of bony resorption increase the severity of the class III skeletal problem. In patients with partially missing dentition, the absence of opposing occlusal forces may allow the supraeruption of teeth, which may complicate subsequent prosthetic restoration.

The assessment of ridge relationships is an important, but often overlooked, aspect of the evaluation of patients for prosthetic treatment. In partially edentulous patients, the evaluation should include an examination of the direction of the occlusal plane and a determination of interarch distances that may be affected by supraerupted teeth or segments. In totally edentulous patients, the interarch space and the anteroposterior and transverse relationships of the maxilla and the mandible must be evaluated with the patient's jaw at the proper occlusal vertical dimension. This determination in the diagnostic phase may require the construction of bite rims with proper lip support. Lateral cephalometric radiographs are also necessary in this evaluation, to confirm the clinical impression.

Segmental Alveolar Surgery in the Partially Edentulous Patient

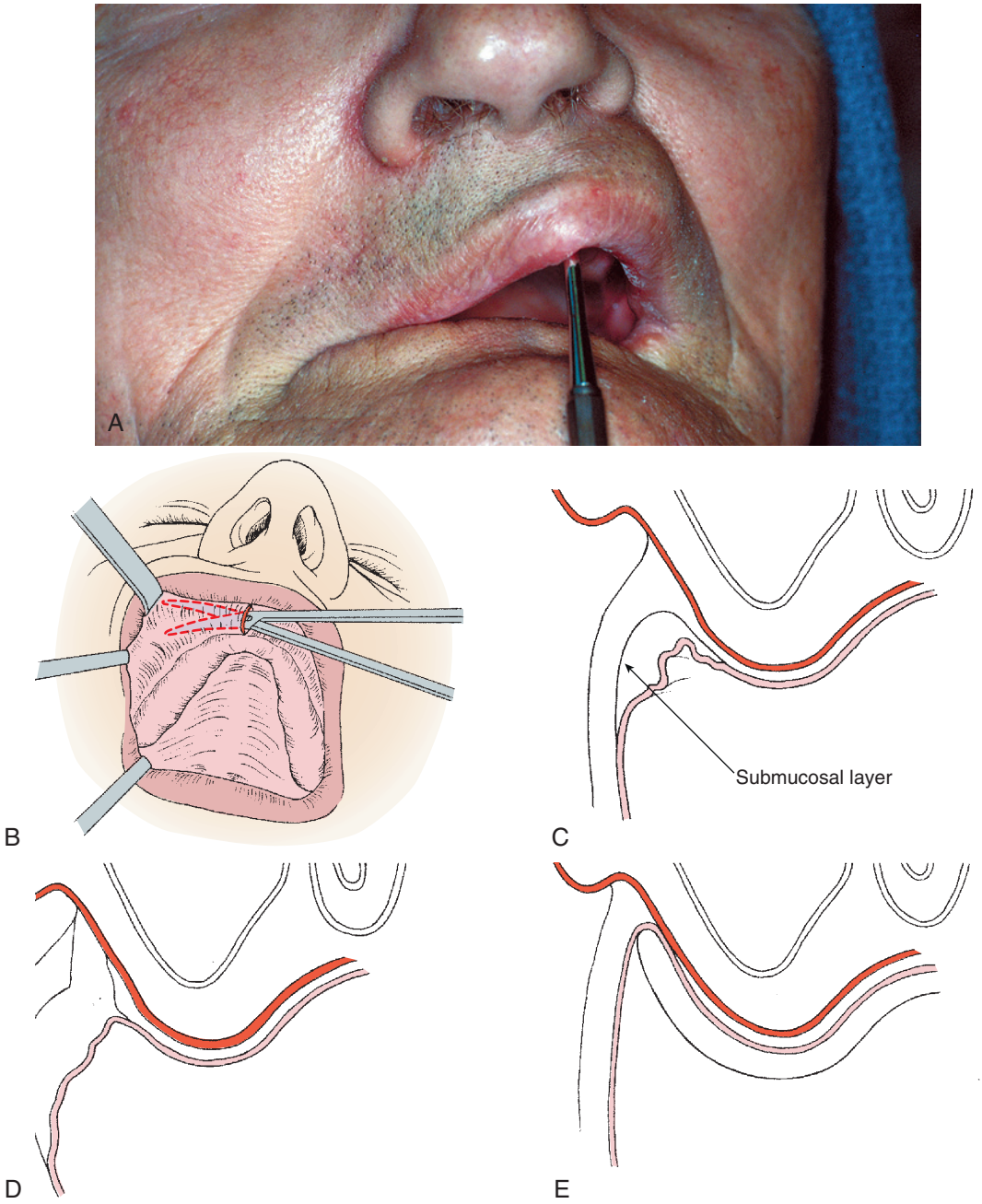
Supraeruption of teeth and bony segments into an opposing edentulous area may decrease interarch space and preclude the construction of an adequate fixed or removable prosthetic appliance in this area. The loss of teeth in one arch may increase the difficulty of obtaining a functional and esthetic prosthetic appliance with prosthetic teeth located properly over the underlying ridge. Several alternatives exist to restore the dentition in these patients, including extraction of teeth in the malpositioned segment or repositioning of these teeth with segmental surgery.

Preoperative considerations should include facial esthetic quality, an intraoral occlusal examination, panoramic and cephalometric radiographs, and models properly mounted on an articulator. If segmental surgery is to be considered, the models can be cut and teeth repositioned in their desired location. The dentist responsible for final prosthetic restoration of the patient must make the final determination of the placement of the segments on the articulated models. Presurgical orthodontic preparation may be necessary to align teeth properly and allow proper segmental positioning. After model surgery, a splint is fabricated to locate placement of segments precisely at the time of surgery and to provide stability during the postoperative healing period. When possible, the splint should be stabilized by contacting other teeth rather than resting on soft tissue. Palatal and lingual flanges on the splint should be avoided because pressure from the splint may interfere with blood supply important for the viability of the bone and teeth that were repositioned with segmental surgery. In some cases, construction of the splint must include contact on the alveolar ridge tissue of the

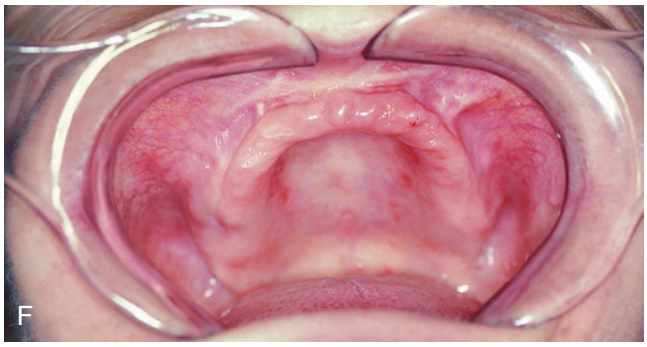
opposing arch to maintain the interridge distance. The patient's deformity and the surgeon's preference and experience dictate the specific surgical procedure performed. Segmental procedures for correction of abnormalities in the maxilla and the mandible are described in Chapter 26 and in other textbooks (Fig. 13.37).[30] A final fixed and removable prosthetic rehabilitation follows the surgical procedure and an adequate postoperative healing period.

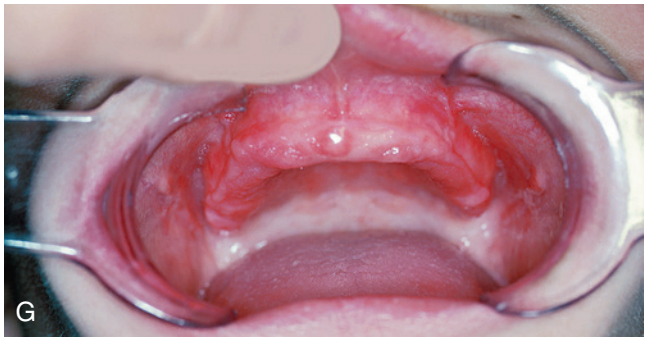
Correction of Skeletal Abnormalities in the Totally Edentulous Patient

After the appropriate clinical and radiographic evaluation, casts should be mounted on an articulator for determination of the ideal ridge relationship. The dentist responsible for prosthetic construction should be responsible for determining the final desired position

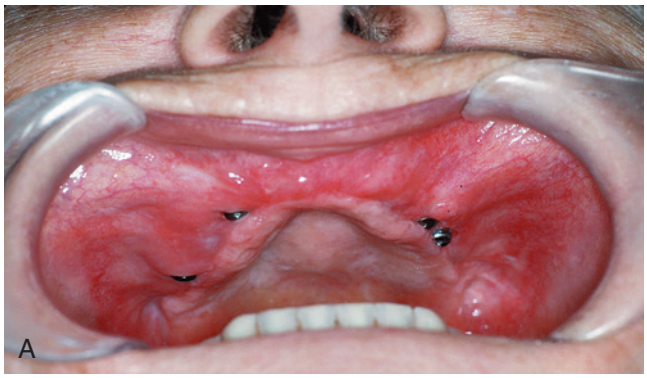


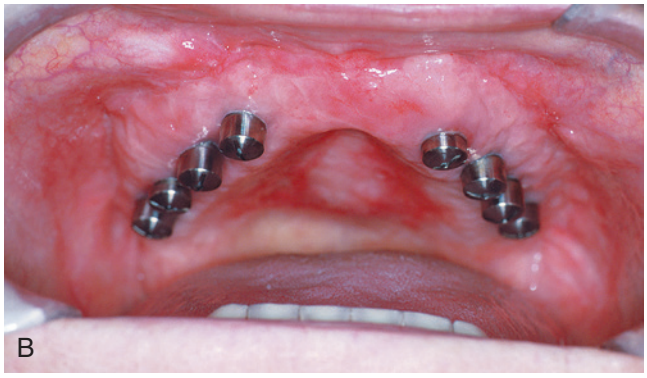
• **Fig. 13.35** Submucosal vestibuloplasty. (A) Mouth mirror placed in the maxillary vestibule under the upper lip and elevated against the anterior wall of the maxilla to the desired postoperative vestibular depth. If no abnormal lip shortening occurs, then adequate mucosa exists to perform submucosal vestibuloplasty. (B) An anterior vertical incision is used to create a submucosal tunnel and then a supraperiosteal tunnel along the lateral aspects of the maxilla. (C) Cross-sectional view showing the submucosal tissue layer. (D) Excision of submucosal soft tissue layer. (E) Splint in place holding mucosa against the periosteum at the depth of the vestibule until healing occurs. Submucosal vestibuloplasty.



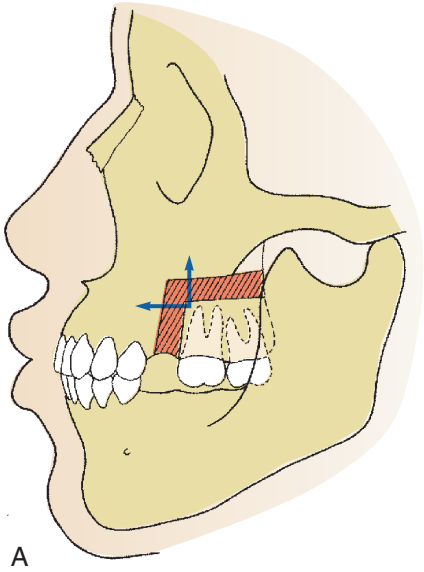


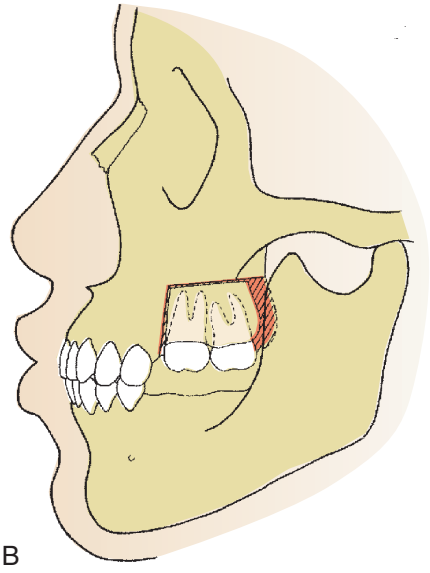
• **Fig. 13.35, cont'd** (F) Preoperative photograph. (G) Postoperative result.

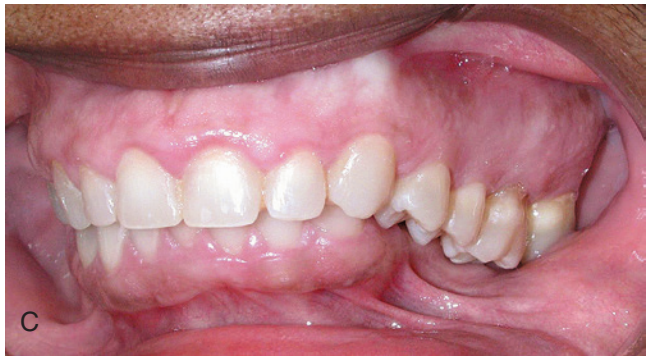


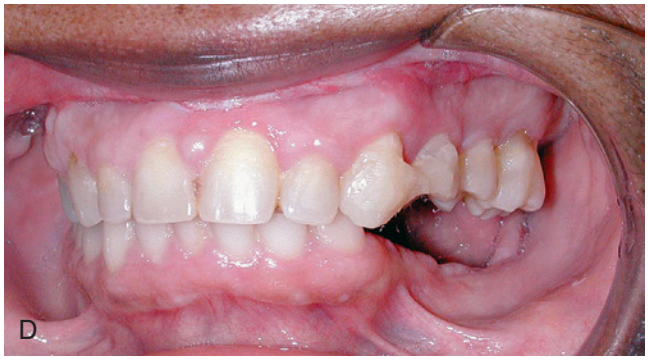


• **Fig. 13.36** Improved soft tissue contours for implant reconstruction. (A) Lack of facial vestibule and deficient keratinized tissue overlying maxillary alveolus. (B) Postoperative result a month later illustrating improved soft tissue contours for implant-supported restoration.









• **Fig. 13.37** Segmental osteotomies. (A–B) Posterior maxillary osteotomy for superior and anterior repositioning of the posterior segment of the maxilla. This improves the interarch space for implant placement or for the construction of removable partial dentures. (C) Clinical appearance of supraerupted maxillary teeth. (D) Postoperative view demonstrating superior repositioning of isolated segment to improve interarch distance.

of the maxilla and the mandible after surgery. In the case of the totally edentulous patient in whom the maxilla, the mandible, or both are to be repositioned, the esthetic facial result must also be considered with the functional result of ridge repositioning. Casts with simulated surgical changes, cephalometric prediction tracings, and experienced clinical judgment are required to determine the desired postoperative jaw position (see Chapter 26). After the desired postoperative skeletal position has been determined, splints are made to allow positioning of the jaws into their proper relationship at the time of surgery. Rigid fixation techniques following repositioning of the maxilla or mandible are reviewed in Chapter 26 and are useful in stabilizing bone segments at the time of surgery and in eliminating a prolonged period of jaw immobilization.

Denture construction can begin within 3 months after surgical repositioning of the maxilla and the mandible. The combination of orthognathic surgery and prosthetic rehabilitation of the patient provides satisfactory functional and esthetic results in many patients with skeletal abnormalities, who would otherwise present significant problems in prosthetic reconstruction.

Summary

The success of preprosthetic surgical preparation depends on careful evaluation and treatment planning. In general, bony abnormalities should be managed first. Associated soft tissue correction is often delayed until bone augmentation and contouring are complete. Simultaneous bony augmentation is attempted when bony augmentation is aimed at improving contour rather than creating significant augmentation in alveolar height or width. Final prosthesis design and goals of long-term function, esthetic quality, and tissue maintenance must be considered during all phases of treatment.

Acknowledgment

We thank Dr. Mark F. Sosovicka for his review and input in updating this chapter.

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14

Implant Treatment: Basic Concepts and Techniques

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CHAPTER OUTLINE

The dental profession has experienced tremendous advancements in dental restoration therapies that are effective, efficient, and predictable. Techniques, materials, instrumentation, and science have evolved to afford the dental patient every opportunity to enjoy a healthy and functional dental life. In spite of all the advancements and opportunities, there still exists a significant population of patients who are either partially or totally edentulous. Dental implants have given the profession and the patient an extremely predictable and effective means of tooth replacement. The partially edentulous patient can now undergo replacement of a single tooth or several missing teeth with implant-retained crowns and enjoy the function and esthetics they had with their natural teeth. The completely edentulous patient no longer has to live with compromised function and the reduced confidence that traditional full denture wearers have historically experienced. Dental implants can offer the edentulous patient comfort, function, and confidence with either fixed prosthetics or implant-retained removable prosthetic options.

Introduction to the Multidisciplinary Approach

Successful implant treatment is dependent on a coordinated approach combining careful treatment planning, meticulous surgical technique, and precise prosthetic restoration. The typical implant team is composed of a trained surgeon who places the implant or implants, a trained prosthetic or restorative dentist who designs

and places the prosthetic replacement, and an experienced dental laboratory technician who creates the prosthetic restoration. The intention of this chapter is to present the basic concepts and techniques that will provide the clinician with a solid foundation for participation in dental implant treatment.

Biologic and Functional Considerations

Hard Tissue Interface

The primary goal in implant placement is to achieve and maintain an intimate bone-to-implant connection. This concept is known as *osseointegration*. Histologically defined, osseointegration is the direct structural and functional connection between organized, living bone and the surface of a load-bearing implant without intervening soft tissue between the implant and bone.[1,2] Osseointegration clinically is defined as the asymptomatic rigid fixation of an alloplastic material (the implant) in bone with the ability to withstand occlusal forces (Fig. 14.1).[3,4]

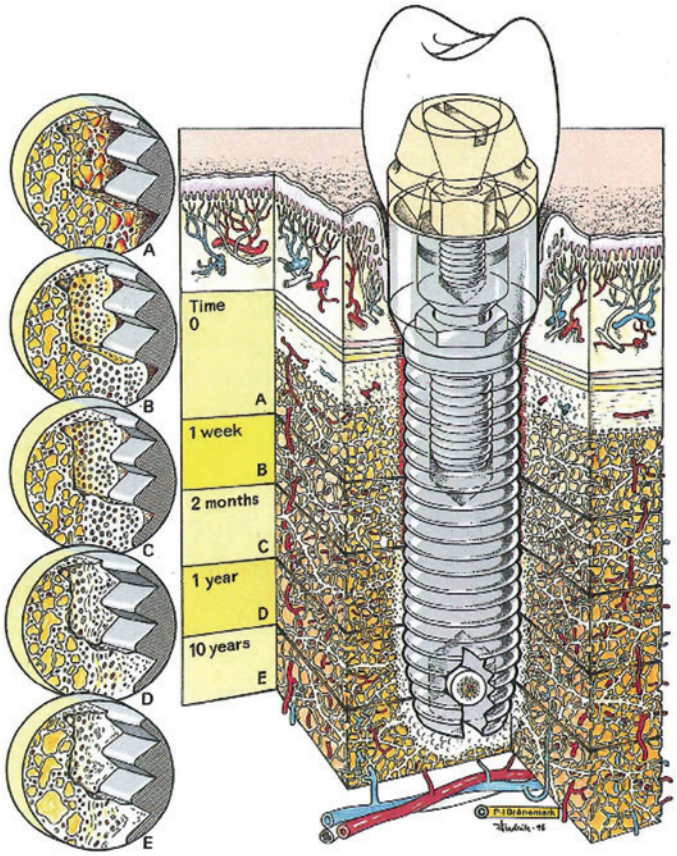
For osseointegration to occur in a predictable fashion, several important factors are required:

1. A biocompatible material (the implant)
2. Atraumatic surgery to minimize tissue damage
3. Implant placement in intimate contact with bone
4. Immobility of the implant, relative to bone, during the healing phase

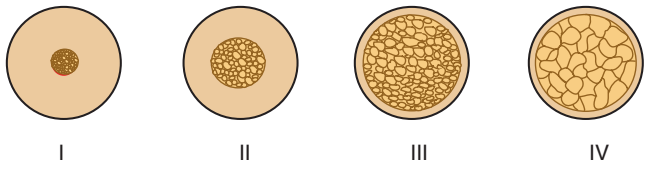
Titanium is the material of choice for dental implants. Titanium is biologically inert and therefore does not elicit a foreign body rejection reaction from host tissue. For the implant to have intimate contact with bone, the implant site must be prepared with a precise technique. All implant systems have specially designed drills that are used in a specific sequence to remove bone as atraumatically as possible. The drill sizes are matched to the size and shape of the implant being placed, creating the precision necessary for developing initial bony contact and stability.

Atraumatic surgical technique in an aseptic environment is critical to minimize mechanical and thermal injuries to bone. This involves using sharp, precision osteotomy drills run at slow speed with high torque while maintaining gentle, intermittent pressure and providing copious irrigation. Irrigation can be accomplished either externally or internally using special handpieces and burrs with internal ports. The goal is to maintain bone temperatures below 47°C during implant site preparation. Any variance causing temperatures to exceed 47°C is likely to cause bone necrosis and failure of osseointegration.

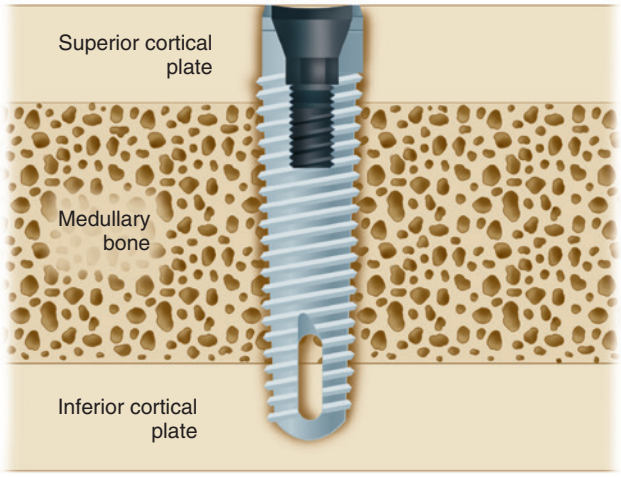
Initial stability of the implant must be achieved and maintained for formation of bone at the implant surface. Stability at the time of placement is predicated on the volume and quality of bone that intimately contacts the implant as well as the length and diameter of the implant (Fig. 14.2). The best-case scenario would be a long, wide-diameter implant that engages a thick superior cortical plate surrounded by dense cancellous bone and terminally engages a thick inferior cortical plate (i.e., anterior mandibular) (Fig. 14.3). Conversely, a short, narrow-diameter implant placed in an area that has a thin superior cortical plate and minimally dense cancellous bone but does not engage the inferior cortical bone would provide



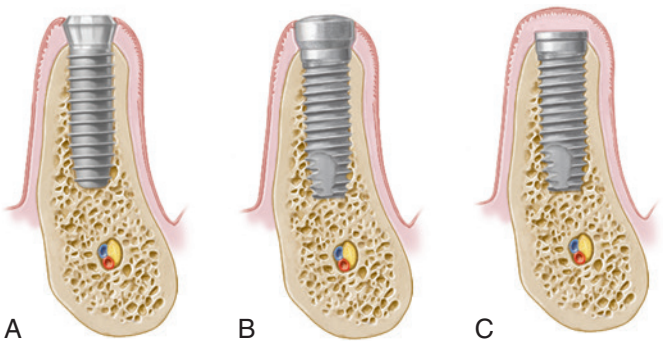
• **Fig. 14.1** Sectioned view of implant interface and adaptation over time. (From Newman MG, Takei HH, Klokkevold PR, et al. *Carranza's Clinic Periodontology*. 11th ed. Philadelphia: Elsevier; 2012.)



• **Fig. 14.2** Bone types based on quantity of cortical bone and density of cancellous marrow. (From Lekholm U, Zasrb GA. Patient selection and preparation. In: Branemark PI, Zarb GA, Albrektsson T, eds. *Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry*. Chicago: Quintessence; 1985.)



• **Fig. 14.3** Whenever possible, implants should engage two cortical plates of bone. (From Rosenstiel SF, Land MF, Fujimoto J. *Contemporary Fixed Prosthodontics*. 4th ed. St. Louis: Mosby; 2006.)



• **Fig. 14.4** One-stage implant versus two-stage implant surgeries. (A) One-stage surgery with the implant designed such that the coronal portion of the implant extends through the gingiva. (B) One-stage surgery with implant designed to be used for two-stage surgery. A healing abutment is connected to the implant during the first-stage surgery. (C) In the two-stage surgery, the top of the implant is completely submerged under the gingiva. (From Newman MG, Takei HH, Klokkevold PR, et al. *Carranza's Clinical Periodontology*. 11th ed. Philadelphia: Elsevier; 2012.)

considerably less stability and resistance to immobility (i.e., posterior maxilla).

During the time required for osseointegration to occur, it is imperative that immobility of the implant be maintained. Therefore, in areas where implant primary stability may be less, a submerged, nonloaded healing period followed by surgical uncovering of the implant would be required (two-stage surgery) (Fig. 14.4). In a clinical situation in which adequate primary stability is achieved, a single-stage, nonsubmerged implant would be appropriate. In such a case the implant may be loaded immediately after surgery.

Soft Tissue–Implant Interface

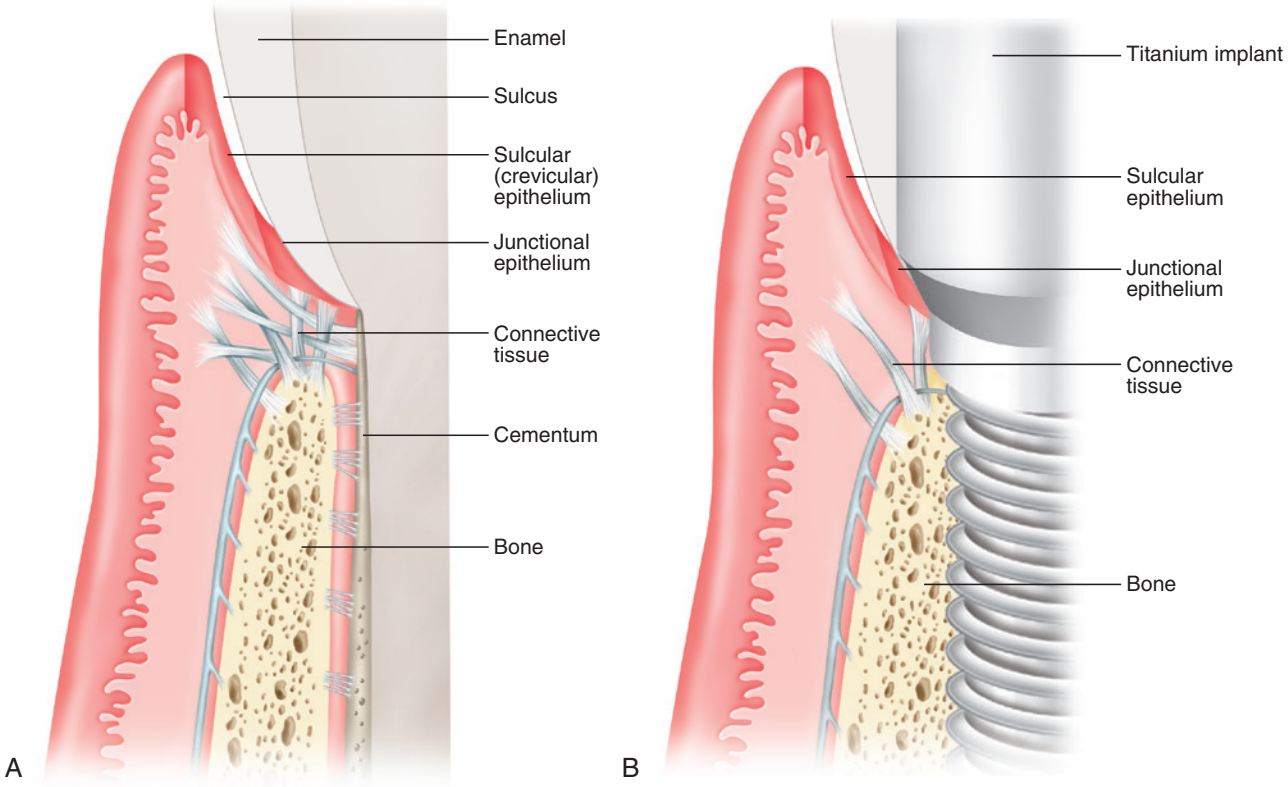
Historically, most basic science and clinical efforts were spent on studying the bone-implant interface of osseointegration. Considerably less attention was given to overlying soft tissues. In contemporary implant dentistry, however, this subject is being researched with great zeal. Driven primarily by the need for satisfactory esthetics as well as maintenance of a soft tissue seal or barrier against bacterial invasion, soft tissue has become a major focus of interest.

It is critical to understand both the striking similarities and the obvious differences between the peri-implant soft tissue and periodontal soft tissue (Fig. 14.5). Peri-implant and periodontal soft tissues do share a number of similarities and only subtle differences. Each emerges from alveolar bone through soft tissue. Soft tissue consists of connective tissue covered by epithelium, which is continuous with an epithelium-lined gingival sulcus, the apical-most portion being lined with junctional epithelium forming an attachment. From that point down to the level of alveolar bone, both types of soft tissue possess a zone of dense connective tissue. This zone of supracrestal connective tissue is responsible for maintaining a stable interface between soft tissue and the implant and acts as a seal or barrier to the oral environment. It is the orientation of the connective tissue fibers adjacent to an implant that differ from a natural tooth. This zone of connective tissue has been measured to be 1 to 2 mm in height.[5,6] Clinically this becomes important when examining the health of peri-implant soft tissue. Probing depths in a healthy implant would be approximately 1 to 2 mm less than the total measured dimension from the crest of the sulcus to the alveolar bone crest. The other obvious difference between teeth and implants is that teeth have a periodontal ligament with connective tissue fibers that suspend teeth in alveolar bone. The implant, however, is in direct contact with bone without any intervening soft tissue. This difference has a dramatic impact on the biomechanics, proprioception, and prosthetic consideration for implants versus natural teeth. Because an implant, unlike a tooth, does not have cementum, most connective tissue fibers run in a direction more or less parallel to the implant surface.

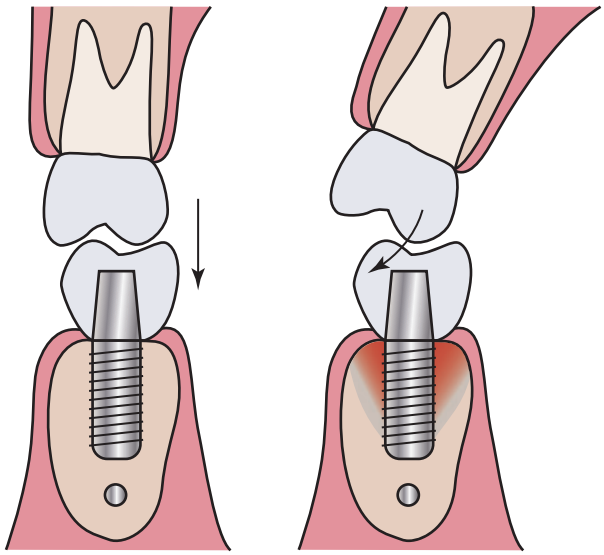
Biomechanical Considerations

As described earlier, sound surgical technique, use of precision instrumentation, an aseptic environment, and intimate contact between bone and the implant are all paramount in achieving osseointegration. Once the implant is properly placed, the long-term success is heavily dependent on restorative biomechanical factors—that is, how the stresses imposed on the functioning implant or prosthetic unit or units will be controlled or distributed. The axiom is simple: The load-bearing capacity of the integrated implant has to be greater than the anticipated load during function. If applied loads are greater than the load-bearing capacity, it is likely to lead to mechanical failure, biologic failure, or both. Mechanical failure may present simply as porcelain fracture or as a loosened or fractured prosthetic screw (the screw that attaches the abutment or framework to the implant). The most devastating mechanical failure occurs when the force is destructive enough to actually fracture the implant fixture. A biologic failure can occur when the functional load exceeds the load-bearing capacity of the implant-bone interface. This initially presents clinically as bone loss around the platform of the implant. If the loss is severe enough and the provocation is long enough, the bone loss may progress around the entire implant and result in complete failure of the implant. The clinician must remember that an implant-retained restoration lacks the "shock absorbing" periodontal ligament that a natural tooth-retained restoration possesses. The periodontal ligament allows slight physiologic movement of teeth, and in the absence of microbe-induced inflammation, natural teeth can move and adapt to the forces without pathologic bone loss. This, however, is not possible with an osseointegrated implant.

The load-bearing capacity of implants is qualified by several factors, including the number and size of the implants, the arrangement and angulation of the implants, and the volume and quality of the bone-implant interface. The same factors that maximize initial implant stability in hard tissue continue to be important. Thick cortical bone and dense trabecular bone surrounding a long, wide-diameter implant that is positioned to be in line with the functional load, would offer the greatest load-bearing capacity and the best prognosis for long-term success. Conversely, a short, narrow-diameter implant placed in an area of thin cortical bone and less dense trabecular bone and in an off-axis angulation would have far less load-bearing capacity and a poorer prognosis for success. The angulation of the implants as it relates to the occlusal plane and the direction of the occlusal forces is an important determinant in optimizing the translation of the forces to the implants and the surrounding bone (Fig. 14.6). Loads directed through the long axis of the implants are tolerated very well. Slight off-axis loads are usually not clinically detrimental, but loads applied at angles greater than 20 degrees or more can result in load magnification and initiate bone loss at the implant-bone interface. Again, if excessive loads persist, bone loss will continue and will likely lead to implant failure.



• **Fig. 14.5** Schematic illustration of hard and soft tissue around a tooth and an implant. (A) Hard and soft tissue anatomy around a natural tooth demonstrates bone support with a periodontal ligament, a connective tissue zone above the crest of bone with connective tissue fibers (Sharpey's) inserting into dentin, a long junctional epithelial attachment, a gingival sulcus lined with sulcular epithelium, and oral gingival epithelium (outer surface of gingiva). (B) Hard and soft tissue anatomy around an implant demonstrates some similarities and some distinct differences. There is supporting bone in direct approximation to the implant surface without any intervening soft tissues (i.e., no periodontal ligament). A connective tissue zone is present above the level of bone with fibers running parallel to the implant surface and no inserting fibers. There is a long junctional epithelial attachment, a gingival or mucosal sulcus lined with sulcular epithelium, and oral gingival or mucosal epithelium (outer surface of soft tissue). (From Rose LF, Mealey BL. *Periodontics: Medicine, Surgery, and Implants*. St. Louis: Mosby; 2004.)

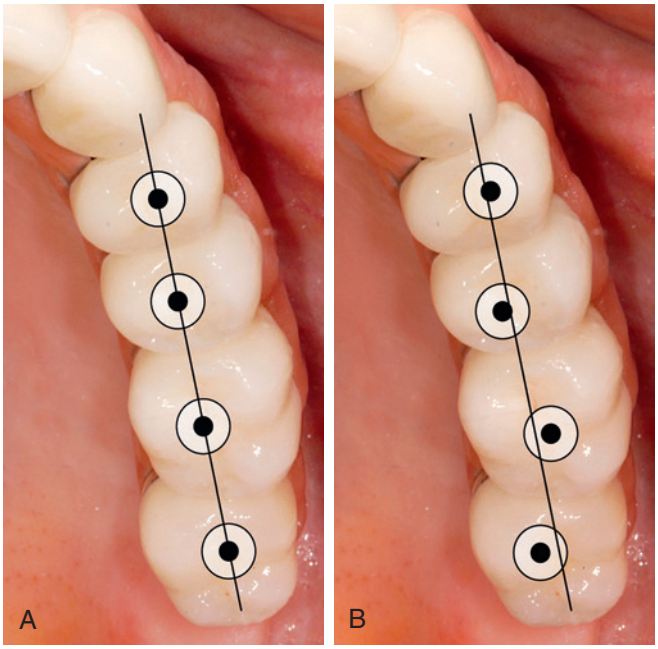


• **Fig. 14.6** Off-axis loading can result in unfavorable forces on the implant, jeopardizing long-term success because of excessive lateral loads.

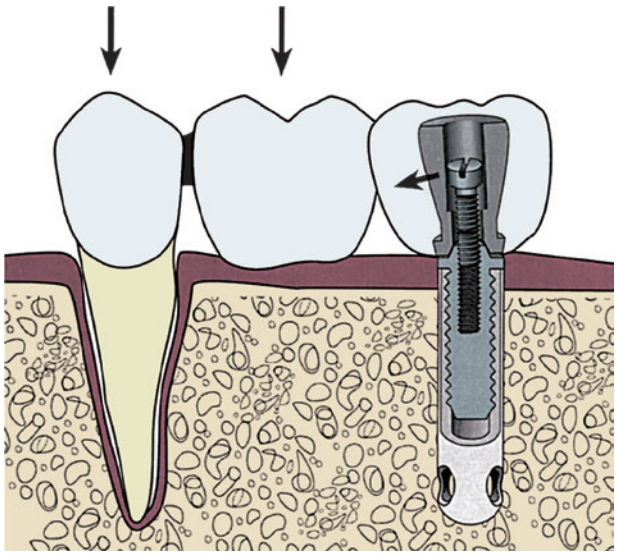
The number of implants placed in multitooth edentulous spans affects the load-bearing capacity of the implanted prosthesis. If there is a three-tooth edentulous span, the fixed prosthetic options would be to place three implants with three splinted crowns, three implants with three single-unit crowns, two implants as terminal abutments for a three-unit fixed partial denture, or two adjacent implants with a fixed partial denture with a cantilevered pontic. The load-bearing capacity decreases with each successive option.

Straight-line or linear arrangement of multiple implants should be avoided as this provides the least biomechanical advantage and is the least resistant to torqueing forces caused by off-center occlusal and lateral loads. Implants should be placed in a more curvilinear or staggered fashion (Fig. 14.7).

Connecting a single integrated implant to one natural tooth with a fixed partial denture will effectively create an excessively loaded cantilever situation. Because of the immobility of the implant compared with the mobility of the natural tooth, when the loads are applied to the fixed partial denture, the tooth can move within the limits of its periodontal ligament. This can create stresses at the implant abutment junction up to two times the applied load on the prosthesis (Fig. 14.8). Additional problems with a tooth



• **Fig. 14.7** Placement of implants. (A) Linear placement of four implants. Lateral forces may result in eventual bone loss and implant failure. (B) Slightly staggered arrangement provides more three-dimensional stability.



• **Fig. 14.8** When a single implant is attached to a natural tooth, biting forces on the natural tooth and pontic cause stress to be concentrated at the superior portion of the implant. (From Rosenstiel SF, Land MF, Fujimoto J. *Contemporary Fixed Prosthodontics*. 4th ed. St. Louis: Mosby; 2006.)

to implant-supported, fixed partial dentures include breakdown of osseointegration, cement failure on the natural abutment, screw or abutment loosening, and possible failure of the implanted prosthetic components.

Detrimental forces can be applied iatrogenically by placing nonpassive, ill-fitting frameworks on implants. When the screws are tightened in an attempt to seat the ill-fitting framework, compressive forces are placed on the implant-bone interface. This excessive force can lead to bone loss and potential implant failure

Preoperative Assessment and Treatment Planning

The ultimate goal of dental implant therapy is to satisfy the patient's desire to replace one or more missing teeth in an esthetic, functional manner with long-term success. To achieve this goal, clinicians must accurately and comprehensively assess the dentoalveolar condition as well as the overall physical and mental well-being of the patient.

Initial Observations and Patient Introduction

At the first meeting with the patient, the experienced clinician begins observing the patient's physicality, physique, complexion, hands, eyes, facial features, voice, posture, personality, and so on. These same initial characteristics will continue to be observed throughout the consultation and through the continuum of the patient's treatment.

Chief Complaint

The patient's chief complaint is a statement in his or her own words that conveys the perceived problem, concerns, expectations, and so on. The goal of the clinician is to explore, conversationally, the details of the patient's concerns, desire for treatment, apprehensions, and goals for the desired outcome. The clinician must assess how realistic the patient's expectations are. Is the patient looking strictly for a functional replacement, or is there a strong esthetic expectation? How does the patient's expectation fit his or her perceived timeline or financial investment? Ultimately, it becomes the clinician's responsibility to sift through all of the information conveyed by the patient and determine the available treatment options that would meet or exceed the patient's expectations and to educate the patient about these options. If the doctor and the patient do not understand each other's expectations, there will inevitably be less satisfaction at the conclusion of the treatment.

Medical History and Medical Risk Assessment

A thorough medical history is required and must be documented for every dental patient. As with any patient planning a surgical procedure, the patient must be assessed preoperatively to evaluate his or her ability to tolerate the proposed procedure, heal, and to have a favorable prognosis.

When the medical history form is completed, it is the responsibility of the clinician to review it and use the reported data as the basis for an efficient verbal medical history taking or interview. This interview is used to gain additional insight or information necessary to fully understand the patient's health status. The interview also allows an opportunity to fill important gaps in the history, as patients often fail to list significant medical information on the questionnaire.

There are only a few absolute medical contraindications to implant therapy. Absolute contraindications to implant placement based on surgical and anesthetic risks are limited primarily to patients who are acutely ill and those with uncontrolled metabolic disease. Often these contraindications are limited in duration; once the illness resolves or the metabolic disease is controlled, the patient may become a good candidate for implant therapy. Relative contraindications are concerned with medical conditions that affect

bone metabolism or the patient's ability to heal. These include conditions such as diabetes, osteoporosis, immune compromise (e.g., human immunodeficiency virus infection, acquired immunodeficiency syndrome), medications (e.g., bisphosphonates—oral and intravenous), and medical treatments such as chemotherapy and irradiation (e.g., of the head and neck).[7,8]

Some psychological or mental conditions could be considered absolute or relative contraindications, depending on their severity. Patients with psychiatric syndromes (e.g., schizophrenia, paranoia) or mental instabilities (e.g., neurosis, somatic symptom disorder), those who have mental impairment or are uncooperative, or those who have irrational fears, phobias, or unrealistic expectations may be poor candidates for implant treatment. Certain habits or behavioral considerations such as smoking, tobacco use, substance abuse (e.g., drugs and alcohol), and parafunctional habits (bruxing and clinching) must be scrutinized as potential contraindications as well. Smoking, in particular, has been documented as a significant risk factor resulting in decreased long-term stability and retention of implants.[9]

Dental History

Like the medical history, a thorough dental history must be obtained from every dental patient, and it is initiated with a history questionnaire. The clinician seeks information regarding the patient's past experiences with restorative dentistry, periodontics, oral surgery, endodontics, orthodontics, and prosthetics. By understanding the patient's prior dental history, the clinician can gain insight into the patient's potential as a candidate for implant therapy. For example, if a patient presents with complex dental needs and has a history of seeking dental care in a consistent and mindful fashion, the clinician may feel that the patient is an above-average risk. However, because of the patient's compliance history, he or she may be a suitable candidate for comprehensive dental treatment. Conversely, if a patient presents with complex dental needs and has shown very little commitment to past dental treatment and has demonstrated very little effort to take care of his or her dentition, the clinician may consider this patient a much higher risk and may suggest a less complex and more easily serviced treatment plan.

Equally as important, the clinician needs to explore the patient's emotional connection to his or her dental history. Has the patient had positive dental experiences in the past, or is the patent extremely apprehensive because of prior experiences? Surgical or restorative implant dentistry requires significant commitment from both the patient and the clinician. It is imperative that the dentist-patient relationship be as constructive as possible.

Intraoral Examination

The oral examination helps assess the current health and condition of existing teeth as well as the oral hard and soft tissues. It is imperative to recognize any pathologic conditions present in any of the hard or soft tissues or the presence of acute or chronic infection. The implant-focused intraoral examination should address the restorative or structural integrity of existing teeth, existing prosthetics, vestibular depths, palatal depths, edentulous ridge topography, periodontal status, oral lesions, infections, occlusion, orthodontic assessment, jaw relationships, interarch space, maximum opening, parafunctional habits, and oral hygiene. Specific attention should be paid to the edentulous ridge anatomy and soft tissue morphology. The height and width of the ridges are evaluated visually, followed by palpation of the area to locate topographic determinants such as undercuts or bony defects.

As previously described, the soft tissue surrounding dental implants contributes to their success and longevity. While examining the periodontal health of the patient, the clinician must consider the health of soft tissue around existing teeth, the edentulous areas, and any previously placed implant. Soft tissue is examined for zones of keratinization (e.g., quantity and location), clinical biotype (e.g., thin, moderate, or thick), redundancy and mobility, and pathology. Clinical inspection of soft tissue often requires radiographic verification, particularly if soft tissue is thick, dense, and fibrous. Thick fibrous tissue can often mask a thin underlying bony architecture. In locations planned for implant placement, the more site-specific evaluation centers on the quality, quantity, and location of keratinized tissue and nonkeratinized mucosa. If the clinician feels that keratinized tissue is inadequate to maintain the health of the implant or is lacking in esthetic support of the planned implant or restorative complex, then soft tissue grafting or augmentation must be considered.

While examining the patient, the clinician should also evaluate the surgical ergonomics, that is, how wide the patient can open the mouth, how resilient the cheeks are, the size of the tongue, perioral musculature, exaggerated gag reflex, airway liability, and overall patient cooperation.

More specific aspects of the hard and soft tissue examination will be presented when addressing specific implant areas. All of the details of the intraoral examination need to be charted and documented. The intraoral examination allows the clinician to then determine what radiographs and other diagnostic records may be required to further evaluate the patient and his or her dental needs.

Diagnostic Casts and Photographs

Mounted study models as well as intraoral and extraoral photographs complete the records collection process. Study models and photographs are often overlooked in preoperative history taking, but both contribute significantly to the assessment and treatment planning phases of implant dentistry.

Study models mounted on a semiadjustable articulator using a face-bow transfer give the clinician a three-dimensional working representation of the patient and provide much information required for surgical and prosthetic treatment planning.

Elements that can be evaluated from accurately mounted models include the following:

1. Occlusal relationships
2. Arch relationships
3. Interarch space
4. Arch form, anatomy, and symmetry
5. Preexisting occlusal scheme
6. Curve of Wilson and curve of Spee
7. Number and position of the existing natural teeth
8. Tooth morphology
9. Wear facets
10. Edentulous ridge relationships to adjacent teeth and opposing arches
11. Measurements for planning future implant locations
12. Visualizing force vectors, both present and planned

Mounted study models have tremendous value when interdisciplinary treatment planning is required. Multiple individuals involved in the treatment of the patient can efficiently evaluate and contribute to the assessment and treatment planning without the patient being

present. Medicolegally, the mounted study models are preserved as an exact reference of the preoperative condition.

Intraoral photographs are equally important. They allow visual evaluation of the patient's soft tissue (e.g., quantity, quality, location, texture, color, symmetry). Extraoral photographs provide views of the patient from many different esthetic perspectives. Elements that are easily assessed are as follows:

1. Facial form
2. Facial symmetry
3. Patient's degree of expression and animation
4. Patient's appearance (e.g., facial features, facial hair, complexion, eye color)
5. Smile line
6. Incisal edge or tooth display
7. Buccal corridor display
8. Potential esthetic demand

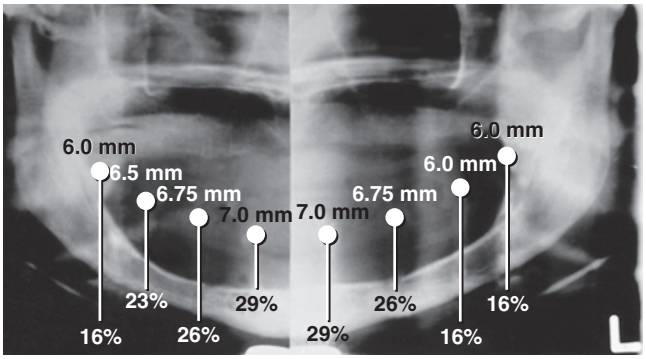
Radiographic Examination

Several radiographic imaging options are available for diagnosis and for planning of dental implantation. Options range from standard intraoral projections (e.g., periapical, occlusal) and extraoral projections (e.g., panoramic, cephalometric), to more complex cross-sectional imaging (e.g., computed tomography [CT], cone-beam computed tomography [CBCT]).

Multiple factors, however, influence the selection of radiographic techniques for any particular case. Such factors as cost, availability, radiation exposure, and the type of case must be weighed against the accuracy of identifying vital anatomic structures within a given bone volume and being able to perform the surgical placement without injury to these structures. Areas of study radiographically include the following:

1. Location of vital structures
   - Mandibular canal
   - Anterior loop of the mandibular canal
   - Anterior extension of the mandibular canal
   - Mental foramen
   - Maxillary sinus (floor, septations, and anterior wall)
   - Nasal cavity
   - Incisive foramen
2. Bone height
3. Root proximity and angulation of existing teeth
4. Evaluation of cortical bone
5. Bone density and trabeculation
6. Pathology (e.g., abscess, cyst, tumor)
7. Existence of anatomic variants (e.g., incomplete healing of extraction site)
8. Cross-sectional topography and angulation (best determined by using CT and CBCT)
9. Sinus health (best evaluated by using CT and CBCT)
10. Skeletal classification (best evaluated with the use of lateral cephalometric images)

Radiographic images allow for quantifying dimensions or for taking measurements. Traditional radiographs must be calibrated for potential magnification. Magnification on a traditional panoramic image can be as much as 25%. One way to determine magnification is to place a metal sphere near the plane of occlusion when taking the radiograph. By comparing the radiographic size with the actual size of the sphere, the magnification can be determined (Fig. 14.9). Digitally acquired periapical, panoramic, lateral cephalometric images and CT and CBCT scans have bundled software applications that allow for very accurate measurement.



• **Fig. 14.9** Panoramic radiograph with standard-sized steel ball bearings placed along the ridge. Magnification varies from site to site.

Critical measurements specific to implant placement include the following:

- At least 1 mm inferior to the floor of the maxillary and nasal sinuses
- Incisive canal (maxillary midline implant placement) to be avoided
- 5 mm anterior to the mental foramen
- 2 mm superior to the mandibular canal
- 3 mm from adjacent implants
- 1.5 mm from roots of adjacent teeth

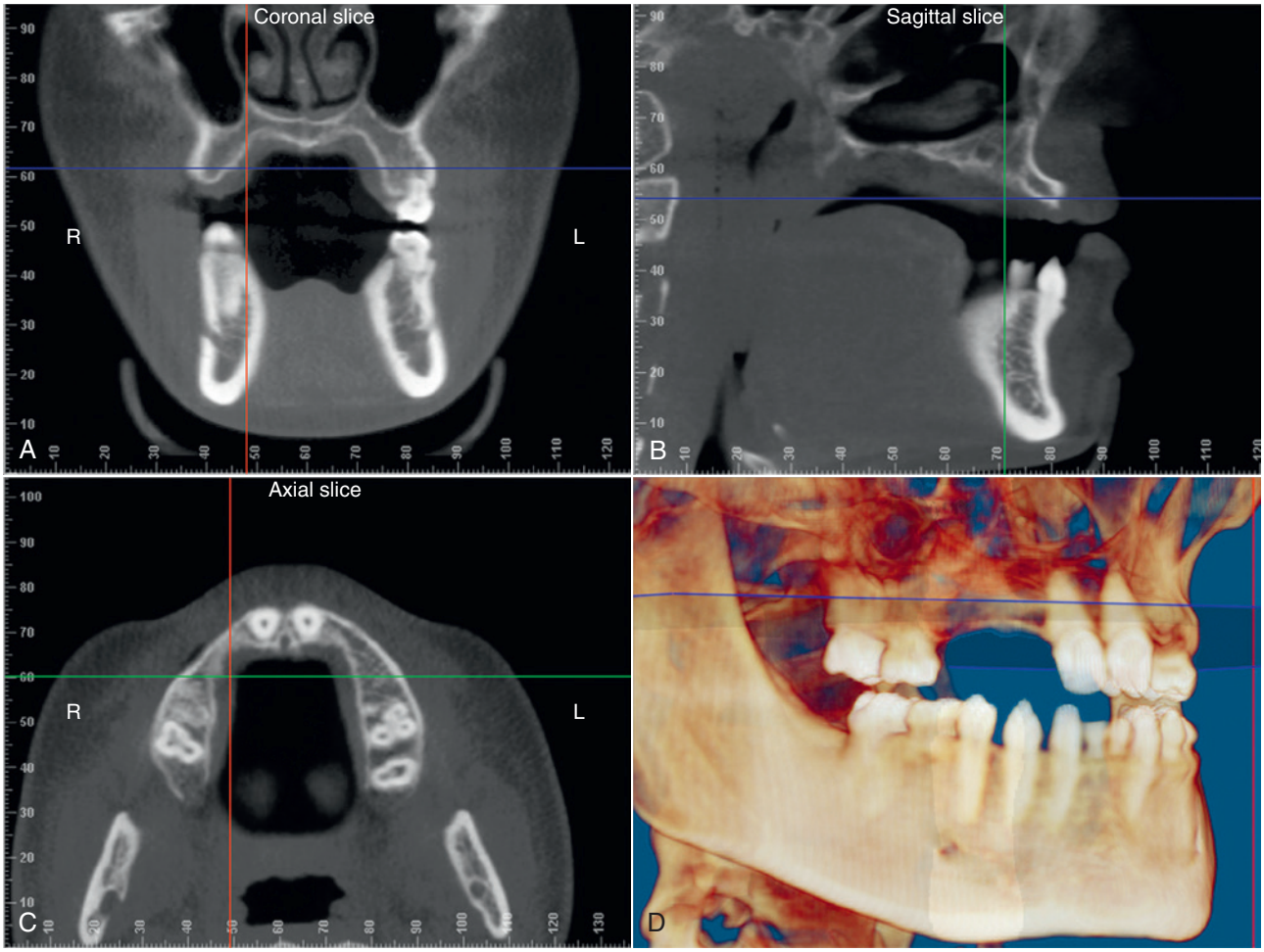
CT and CBCT image data files can be reformatted and viewed on personal computers using simulation software. This allows the diagnosis and treatment planning processes to be more accurate with regard to measurements and dimensions. Critical anatomic structures can be visualized in all three coordinate axes so that their superoinferior, anteroposterior, and buccolingual locations can be identified (Fig. 14.10).

Prosthetic Considerations in Implant Treatment Planning

The prosthetic assessment takes the diagnostic data that has been gathered and combines it with the clinical judgment of the clinician performing the restoration, the patient's expectations, and an understanding of what is surgically reasonable to form the treatment plan. Assessment for prosthetic treatment is multifactorial, is unique to each individual, and can range from simple to extremely complex.

A simple starting point is to determine what needs to be replaced: a single tooth, multiple teeth, or all of the patient's teeth. Will the replacement be more functional (e.g., a mandibular first molar), or will the replacement have a strong esthetic consideration (e.g., maxillary central incisor)? Is the patient expecting to have a fixed prosthetic option or one that is removable? Does the prosthetic solution include replacing just the tooth; the tooth and gingival tissue; or bone, gingival tissue, and the tooth (Fig. 14.11)?

In the partially edentulous patient, evaluation of existing natural teeth and their periodontal support is imperative. The prognosis for the remaining teeth and their value in the overall dental health of the patient must be determined. If the patient is only missing a single tooth and all the remaining teeth are healthy, then the prognosis for the patient's overall dental health is clear. If the patient only has a few teeth scattered throughout the maxillary and mandibular arches and the remaining teeth are heavily restored and periodontally compromised and their prognosis is questionable or guarded, decisions must then be made as to whether the remaining teeth hold any prosthetic value or are best removed.



• **Fig. 14.10** Cone-beam computed tomography scan allowing visualization of multiple structures in three dimensions. (A) The coronal slice through the posterior edentulous area demonstrating anatomy of the maxillary sinus and alveolar ridge bone. (B) A cross-sectional view of the edentulous anterior maxillary ridge. (C) An axial view showing deficiency of the anterior maxillary ridge. (D) Three-dimensional reconstruction.

The patient's occlusion needs to be examined. Are the components of occlusion favorable, or will they have to be reestablished? The clinician must evaluate the occlusal scheme (e.g., cuspid protected, group function, or some variation). The occlusion can be classified (e.g., class I, class II, class III) and compared with the patient's skeletal classification (e.g., class I, class II, class III). Open bites, deep bites, and crossbites need to be recognized and their liability assessed. The maxillary occlusal plane, curve of Spee, and curve of Wilson need to be evaluated. Compensatory conditions to the occlusion need to be taken into consideration (e.g., wear facets, abfraction lesions, gingival recession, mobility, tooth migration, anterior splaying, mesially inclined molars, and fractures). All of these conditions have a direct impact on the biomechanics of any proposed treatment.

Evaluation of the interarch space is critical in both the partially edentulous patient and the totally edentulous patient. The interarch space determines spatial limitations or an opportunity for specific prosthetic options. For example, a cement-retained, abutment-supported crown on an implant replacing the mandibular right first molar requires a minimum of 8 mm of interarch space from the osseous crest of the edentulous space to the occlusal surface of the opposing tooth. If 8 mm of interarch space is not available, then a screw-retained implant crown would be necessary. For the edentulous patient, approximately 15 to 17 mm of interarch space is required for a bar-retained overdenture. If less interarch space is available, then an abutment-retained (e.g., locator attachment, O-ring) overdenture would be necessary.

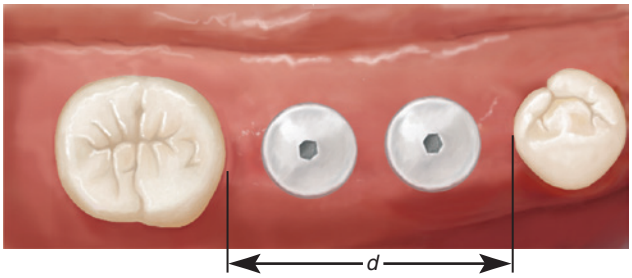
The crown-implant ratio needs to be carefully considered in the implant treatment planning. The clinician must measure the interarch space in the area planned for the crown and implant and reference that measurement against the intended implant length. For example, if the interarch space between the osseous crest of the edentulous site of the lower right first molar and the opposing occlusal surface is 10 mm and the longest implant that can be placed is 10 mm, then the crown-implant ratio is 1:1. Any ratio less than 1:1 provides increased confidence for favorable biomechanics (e.g., a crown height of 8 mm supported by an implant that is 13 mm in length). When the ratio becomes greater than 1:1, the clinician must understand the potential biomechanical liability of incrementally exceeding that ratio (e.g., a crown height of 15 mm supported by an implant that is 8 mm in length).

Implant spacing must be understood as a dimensional requirement. Implants need 1.5 mm of space from the outer surface of the implant to the adjacent root surface and 3 mm of space between adjacent implants. For example, if a 4-mm-diameter implant were planned to replace a missing tooth, the minimum edentulous space

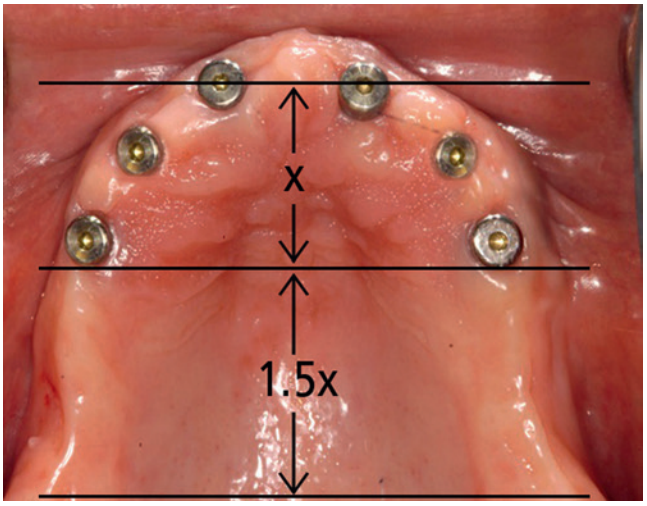
• **Fig. 14.11** Implant treatment options. (A–B) Single tooth replacement. Replacement of a single missing mandibular first molar. (C–D) Restoration of missing teeth #7 to #10. The prosthesis replaces teeth and gingival tissue. (E–F) Restoration of missing teeth #8 to #11. Prosthesis replaces teeth, gingival tissue, and bone.

required would be 7 mm (1.5 + 4 + 1.5 mm = 7 mm). If two adjacent 4-mm implants were planned between natural teeth, the edentulous span would have to be at least 14 mm (1.5 + 4 + 3 + 4 +1.5 = 14 mm) (Fig. 14.12).

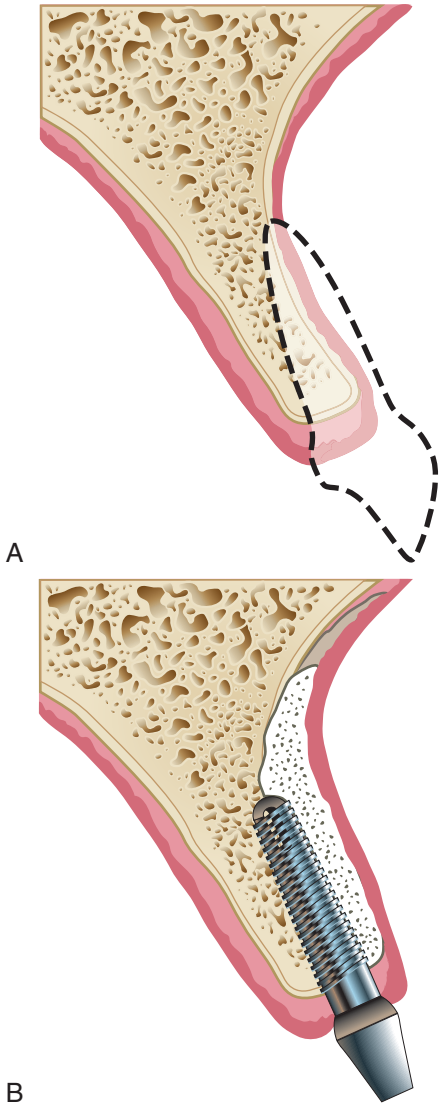
The edentulous maxilla requires scrutiny in selecting prosthetic options. Because of the pattern of resorption (apically and palatally), consideration must be given to the intended location of the implant platform and the final position of teeth. In the case of a missing single tooth or a few anterior teeth, the ridge resorption may require grafting prior to implant placement (Fig. 14.13). In a more severely resorbed atrophic maxilla opposing a dentate mandible, the anteroposterior difference may be too great to have a conventional, abutment-supported, fixed partial denture prosthetic option. In this case, a framework-supported, fixed hybrid prosthesis or a removable overdenture option would need to be utilized. Close attention must be paid to the upper lip esthetics as well. Many patients need the support provided by the labial flange of the maxillary denture to support their upper lip, while others can have an acceptable result without the flange. One of the major motivators for patients seeking implants to retain a maxillary denture is the



• **Fig. 14.12** Minimal amount of mesial-distal space *(d)* required for placement of two standard-diameter (4-mm) implants between natural teeth is 14 mm. This allows approximately 1.5 mm between teeth and implants and 3 mm between implants. (From Newman MG, Takei HH, Klokkevold PR, et al. *Carranza's Clinical Periodontology*. 11th ed. Philadelphia: Elsevier; 2012.)



• **Fig. 14.14** Anteroposterior spread lines for cantilever stability. Edentulous maxilla with six implants placed and depiction of the quantitative determination for the ability to extend a prosthesis or a framework.



• **Fig. 14.13** Deficient anterior maxillary ridge. (A) After tooth loss there is often significant vertical and buccolingual loss of alveolar bone (original position of tooth shown). (B) To facilitate implant placement, this type of bone defect will have to be grafted prior to implant placement.

possibility of having a prosthesis without any coverage of the hard palate. In most cases, with appropriate implant support, this is, indeed, possible, but in cases where there is an extremely shallow buccal vestibule and palatal vault, the prosthesis may require palatal coverage for stability and enhanced biomechanics.

A major determinate in overdenture support as well as fixed prosthetic options in the edentulous arch is the concept of the anteroposterior (AP) spread of the implants.

The AP spread is defined by the distance measured between a line drawn horizontally through the middle of the most anterior implant and a line drawn horizontally through the distal of the most posterior implant on each side of the arch. The greater the AP spread, the more stable the prosthesis will be. If a retentive bar or fixed framework needs to be cantilevered to increase its length and thus its support, the AP distance measured can be multiplied by a factor of 1.5 to determine the additional length that can be added to the bar or frame. Therefore if the distance measured from the center of the most anterior implant to the distal part of the most posterior implant is 10 mm, then a retentive bar or fixed framework could be extended 15 mm further posterior to the most posterior implant on that side (Fig. 14.14). If the cantilevered distance is excessive, this may lead to failure of the prosthetic structure or may place undue stress on the implants, compromising implant integrity and potentially causing implant failure.

Many prosthetic options are available for implant reconstruction, each with a specific list of attributes and liabilities. The clinician must be aware of the pros and cons of each. Factors to take into consideration include cost, durability, retrievability (cement- or screw-retained), reparability (degree of difficulty, time, and cost), material choices (acrylic, resin, porcelain), fixed or removable, clinical demand, patient expectation, and patient dexterity. For example, a patient with a completely edentulous maxilla may be a candidate for a removable, attachment-retained overdenture or a fixed, all-ceramic, hybrid prosthesis. The cost and durability of the all-ceramic hybrid is considerably higher than that of the overdenture, but the retrievability and reparability of the overdenture is far easier and less expensive. The patient may have the financial means to afford the far more expensive all-ceramic hybrid prosthesis

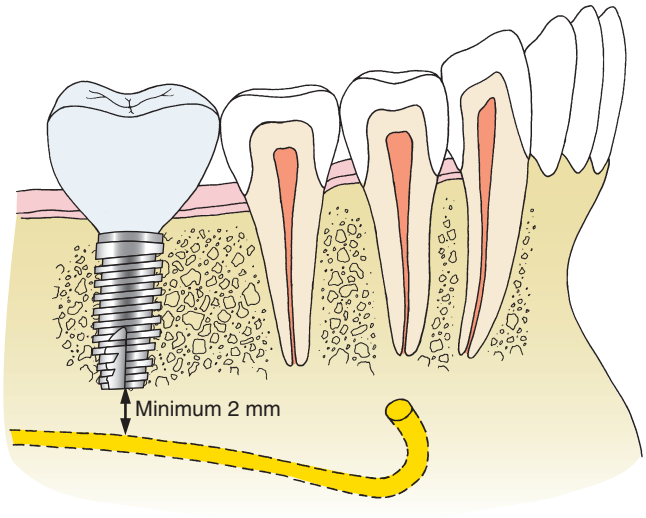
but may not have the physicality for the increased clinical demand or the dexterity to care for the fixed option.

Surgical Treatment Planning Considerations

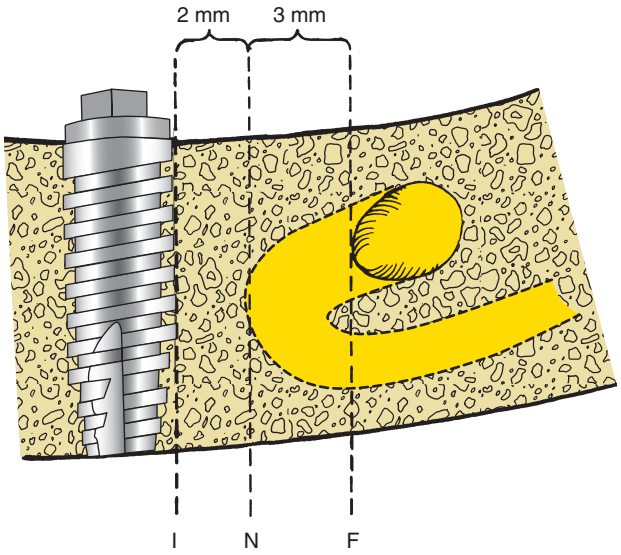
Surgical treatment planning takes the diagnostic data that have been gathered and combines them with the surgeon's clinical judgment to determine the potential surgical options. The surgeon must be mindful of the proposed prosthetic goals, typically driven by the number of implants required in suggested locations for a specific prosthetic design. Because implant dentistry is often a team endeavor, it is advantageous for the surgeon to have a reasonable understanding of the prosthetics and for the restoring dentist to have an understanding of the surgical aspects of implant placement.

After evaluating all of the previously described information, the surgeon must determine the prognosis of implant placement based on specific limitations as a result of anatomic variations, bone quality, and bone quantity in different areas of the jaw. The anterior mandible is usually tall enough and wide enough to accommodate implant placement. Bone quality is usually excellent, typically the densest of any area in the two arches. Primary surgical concerns in this area include proper angulation of the implants and avoiding the mental foramen and mandibular canal. Implants should be placed at least 5 mm anterior to the most anterior portion of the mental foramen, avoiding the anterior loop of the mandibular canal (Fig. 14.15).

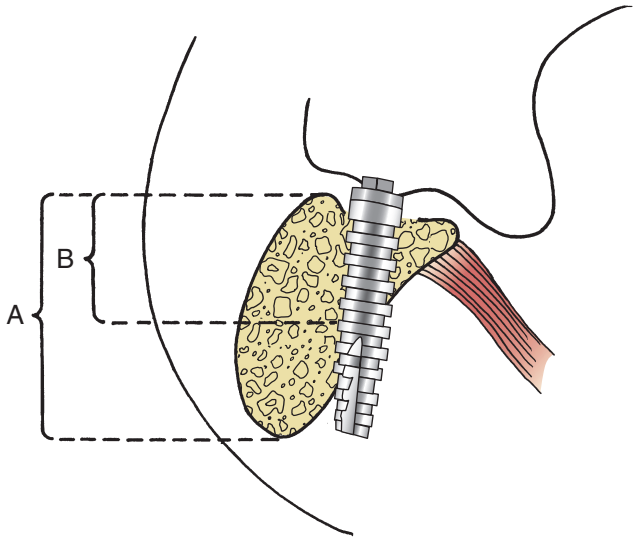
The posterior mandible limits the length of the implants based on the position of the mandibular canal that traverses the body of the mandible in this region (Fig. 14.16). Ideally, the tip of the implant should be at least 2 mm from the inferior alveolar nerve (IAN). It is important to consider the buccolingual position of the nerve as well. The width of the posterior mandible must also be considered. If the nerve is located very near the buccal cortex, a longer implant could be placed, with the implant extending lingual to the IAN, even though the implant extends vertically past the nerve. CT or CBCT can be helpful in making this determination. The mandibular canal also precludes any posterior implants from engaging the inferior cortical plate, which could lessen the initial primary stability of the implant. The attachment of the mylohyoid muscle helps maintain the bony width along the superior aspect of the ridge, although this can often be deceiving because a deep lingual depression, "the lingual undercut," usually is present immediately below this attachment. This is a critical area to be examined and palpated during the clinical examination (Fig. 14.17).



• **Fig. 14.16** Implants should be placed a minimum of 2 mm from the inferior alveolar canal.



• **Fig. 14.15** The most anterior extent of the bony mental foramen *(F)* is frequently located posterior to the most anterior extent of the mental nerve before its exit from bone *(N)*. The most posterior aspect of the implant *(I)* should be placed a minimum of 2 mm from the nerve. This means that the implant must be placed 5 mm anterior to the most anterior aspect of the bony mental foramen.



• **Fig. 14.17** Mylohyoid muscle will maintain bone along its attachment on the medial aspect of the mandibular body. Frequently a significant depression is found just below this. If the implant position and angulation do not compensate, lingual perforation may result. *A,* Apparent bone height on the radiograph. *B,* Actual height in desired area.

In planning the implant placement, if primary stability is questionable, increased time for osseointegration may be considered. The clinician may also want to consider "overengineering" the case by using more implants (e.g., three implants replacing three teeth, vs. two implants replacing three teeth).

The posterior maxilla poses two specific concerns related to implant placement. The first is the quality of bone in this area. As previously discussed, bone quality in the posterior maxilla is typically the poorest of any area, limited by thin cortical bone at the ridge crest and the least dense trabecular bone. This often results in less implant stability at the time of placement. For this reason, more time (6 months or longer) may be required for osseointegration to occur in this region. The second concern is the proximity of the maxillary sinus to the edentulous ridge. Often, as a result of bone resorption and increased pneumatization of the sinus, a limited height of bone remains for implant placement. If an adequate height of bone is present, the implant should be placed, leaving 1 mm of bone between the sinus and the implant. If there is inadequate bone height, then either a "sinus bump" or "sinus lift" procedure would be necessary to augment the height of bone. Both procedures are considered more advanced procedures and are covered in a later chapter.

The anterior maxilla, even though it is the most surgically assessable area, may be one of the most difficult regions for implant placement. This area, even when healthy teeth are present, usually has a thin buccal plate. After tooth loss, the resorption of the ridge follows a pattern of moving apically and palatally, only exacerbating an already tenuous anatomy (see Fig. 14.13). The residual ridge anatomy results in a ridge that is narrow and angulated such that ideal implant positioning may be impossible and the esthetic outcome may be compromised. The nasal cavity and the incisive canal are vital structures that also define the anatomic limitations of anterior implant placement. Implants should be placed 1 mm short of the nasal floor and should not be placed in the maxillary midline. A number of advanced procedures help with ideally placing maxillary anterior implants and are covered in a later chapter.

Final Treatment Planning

The final stage of treatment planning involves consolidating all of the clinical and radiographic information in combination with surgical options and limitations to produce the best final result of the prosthetic treatment. The positioning and angulation of implant placement is critical to the biomechanical stability and esthetics required for long-term success. To facilitate ideal implant placement, surgical guides are frequently utilized. The surgical guide template is a critical factor for implants placed in an esthetically important area because even slight variations of angulation can have large effects on the appearance of the final restoration. The construction of the surgical guide template is nearly indispensable in patients for whom it is necessary to optimize implant placement to ensure correct emergence profiles in the anterior esthetic zone. The four objectives of using a surgical template for the partially edentulous patient are as follows: (1) delineating the embrasure, (2) locating the implant within the tooth contour, (3) aligning the implants with the long axis of the completed restoration, and (4) identifying the level of cementoenamel junction or tooth emergence from soft tissue. This template can be constructed by using a diagnostic wax-up over the preoperative cast to construct a clear resin template with a guide hole. This provides the surgeon ease of access to bone and uninterrupted visual confirmation of frontal and sagittal positions and angulation. Although underlying bone may dictate some minor variation, the surgeon must stay as close as possible to the template during implant placement. With the aid of computer technology, accurate "virtual" treatment planning can be accomplished. CBCT data are used to produce a three-dimensional reconstruction, which offers the ability to view anatomic structures in cross-section. The ideal prosthetic position can be simulated and the position and angulation of the implant determined (Fig. 14.18). A computer-generated splint can then be constructed with guide sleeves matched to implant drill sizes. This allows precise placement of the implant at the time of surgery. The ultimate result should allow the surgeon to place the implant optimally in bone while maintaining the angulation that provides the best foundation for the final restoration.

The surgical template for the completely edentulous mandible should allow the surgeon maximal flexibility to select the implant position in resorbed bone and yet provide guidance for the angulation requirements of the restorative dentist. A template with a labial flange that simulates the labial surface of the anticipated position of the denture teeth but that is cut out on the lingual aspect satisfies these two requirements. The surgeon places the implants within the arch form as close to the surgical template as possible to prevent the placement of the implants too far lingually or labially.

Surgical Techniques (Basic)

Surgical Armamentarium

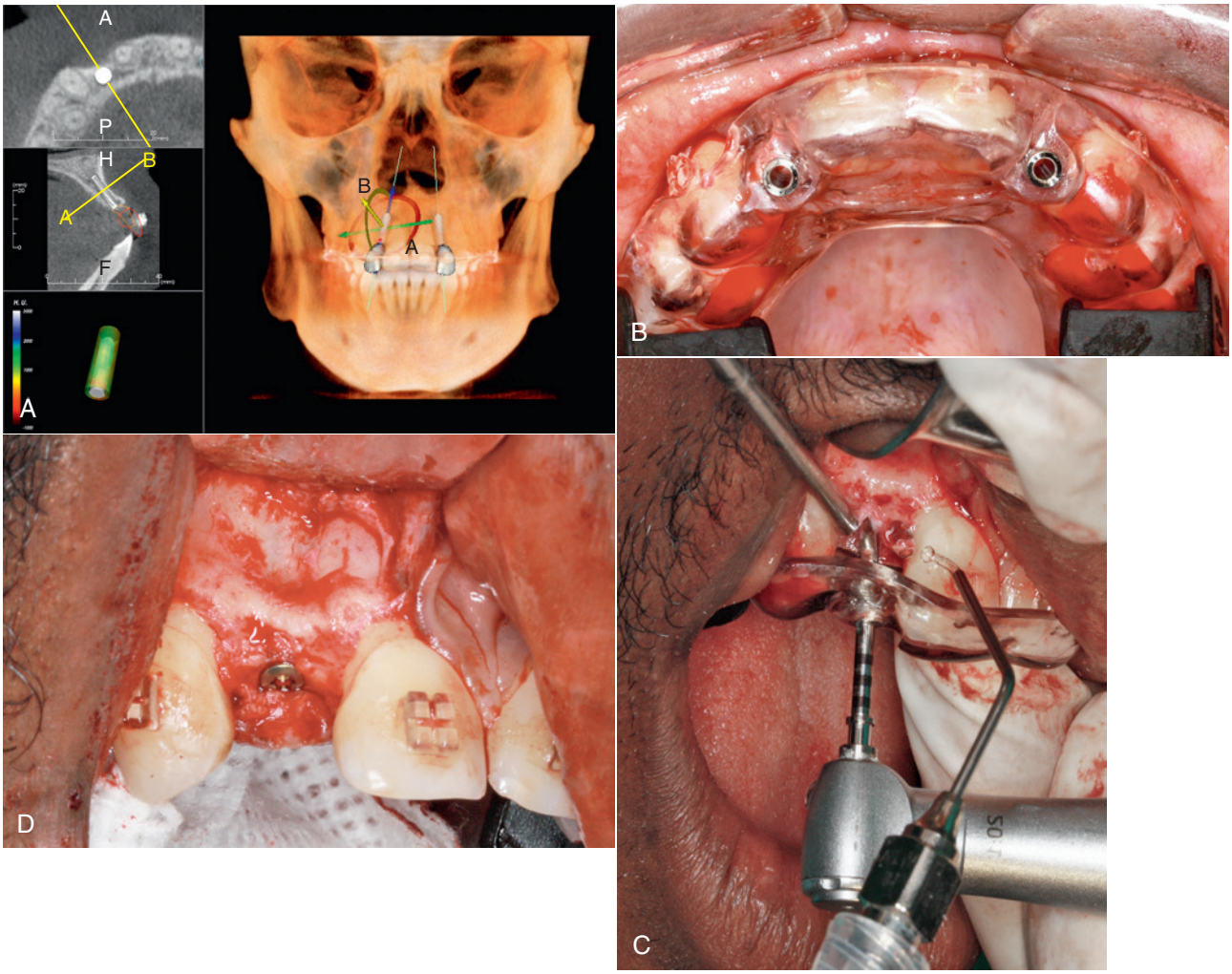
The surgical armamentarium for implant placement consists of the following instruments categorized by utility (Fig. 14.19):

- *Anesthesia:* syringes and cartridges of anesthetic
- *Retractors:* for cheeks, tongue, and soft tissue
- *Incision:* scalpels and blades
- *Exodontia:* peritomes, elevators, and forceps
- *Bone modification:* rongeurs, burrs, bone files, chisels, and mallet
- *Osteotomy development:* implant drills, motors and handpieces, and osteotomes
- *Soft tissue manipulation:* scissors and tissue forceps
- *Suturing:* sutures, needle holders, scissors, and tissue forceps
- *Irrigation:* syringes and solution
- *Suction:* Suction tips
- *Miscellaneous:* bowls, mouth props, gauze, tile clips

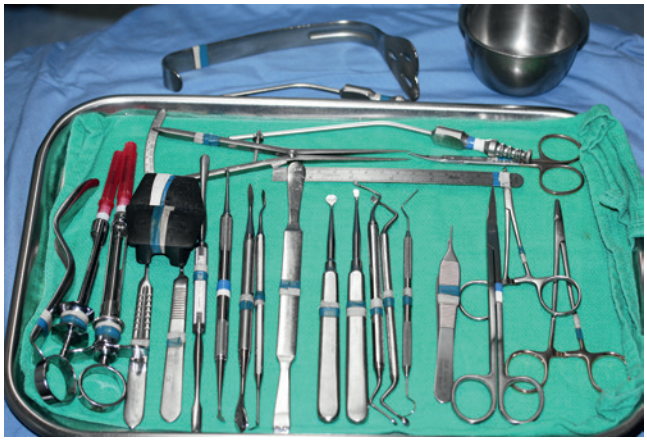
Each of the listed categories has many uniquely designed instruments. Often, the surgeon specifies which design of a specific type of instrument he or she prefers.

Surgical Preparation

Surgical procedures always start with detailed surgical preparation. Preparation for implant surgery requires a thorough review of the patient's chart, including medical and dental histories, operatory notes, radiographs, anticipated implant sizes and locations, surgical guides, surgical sequencing and strategy, possible complications, patient management, anesthesia, operating time, instrumentation, postoperative management, and restorative plan. Preoperative antibiotic prophylaxis is sometimes recommended. An oral dose of 2 g amoxicillin 1 hour preoperatively or, in patients unable to take oral medications, cefazolin 1 g or ampicillin 2 g intramuscularly or intravenously 1 hour before the dental procedure are effective. Alternative medications include 600 mg of clindamycin orally or intravenously. No postoperative antibiotic administration is necessary.



• **Fig. 14.18** Anterior surgical guide. (A) Computer image showing three-dimensional reconstruction of the anterior maxilla and cross-sectional view with proposed implant placement. (B) Computer-generated surgical guide in place. (C) Drill position and angulation determined by the surgical guide. (D) Implant in place.



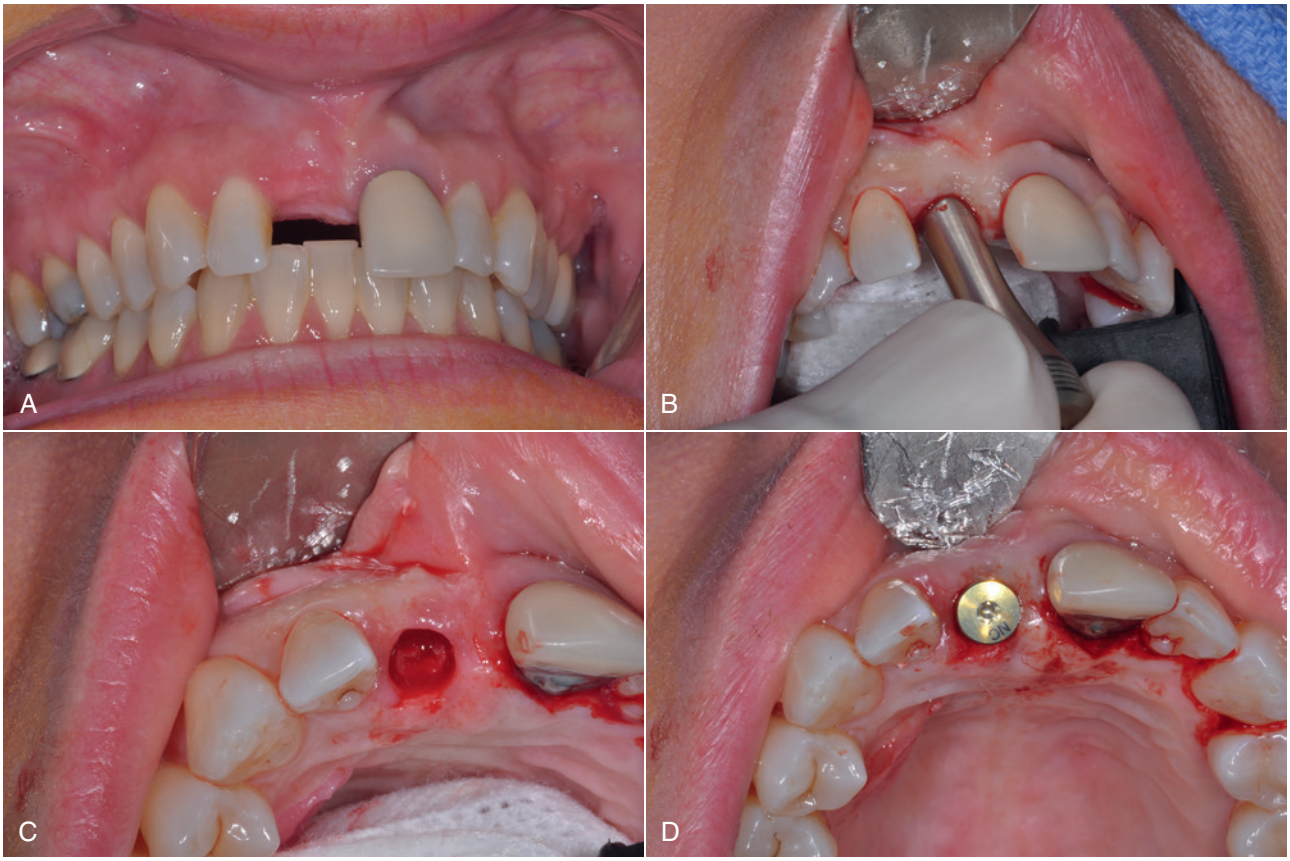
• **Fig. 14.19** Typical surgical instrument tray set up for implant placement.

Once the patient has been draped in a sterile fashion and the surgical team has been gloved and gowned, the patient is anesthetized. In many cases, the implants can be placed using local anesthetic block or infiltration techniques. However, in more complex and lengthy procedures, some type of sedation or general anesthesia may be preferred. Local anesthetics containing vasoconstrictors are usually used for hemostasis. Additional long-acting anesthetics for postoperative pain control may be warranted. It is imperative to have good access to the operative site via effective retraction of cheeks and the tongue. A mouth prop is invaluable.

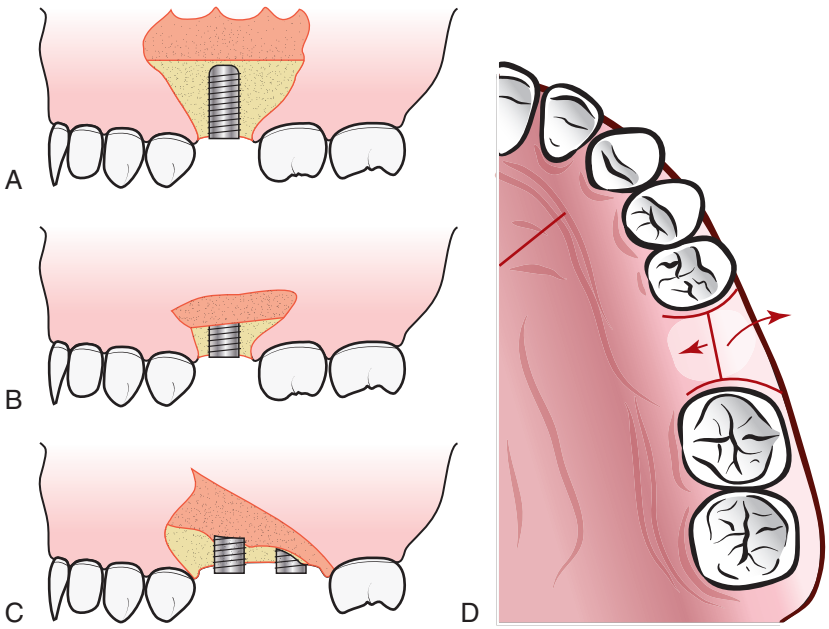
Implant Site Exposure

Exposure of the implant site can be accomplished in several ways, including flapless surgery or with tissue elevation that may include sulcular, midcrestal, and vertical releasing incisions. Flapless surgery may be indicated when there is adequate keratinized tissue over an ideal ridge form (Fig. 14.20). This creates the least soft tissue trauma and may provide the best postoperative esthetics in patients with excellent presurgical anatomy and papilla shape. In flapless surgery, the implant and the healing or provisional restoration are placed in a single stage.

When a flap is required, the incision should be designed to allow convenient retraction of soft tissue for unimpeded access for implant placement (Fig. 14.21). This is usually necessary when better access and visualization of the underlying bone is necessary



• **Fig. 14.20** Flapless surgery. (A) Preoperative view. (B) Tissue is excised in the exact diameter of the implant to be placed using a tissue punch. (C) Tissue removed. (D) Implant placement.



• **Fig. 14.21** Various incision designs. (A–B) Papilla-sparing midcrestal incision, conservative release. (C) Incision with more generous anterior-releasing incision. (D) Mesial- and distal-releasing incision providing more generous exposure.

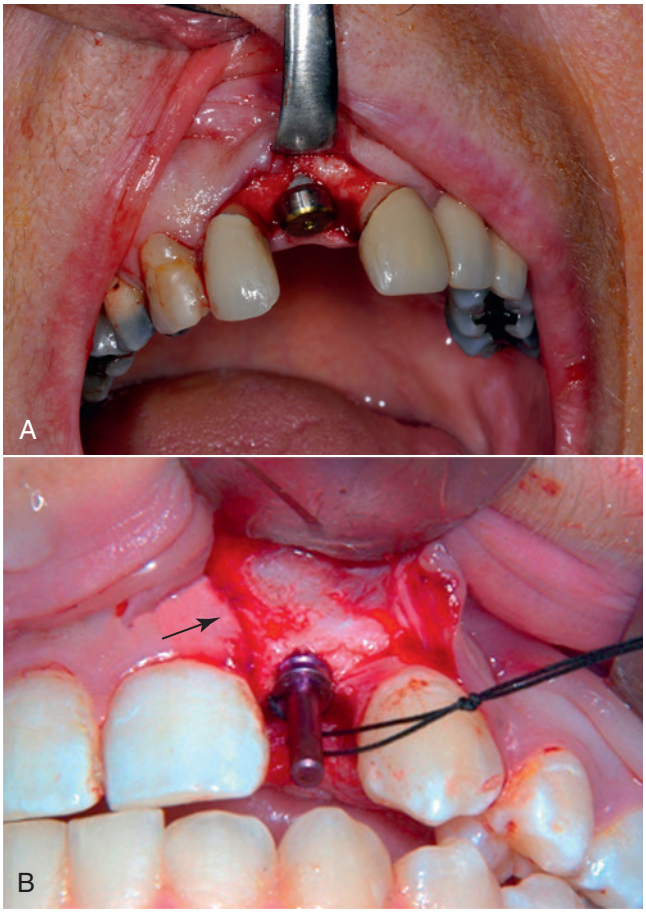
and when additional procedures such as bone or soft tissue grafting are done at the time of implant placement.

- *Midcrestal incision:* The incision should be made through the keratinized tissue, being sure to place the blade up against the mesial-distal surfaces of the teeth adjacent to the edentulous space. In areas with a narrow zone of keratinized tissue, the incision can be made slightly to the palatal or buccal aspect to allow for keratinized tissue transfer to the buccal or facial aspect and better soft tissue closure. If sulcular incisions are necessary, great care is taken to follow the contour of the sulcus so as not to damage the soft tissue architecture.
- *Vertical releasing incision:* Using a sharp no. 15 blade, a curvilinear, beveled (~45 degrees), papilla sparring incision should be made to reduce or eliminate incision scarring. It must be ensured that the vertical releasing incision is extended apically enough to allow complete release of the flap.

Implant Placement

Flap Reflection

- Reflection at the papilla is initiated with a periosteal or Molt elevator, using gentle, well-directed, controlled pressure. The periosteal elevator's edge can be used in a "light painting stroke" to cleanly release the subperiosteal fibers. At this point, the flap is developed from the papilla up along the vertical release.
- The dissection is then directed along the sulcular tissue to the point where it meets the crestal portion of the incision. The index finger of the opposing hand supporting the facial aspect of the ridge allows greater control and protection of the flap during reflection.
- The reflection is continued by the elevation sulcularly to the distal extent of the incision.
- Once the buccal flap is reflected, the palatal or lingual flap can be reflected enough to visualize the width of the ridge. Any soft tissue tags should be carefully removed.
- When the buccal flap has been reflected completely, a retractor can be positioned against the bone inside the flap. This allows good visualization of the operative site while protecting the integrity of the flap (Fig. 14.22). It is extremely important to avoid inadvertent trauma to the flap with the tip if the retractors.



• **Fig. 14.22** Typical examples of flap reflection for exposure to the implant site. (A) Without releasing incisions. (B) With releasing incisions *(arrow)*.

Preparing the Osteotomy

- The surgeon must confirm that the handpiece and motor are functioning properly: the speed setting on the motor should be checked; it must be confirmed that the drill is spinning in the forward mode. The speed should be set to the appropriate speed as recommended by the manufacturer of the implant system being used.
- All drills, including osteotomy drills, should be copiously irrigated internally, externally, or both when preparing the bone.
- The depth indicator markings on the precision and pilot drills should always be reviewed.
- The entry point and its ideal angulation should be determined with the precision drill. The proper angulation should be verified from different vantage points. A surgical guide is usually used to facilitate orientation.
- Drilling is done with the precision drill at full speed to a depth of 1 to 2 mm short of the depth of the intended implant (e.g., 8 mm deep for a 10-mm implant).
- The area is irrigated and the 2-mm pilot drill positioned in the exact same location after verifying the correct angulation. Once position and angulation are confirmed, the 2-mm pilot drill is run at full speed to the intended depth of the implant (e.g., 10 mm deep for a 10-mm implant).
- The area is rinsed, and the guide pin that corresponds to the intended final size of the planned implant is placed. Use of the guide pin allows the surgeon to evaluate the position, spacing, and angulation of the developing osteotomy. It also helps evaluate where the pin lines up against the opposing dentition.
- The surgeon then determines the location on the twist drill that corresponds to the intended platform position of the implant to the ridge. Typically, the top of the platform would be even with the mesial and distal bone height.
- The tip of the narrowest twist drill is placed into the pilot hole, and the correct position and angulation of the drill are verified. Once confirmed, the drill is run at full speed in a gentle pumping motion. It may be necessary to remove the drill and clean the accumulated bone off the drill. The osteotomy is rinsed, and the drill is then repositioned and the angulation confirmed. The drill is again run at full speed and taken to the final depth of the intended implant. The site is sequentially prepared in this manner.
- The osteotomy is rinsed, and the appropriate guide pin is placed to reevaluate position and alignment.
- The tip of this final twist drill is placed into the opening of the osteotomy; then its position and angulation are verified. Great care is taken to achieve perfect position and angulation, as this is the drill that finalizes the osteotomy.

- Once the drill is properly positioned, it is run at full speed in a gentle pumping motion to the final depth of the intended implant. The osteotomy is then inspected with a thin instrument for possible bone perforation (e.g., sinus communication or buccal wall perforation).
- Immediately after completing the osteotomy, the speed of the motor is changed to the desired and/or recommended torque, measured in newton centimeters (Ncm—typically around 30 Ncm) for the insertion of the implant. If the speed is not changed and the implant is put in at the original setting of 800 to 1500 rpm, the osteotomy could easily be damaged, the implant seated too deep, or primary stability lost (Fig. 14.23).

Inserting Implant

- The implant is opened and placed on the driver that has been inserted into the handpiece. The handpiece must be held such that the tip of the implant is pointing up. This will lessen the likelihood of the implant falling off the driver.
- The tip of the implant is inserted into the osteotomy, and the position and angulation are verified again. The implant is driven into position by keeping light pressure in an apical direction until the implant is almost completely seated or until the motor torques out (approximately 1 to 2 mm short of complete seating).
- Using the hand torque wrench, the surgeon continues to seat the implant, using the torque lever of the wrench to quantify the amount of torque present. If the torque exceeds the lever, the implant is hand torqued to its final position by using the handle of the torque wrench.
- The seating of the implant is finalized by verifying that the platform is even with the mesial and distal heights of bone and that any orientation marker is pointed in the correct position.
- The area is irrigated thoroughly.
- It should be determined if there will be a single- or two-stage healing period. This is determined by the torque value measured on the surgical motor or the hand torque wrench. An implant with a torque value of 35 Ncm or greater is considered to have good primary stability, and single-stage healing is possible. If so, an appropriate-sized healing abutment is placed. If a two-stage process is required, then an appropriate-sized cover screw is placed.
- The abutment should protrude 1 to 2 mm through the tissue. A tapered abutment rather than a parallel abutment must be determined. The intended tissue emergence of the planned restoration helps determine whether the healing abutment is tapered or parallel.
- The healing abutment is placed onto the insertion wrench, again by holding the screw pointing up. The abutment is screwed into the implant and tightened with finger pressure, making sure that no tissue is caught under the abutment.

Suturing Flap

- The flap is sutured using some type of resorbable suture (chromic gut or Vicryl) or nonresorbable suture (proline).
- The anterior papilla is secured first. The buccal aspect of the papilla is entered with the suture needle, which is passed through the embrasure to engage the palatal tissue. The needle is then positioned lower on the palatal tissue and penetrated and brought through the embrasure to the buccal and the papilla engaged apically to the first entry point.
- The vertical release is then sutured, followed by the mesial and distal sides of the abutment. These are simple interrupted sutures tied in the same fashion as the first suture described.

Postoperative Management

A radiograph should be taken postoperatively to evaluate the position of the implant in relation to adjacent structures such as the sinus and the inferior alveolar canal and relative to teeth and other implants. This radiograph also serves to verify the complete seating of the cover screw or healing abutment.

Patients should be given analgesics. Mild to moderate strength analgesics are usually sufficient. Antibiotics are often given prophylactically before surgery but are usually not required in the postoperative period. Patients may also be instructed to use 0.12% chlorhexidine gluconate (Peridex) rinses for 2 weeks after surgery to help keep bacterial populations at a minimum during healing. The patient is evaluated weekly until soft tissue wound healing is complete (approximately 2 to 3 weeks). If the patient wears a tissue-borne denture over the area of implant placement, the denture can be relined with a soft liner after 1 week. Interim partial dentures or orthodontic retainers with an attached pontic may be worn immediately but must be contoured to avoid soft tissue loading over the implant site.

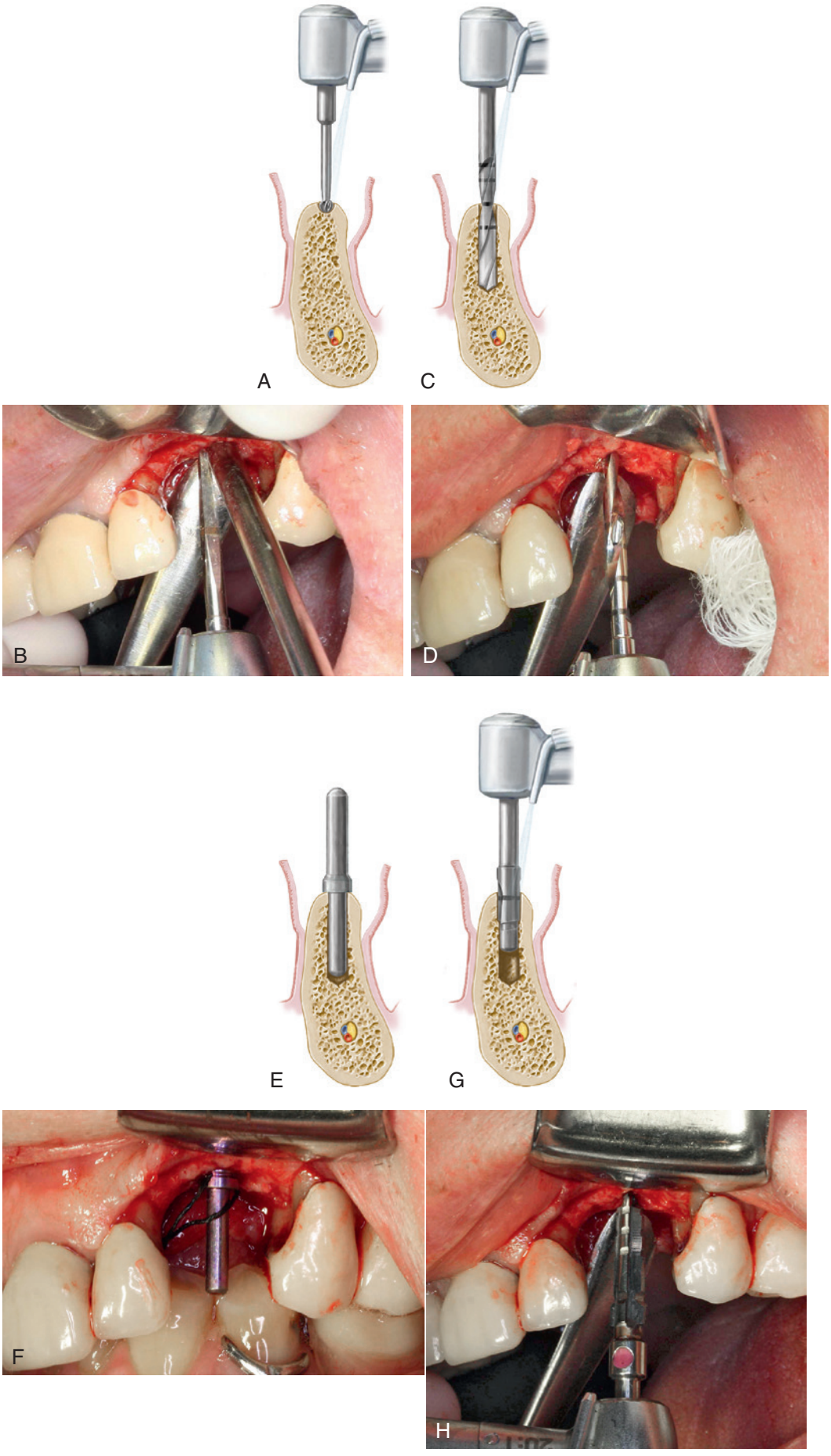
Uncovering

The healing time or the length of time necessary to achieve osseointegration varies from site to site and from patient to patient. Insertion torque values, quality of bone, bone grafts, patient health, location, number of implants, and soft tissue health all have an impact on healing time. Typical healing times are 4 to 6 months.

In single-stage surgery, no surgical uncovering is necessary. The implant stays exposed via the healing abutment after surgery and throughout the healing phase. After an appropriate integration time, restoration of the implant can proceed.

In a two-stage system, the implant must be surgically uncovered and a healing abutment placed. The goals of surgical uncovering are to attach the healing abutment to the implant, preserve keratinized tissue, and modify the form or thickness of tissue. A soft tissue healing period after uncovering must be allowed before restoration of the implant can take place, typically 2 to 4 weeks.

The simplest method of surgical uncovering is the "tissue punch" (Fig. 14.24). This method of uncovering utilizes a soft tissue punch equal to or slightly larger than the diameter of the implant placed. The implant is palpated through the tissue to determine its location. The tissue punch is placed directly over the implant circumference and twisted through the soft tissue thickness, taking care not to damage the bone at the level of the implant platform. The punch is then removed, along with a precisely determined piece of tissue that was lying directly above the implant, easily exposing the implant cover screw. The cover screw is then removed, and an appropriate-sized and appropriate-shaped healing abutment is placed. The advantage to this technique is that it is less traumatic, no periosteum needs to be reflected, and only a short soft tissue healing time is required. This technique does, however, require an adequate zone of keratinized tissue so that the implant can be accurately located. Disadvantages to this technique include sacrifice of a portion of the keratinized tissue, inability to visualize the bone surrounding the implant, and the inability to directly visualize the precise abutment–implant interface.



• **Fig. 14.23** Typical implant site preparation and placement. (A–B) Initial marking or preparation of the implant site with a round burr. (C–D) Use of a 2-mm twist drill to establish depth and align the implant. (E–F) Guide pin is placed in the osteotomy site to confirm position and angulation. (G–H) Pilot drill is used to increase the diameter of the coronal aspect of the osteotomy site.

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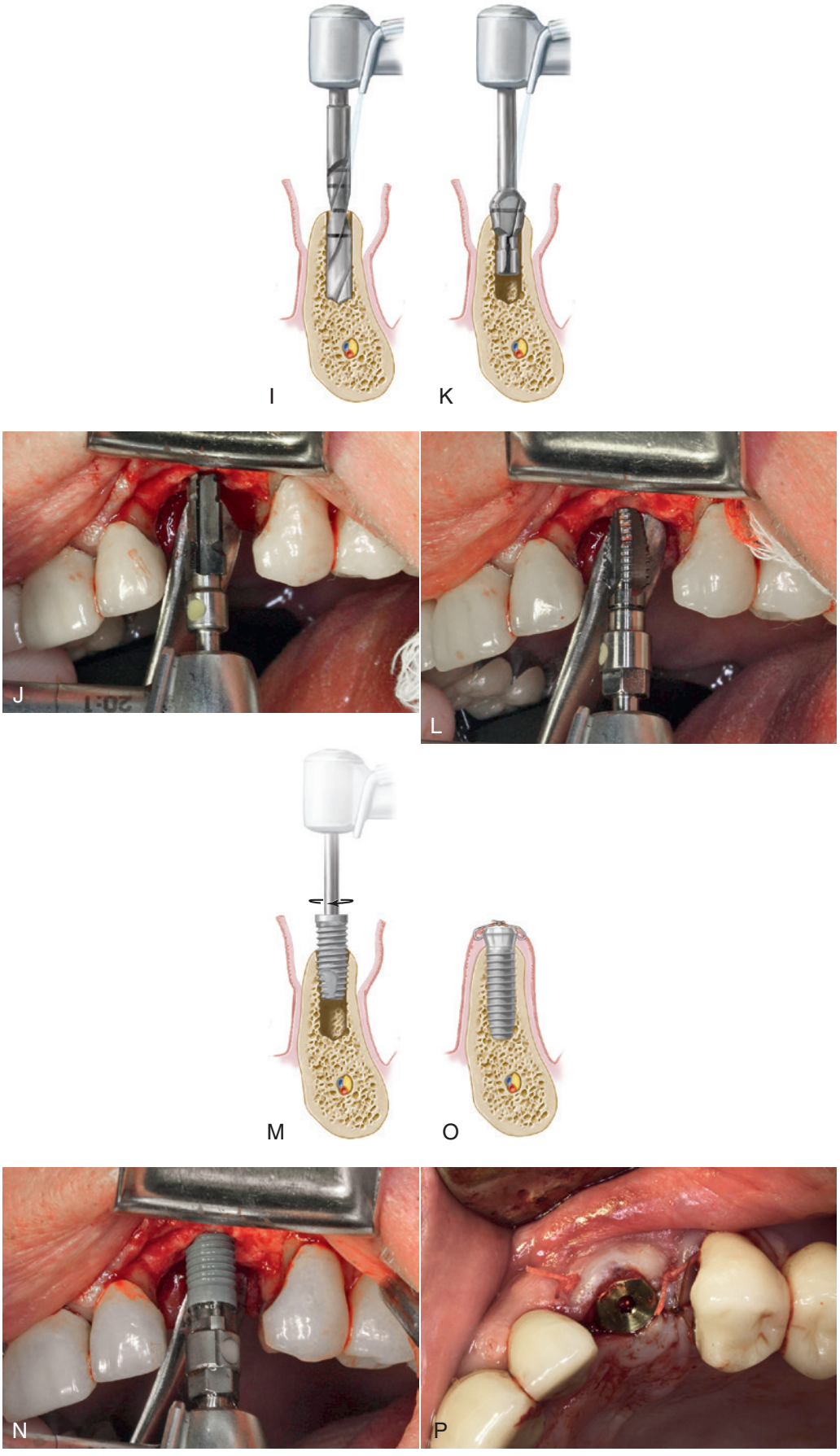
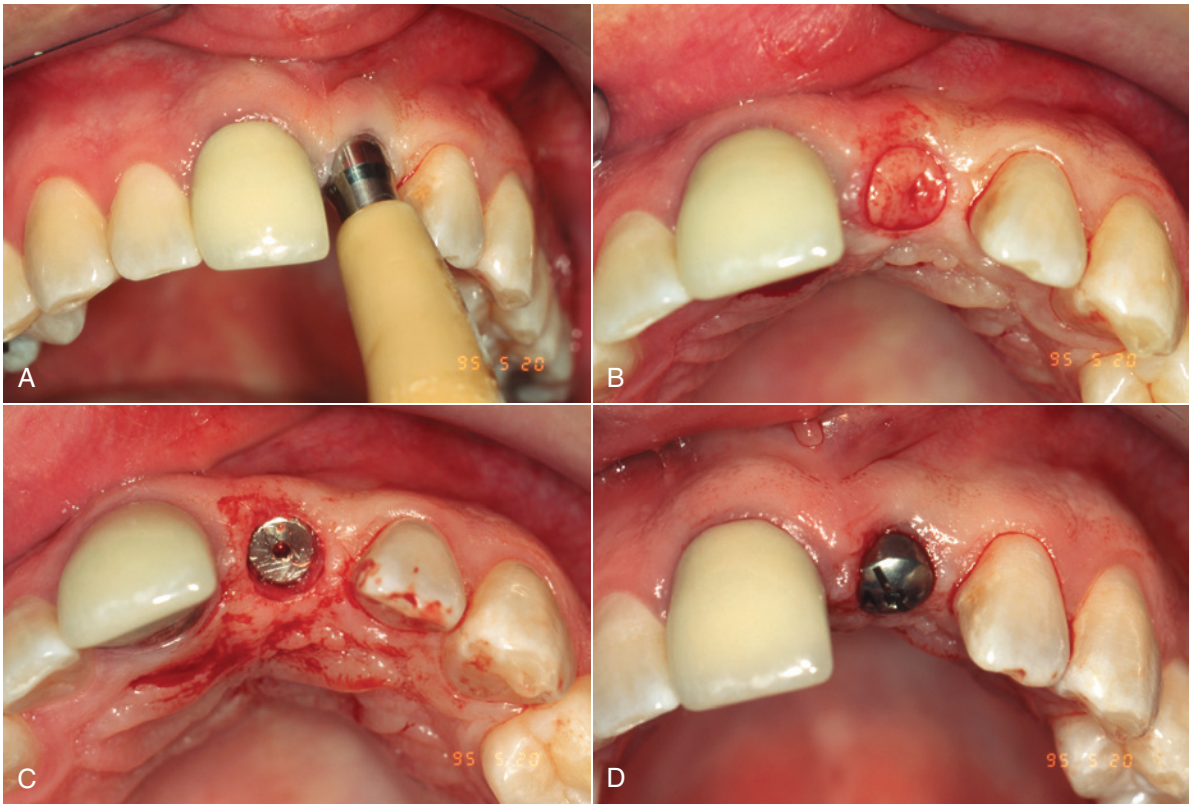
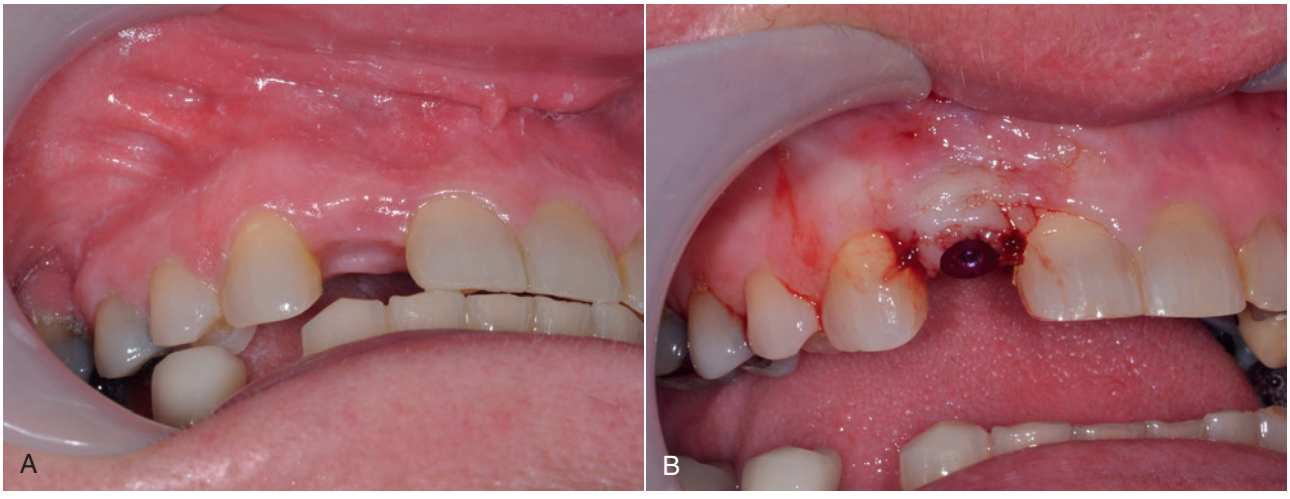


• **Fig. 14.23, cont'd** (I–J) Final drill used is the 3-mm twist drill to finish preparation of the osteotomy site. (K–L) Countersink drill is used to widen the entrance of the recipient site and allow for the subcrestal placement of the implant collar and cover screw. An optional tap (not shown) can be used after this step to create screw threads in areas of dense bone. (M–N) Implant is inserted into the prepared osteotomy site with a handpiece or handheld driver. *Note:* In systems that use an implant mount, it would be removed prior to placement of the cover screw. (O–P) Cover screw is placed and soft tissues readapted and sutured. (From Newman MG, Takei HH, Klokkevold PR, et al. *Carranza's Clinical Periodontology.* 11th ed. Philadelphia: Elsevier; 2012.)



• **Fig. 14.24** The simplest method of implant uncovering is the tissue punch. This method of uncovering is easy to perform, only minimally disturbs the tissue surrounding the implant, and produces minimal patient discomfort. To use this technique, the implant must be located with certainty below the tissue.



• **Fig. 14.25** Second-stage exposure of implant with a small tissue flap. (A) Prior to uncovering. (B) After small flap elevation, the tissue is recontoured and sutured to maintain adequate keratinized tissue around the implant.

If the implants cannot be accurately located, if the clinician needs to visualize underlying bone, or if a slight keratinized tissue transfer is indicated, then a crestal incision with the creation of a slight soft tissue flap is required to uncover the implants. If an adequate zone of keratinized tissue is present, the soft tissue flap can be contoured with a scalpel, scissors, or a punch to conform to the shape of the healing abutment (Fig. 14.25). This allows for a nicely shaped and contoured soft tissue cuff around the healing abutment and eventually the final implant restoration. Obvious advantages to this technique include easy access, minimal invasiveness, and ability to directly visualize the bone surrounding the implant and to precisely fit the healing abutment to the implant platform. The disadvantage to reflecting a flap during uncovering is the possibility of bone loss due to stripping the periosteum from bone during the uncovering. Advanced techniques for cases with an inadequate zone of attached tissue include tissue transfer

procedures, tissue grafting, and split-thickness apically repositioned flaps.

Implant Stability

Initial implant stability is one of the most important predictors of long-term implant success. This depends on the depth and density of bone, implant size, and precision of the surgical technique. A good sense of implant stability can be obtained during the seating process and by verifying adequate torque resistance capability of the seated implant.

Radiofrequency analysis has been used to measure and verify implant stability. This technology involves attaching a transducer to an implant and applying a steady-state resonance frequency to the implant. The advantage of this technology is that it is not dependent on measuring implant movement in just one direction but rather by evaluating the complete bone-implant interface.[10]

Complications

Implant placement surgery can be performed with great accuracy and with little complication if the case has been diagnosed, planned, and surgically performed well. However, as with any surgical or clinical procedures, complications are possible and include the following:

- Complications that can occur with any surgical procedure, including pain, bleeding, swelling, or infection.
- A positioning error resulting in implants placed at a compromised angulation or position. The implant may be placed too close to an adjacent tooth root or too far to the mesial, distal, or buccal aspect, thus compromising bony support. The implant can be placed too far into bone, making prosthetic access difficult. If the implant is not placed deep enough into bone, leaving threads of the implant body above the osseous crest, there will be compromise to bony support, soft tissue health, hygiene, and esthetics.
- Surgical technique complications such as a tear of the soft tissue flap, poor closure of the incision, or excessive soft tissue trauma from retraction may result in tissue dehiscence, infection, and eventual loss of the implant. Poor attention to detail in preparation of the osteotomy such as overdrilling the diameter of the osteotomy could result in poor prognosis for integration.
- Invasion of critical anatomic structures can create more serious complications. If the implant invades or impinges on the canal of the IAN, this may result in paresthesia (altered sensation that the patient does not find painful, e.g., numbness, tingling), or dysethesia (altered sensation that the patient finds painful or uncomfortable). If the implant invades the maxillary sinus or the nasal cavity, this may result in an infection. Bone structure compromise can present as overthinning of the buccal or facial plate or dehiscence or fenestration of overlying tissue. Bone perforation can occur at the inferior border of the mandible because of inaccurate drilling depth or on the lingual aspect of the posterior mandible because of the lingual undercut from poor positioning or angulation of the implant drills.
- Mechanical complications can present as an implant platform fracture because of excessive insertion torque. If the osteotomy is improperly prepared in dense bone, it is possible to get the implant "stuck" in bone, short of complete seating, making it extremely difficult to retrieve the implant.
- Incision line opening can occur from inadequate suturing or not having tension-free closure.
- Esthetic complications can occur from poor implant positioning or angulation, making proper prosthetic restoration unrealistic.

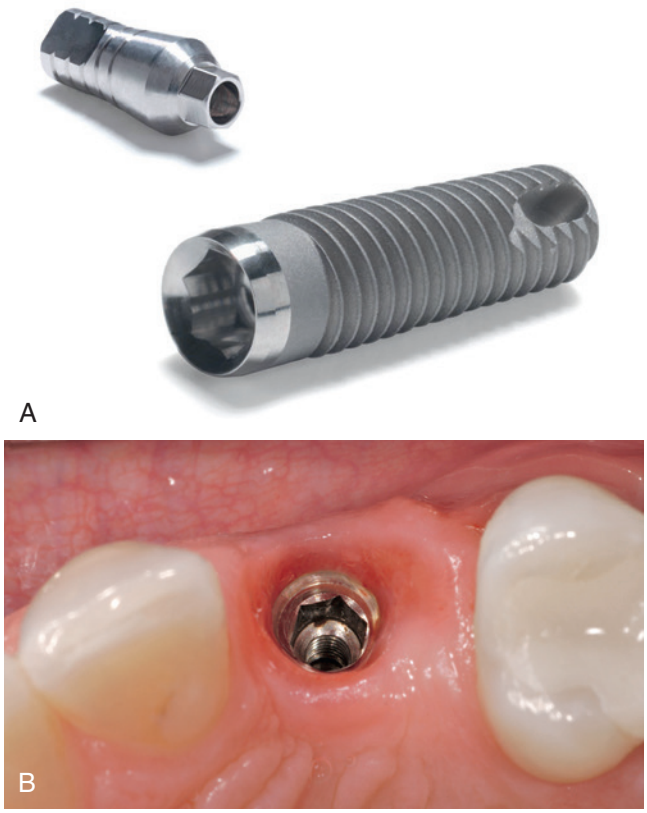
Implant Components

Successful surgical placement and proper healing typically result in an osseointegrated implant ready for prosthetic restoration. Contemporary dental implants have an internally threaded portion that can accept second-stage prosthetic components, allowing the restoring clinician to assemble a restorative platform. Implant restorations require the use of several component parts. For the inexperienced implant clinician, the sheer number of parts, as well as the infinitely unique restorative needs presented by patients can be overwhelming. This section describes, in generic terms, the component parts typically used in the restoration of dental implants. It should be noted that the component nomenclature may differ from one manufacturer's implant system to that of another, but conceptually, the components have similar purposes.

Implant Body or Fixture

The implant body, or fixture, is the implant component placed within bone during the first stage of surgery. Most contemporary implant fixtures are referred to as *root form implants*, taking the form of a cylinder or a tapered cylinder, and are made of titanium or titanium alloy (Fig. 14.26). Most current implant fixtures have an external threaded design, although historically, there have been smooth-surfaced implants that were pressed into position. A wide variety of external thread designs and different surface textures and coatings that attempt to maximize implant stability and the process of osseointegration have been offered by manufacturers. Most implant fixtures incorporate an antirotational design feature at the interface of the adjoining prosthetic components. This

• **Fig. 14.26** Typical root form implant. (Courtesy Zimmer Dental Inc., Carlsbad, CA.)



• **Fig. 14.27** Internal antirotation hex. (A) Internally hexed Zimmer implant and titanium abutment. (B) Intraoral view of an internally hexed Zimmer implant after removal of the healing abutment. (A, Courtesy Zimmer Dental Inc., Carlsbad, CA.)

antirotational feature may be located internally or externally to the implant platform (Fig. 14.27).

The overwhelming majority of implants are referred to as *two-stage implants*, that is, the surgically placed fixture is the first stage, and the screw-in prosthetic components are the second stage. The second-stage components attach to the implant body via an internally threaded feature within the implant body. There are, although in a much smaller number, one-piece implants (one-stage implants) that have the threaded portion housed in bone and the prosthetic abutment together as one unit. It is important to recognize the difference between a two-stage implant and a two-stage surgical approach. A two-stage implant with a healing abutment can be placed in a one-stage surgical approach or with a cover screw in a traditional two-stage surgical approach. All one-piece (one-stage) implants are placed in a one-stage surgical approach (Fig. 14.28).

Cover or Healing Screw

After placement of the implant fixture in a two-stage surgical approach, prior to suturing, the implant fixture is sealed at its platform with a low profile, intraimplant cover screw. It is important that the surgeon be sure that the cover screw is fully seated on the implant platform prior to suturing the flap to prevent bone from growing between the screw and the implant. In the second-stage uncovering procedure, the cover screw is removed and replaced with a healing abutment.

Healing or Interim Abutment

Healing abutments are dome-shaped intraimplant screws that provide permucosal access to the implant platform. Healing abutments are placed at the completion of the implant placement surgery in a one-stage surgical approach or after uncovering in a two-stage surgical approach. Healing abutments are made of titanium or titanium alloy. The abutments can be parallel walled or tapered and range in height from 2 to 10 mm. The height of the abutment used is determined by the thickness of tissue present. The healing abutment should project 1 to 2 mm superior to the height of the gingival tissue (Fig. 14.29). A tapered healing abutment is used to help shape soft tissue to a more appropriate emergence for the planned restoration (e.g., a crown). A parallel-walled abutment would be used where the tapered emergence is not necessary (e.g., a retentive bar for an overdenture). It is important to allow for sufficient healing of soft tissue after placing the healing abutment prior to making any impressions for the final prosthetics.

Impression Coping

Impression copings facilitate transfer of the intraoral location of the implant to the same position on the laboratory cast. Impression copings can be either screwed into the implant body or screwed or snapped onto an implant abutment. Some impression copings have a flat side that acts to orient the threads or the antirotational design of the implant (e.g., hexagon or trilobe). This is important when using stock-type abutments or components (Fig. 14.30). Typically, the impression transfer can be either closed-tray transfer or open-tray transfer. The closed-tray technique captures the index of the impression coping, and after the impression is removed from the mouth, the impression coping is unscrewed from the implant and placed along with an implant analog back into the impression. An open-tray transfer uses a specific impression coping that is designed to emerge through the impression tray. When the impression is ready to be removed from the mouth, the impression coping is unscrewed and pulled out in the impression. The open-tray method is considered the more accurate transfer method and is indicated when large-span frameworks or bar structures are planned or when the implants are too divergent to easily remove the impression tray in the closed-tray technique. A heavier-bodied polyvinyl siloxane or polyether impression material is recommended. Prior to making the transfer impression, it is imperative that the clinician take a radiograph to confirm that the impression coping is accurately seated on the implant platform. If the impression coping is not properly seated, the accuracy of the transferred location of the implant will be incorrect. On completion of the transfer impression, an implant analog is screwed onto the impression coping to allow the fabrication of a laboratory cast.

Implant Analog or Replica

Implant analogues are manufactured to replicate exactly the top of the implant fixture (fixture analog) or abutment (abutment analog) in the laboratory cast. Both are screwed directly into the impression coping. The impression coping or analog component is then placed back into the impression (closed-tray transfer) or is maintained in the impression (open-tray transfer), and the impression is ready to be poured. It is tremendously beneficial to create a soft tissue moulage in the impression prior to pouring. The soft tissue moulage is an elastomeric product that simulates the soft tissue portion on the dental cast. This allows the laboratory

• **Fig. 14.28** Single-stage and two-stage implants. (A) Two-piece implant and abutment *(top)* and a one-piece implant *(bottom)* (Zimmer). (B) One-piece implant (Nobel Biocare). (C) One-piece implant replacing tooth #24. (D) The final restoration of the implant replacing tooth #24. (A, Courtesy Zimmer Dental Inc., Carlsbad, CA. B, Courtesy Nobel Biocare USA, Yorba Linda, CA.)

technician to have an accurate and flexible representation of soft tissue. The laboratory technician then has a working model that can be used to fabricate either the abutment or the framework for the intended prosthetic design.

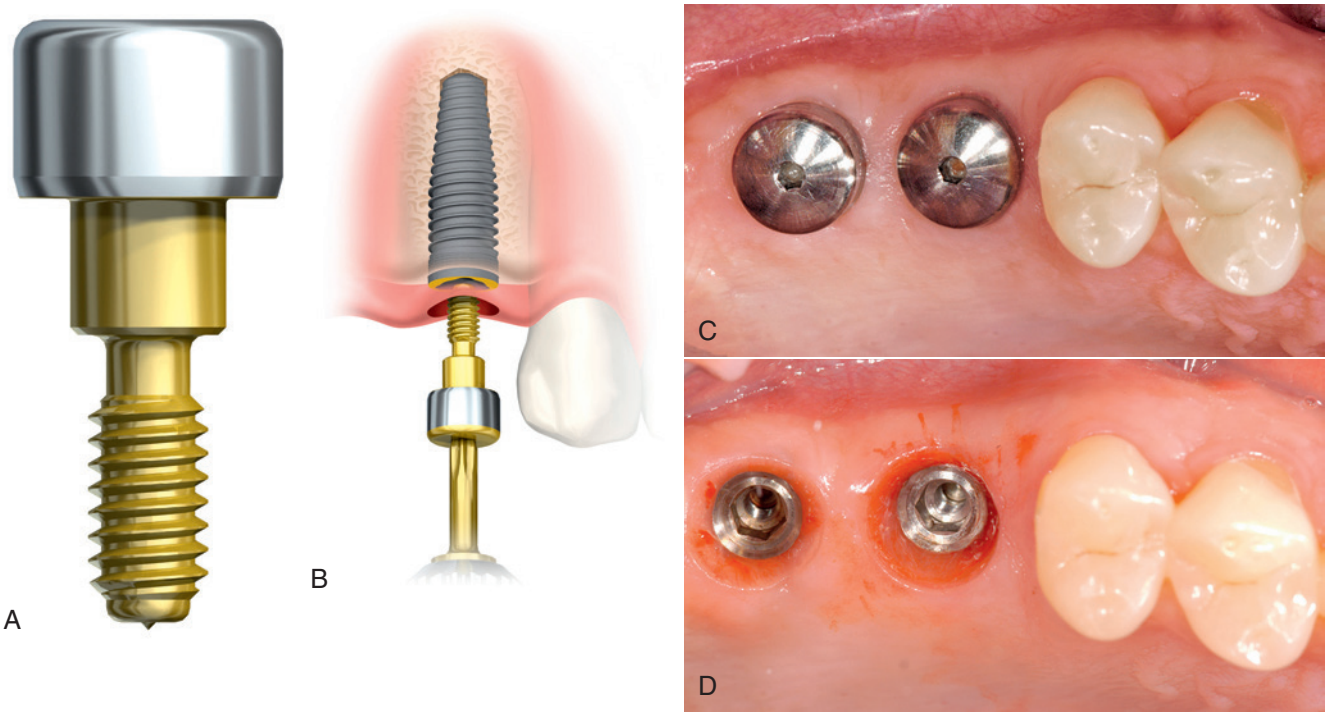
Implant Abutment

The abutment is the portion of the implant that supports or retains a prosthesis or implant superstructure. A *superstructure* is defined as a metal or zirconia framework that attaches to either the implant platform or the implant abutment(s) and provides retention for a removable prosthesis (e.g., a cast or milled bar retaining an overdenture with attachments) or the framework for a fixed prosthesis. Abutments are described by the method in which the prosthesis or superstructure is retained to the abutment. Abutments can be divided into three main categories: (1) screw retained, (2) cement retained, and (3) prefabricated attachment abutments. A screw-retained abutment uses a screw to retain the prosthesis or superstructure, whereas a cement-retained abutment uses cement to retain the prosthesis or superstructure. A prefabricated attachment abutment (e.g., locator or O-ring attachments) helps retain a removable prosthesis.

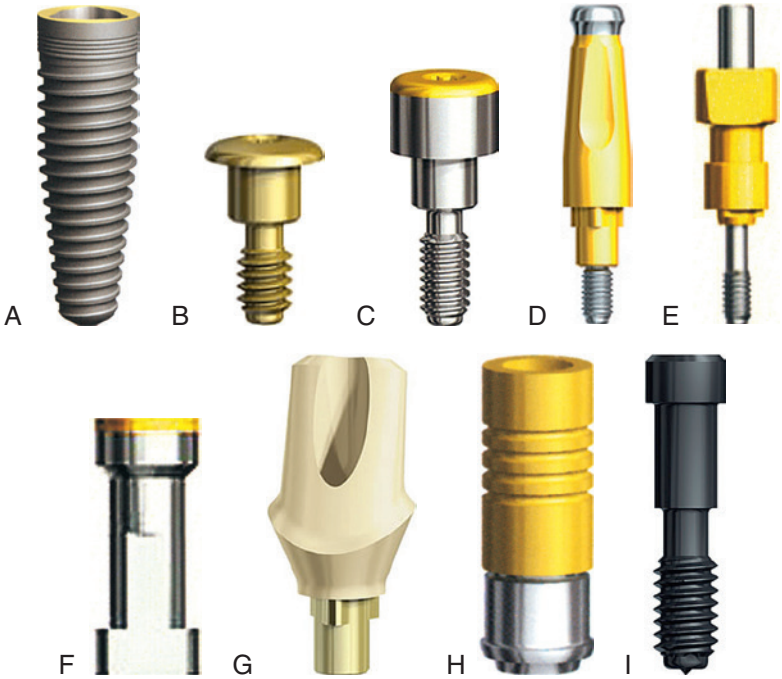
Because of the unique set of circumstances presented by each implant case, manufactures have become very creative in offering many different options within each of the described categories. Today, computer-aided design and computer-aided manufacturing technology is becoming more prevalent. The ability to design an abutment or superstructure specifically for the individual situation and mill that same component with tremendous accuracy in either titanium or zirconium has made a tremendous impact in implant prosthetics.

Prosthesis Retaining Screw

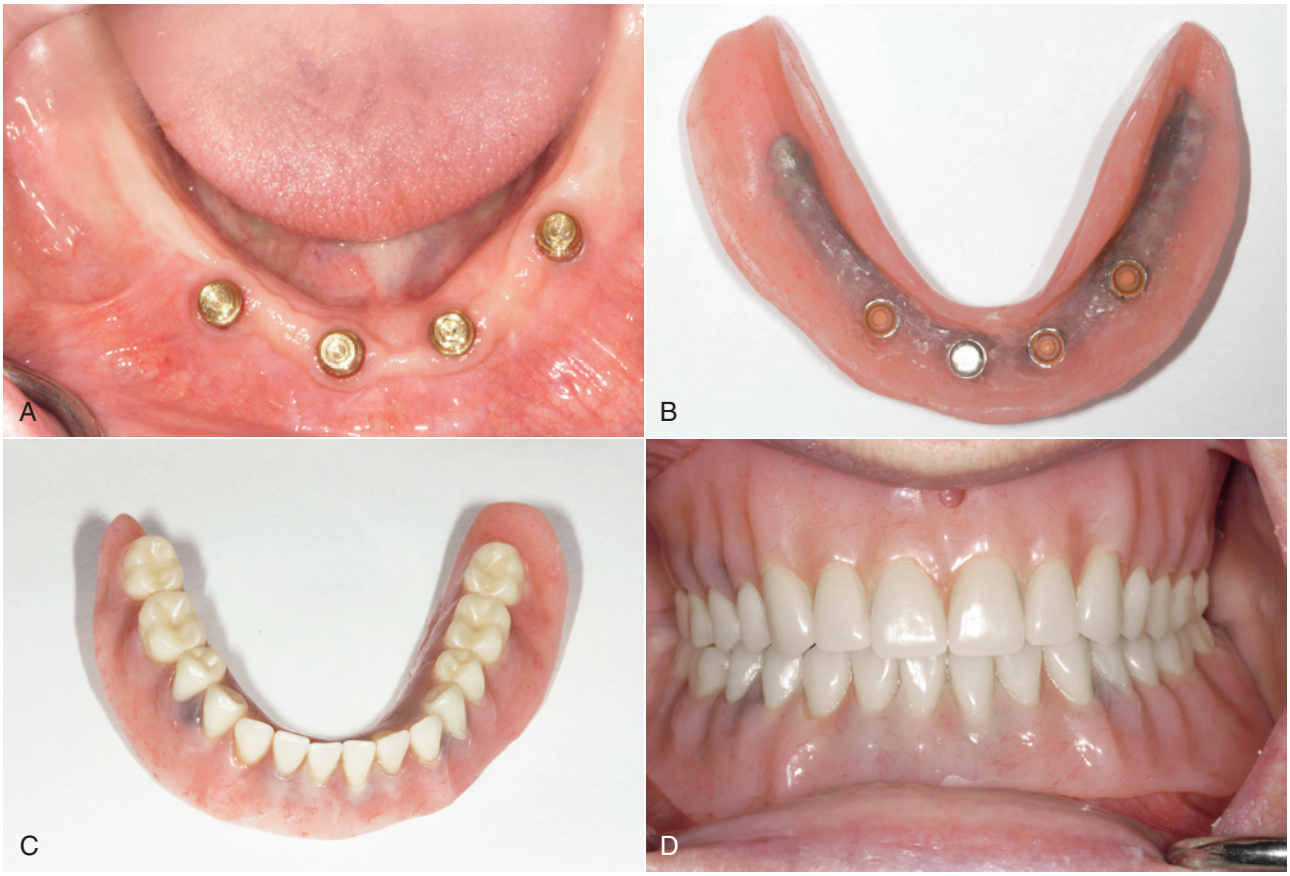
Prosthesis retaining screws are intended to attach prosthetic abutments, screw-retained crowns, or frameworks to the implant fixture



• **Fig. 14.29** Healing abutment. (A) Nobel Biocare healing abutment. (B) A healing abutment being placed into the implant. (C) Two healing abutments in place. (D) Clinical view after the removal of the healing abutment. Note the way the tissue has been shaped by the contour of the healing abutment. (A–B, Courtesy Nobel Biocare USA, Yorba Linda, CA.)



• **Fig. 14.30** Implant restorative components. (A) Implant fixture. (B) Cover screw. (C) Healing abutment. (D) Closed tray impression post. (E) Open tray impression post. (F) Implant analogue. (G) Custom zirconia abutment. (H) Waxable/castable abutment. (I) Prosthetic screw. (Courtesy Nobel Biocare USA, Yorba Linda, CA.)



• **Fig. 14.31** Implant and prosthetic treatment of the edentulous mandible with implant- and soft tissue–supported overdenture. (A) Four implants with locator attachments in place for an implant-retained overdenture. (B–C) The overdenture is reinforced with a cast metal framework. (D) The completed maxillary conventional denture opposed by a mandibular locator-retained overdenture.

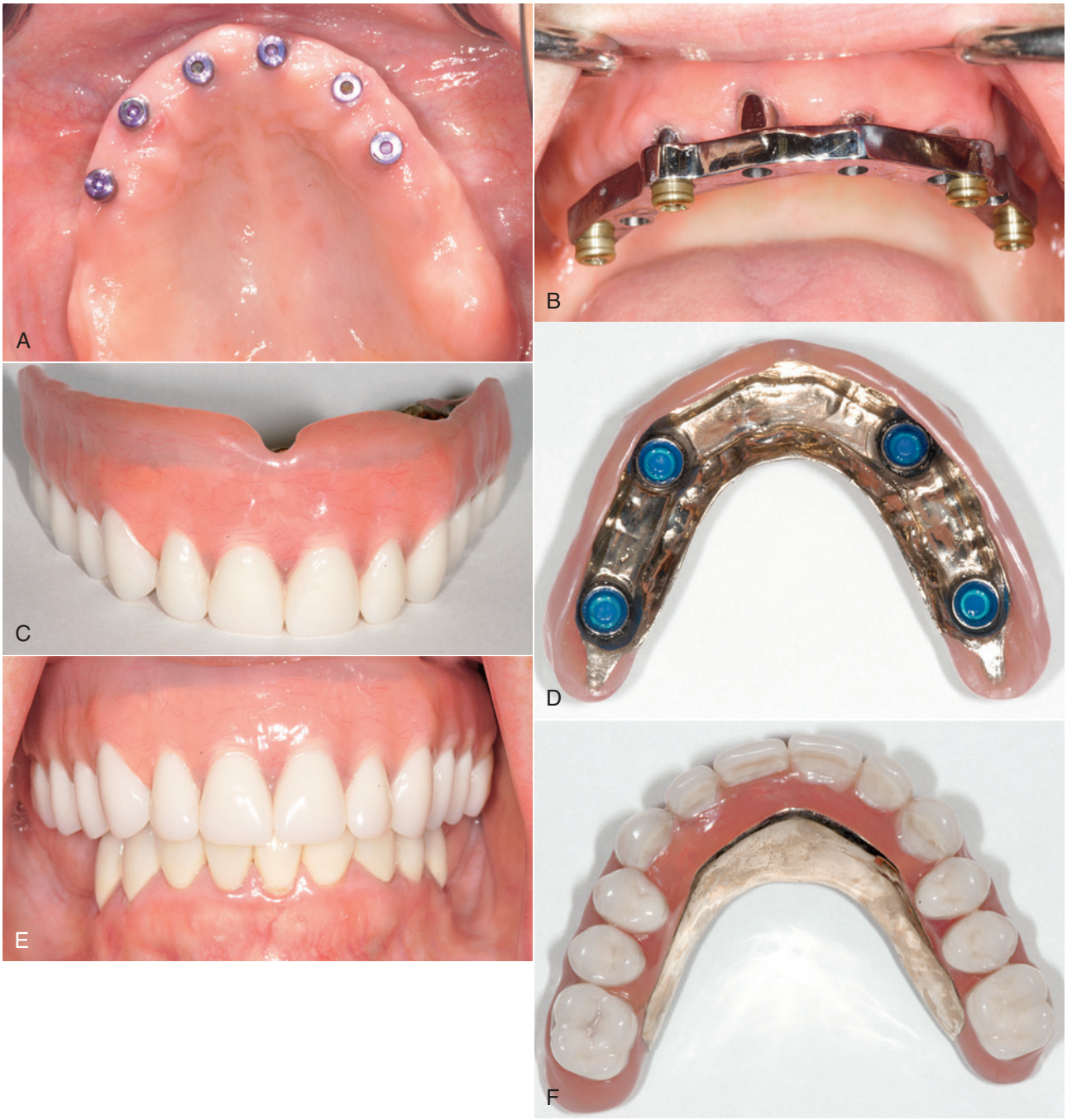
or implant abutment. The screws are generally made of titanium, titanium alloy, or gold alloy and are sized specific to the type, size, and design of the implant or abutment system. The screws typically have a hex or square design to accept a specific size and shape of wrench or driver. Most prosthesis screws are tightened to specific tolerance by a torque wrench or handpiece. The torque value is measured in newton centimeters and typically ranges from 10 to 40 Ncm.

Implant Prosthetic Options

Options for the Edentulous Patient

Completely edentulous patients can benefit greatly from an implant-retained or implant-supported prosthesis. Three basic implant options exist for the edentulous patient. The options include (1) the implant and soft tissue–supported overdenture, (2) the all-implant–supported overdenture, and (3) the complete implant-supported fixed prosthesis.

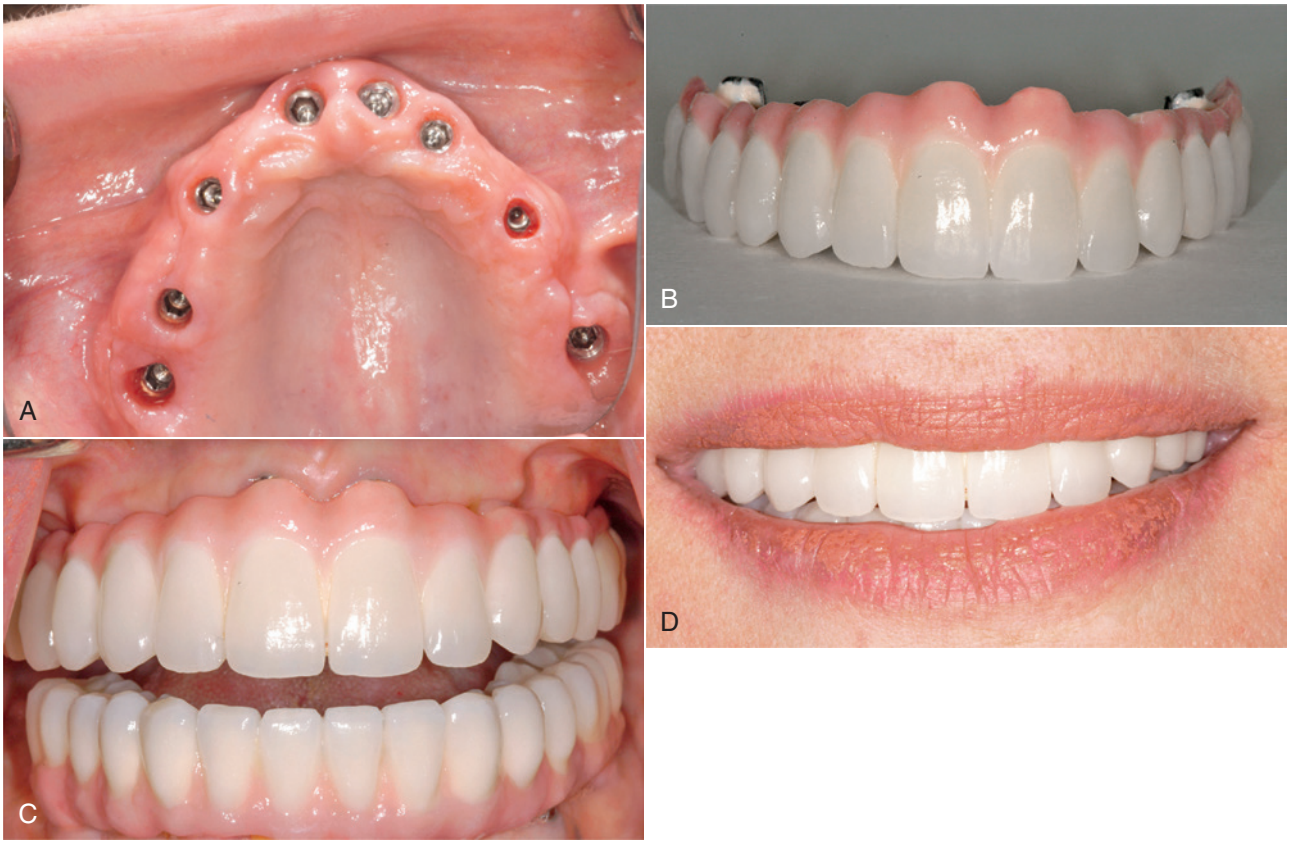
- The implant-supported and soft tissue–supported overdenture can be used in either the maxilla or the mandible, although the mandibular overdenture is typically the most requested. The principle is to have the implants (two to four implants, ideally four in the maxilla) help retain and support the overdenture in conjunction with the soft tissue of the edentulous ridge. In these cases it is imperative to follow strict prosthetic protocol in fabricating an overdenture, ensuring that the prosthesis maximizes the soft tissue support and the patient enjoys the retentive advantage of the implants without overloading the implants and their attachments (Fig. 14.31). Both the clinician and the patient must understand the need to monitor the fit of the overdenture over time. Timely relines to maintain the soft tissue support are extremely important. The attachment assemblies should also be monitored with the attachment inserts replaced regularly to maximize their retentive opportunity. For a maxillary overdenture, it is possible to eliminate the palatal portion of the denture when there are at least four implants present in good quality bone and there is reasonable depth to both the buccal vestibule and the palatal vault. It is recommended that a metal framework be incorporated into the denture bases to add additional strength to the overdentures. With the increased retention and security, patients often are able to engage in much more vigorous functions and can easily fracture an acrylic-only denture base.
- The all-implant–supported overdenture offers the patient increased retention and support with little need for soft tissue support. Typically a minimum of four implants is required for the mandible, and six implants are recommended for the maxilla to support the entire load. The typical design is either a cast or milled bar, with retentive abutments attached to the bar in strategic locations that engage the overdenture (Fig. 14.32). The goal in implant placement and bar fabrication is to maximize



• **Fig. 14.32** Treatment of the edentulous maxilla with all-implant–supported overdenture. (A) Maxilla with six implants. (B) Milled titanium bar with four locator attachments. (C–E) Maxillary overdenture with open palate and internal casting that fits accurately to the milled bar. (F) Final result.

the AP spread of the implants and the bar with its attachments. The advantage of utilizing a bar structure is that its length can be cantilevered up to 1.5 times the AP spread of the implants, thereby providing additional posterior support to the overdenture. In the maxilla with six implants, the design can be one continuous bar or two individual bars, each supported by three implants. The clinician must be aware of the interarch spatial requirement (approximately 15 to 17 mm) for an all-implant–supported overdenture. Again, it is important to monitor the overdenture and its attachment assemblies over time. Metal frameworks can be utilized to strengthen the denture bases. Specialized framework designs can be cast to fit precisely to the fabricated bar, increasing retention and stability while reinforcing the denture bases.

- The complete implant-supported fixed prosthetic option can be achieved in two basic designs. The first design is a fixed partial denture, which is either screw retained or cement retained to six to eight implant abutments. This design mimics that of conventional crown and bridge. This option is typically best suited to the patient who has lost little bone and is just replacing missing teeth. The more common scenario is one where the patient is missing bone, soft tissue, and teeth, and the prosthesis must be designed to replace all three (Fig. 14.33). This second



• **Fig. 14.33** Treatment of edentulous maxilla with fixed-implant–supported prosthesis. (A) Maxilla with eight implants. (B) Hybrid prosthesis fabricated with a milled titanium framework and porcelain applied to replace both the gingiva and teeth. (C) Completed maxillary and mandibular hybrid prostheses. (D) Esthetic result of the case.

design is commonly referred to as a *hybrid prosthesis*. A hybrid prosthesis utilizes a cast or milled framework, which accepts acrylic, resin, or porcelain to create the replacement of the patent's missing bone, gingival tissue, and teeth. These frameworks are usually fabricated utilizing computer-aided design–computer-aided manufacturing technology to mill either titanium or zirconium. Once the material has been milled, the choice for soft tissue and tooth replacement can be made. The most economical version is one where denture acrylic and denture teeth are used. The more sophisticated options have laboratory resin or layered porcelain replacing soft tissue and either layered porcelain directly fused to the framework or cement-retained individual crowns cemented directly onto the framework. The hybrid prosthesis is most often screw retained and can, therefore, be easily retrieved by the clinician. Consideration must be given to the ease and cost of repair for the various hybrid options. The acrylic hybrid is the easiest and least expensive hybrid to repair. The laboratory resin hybrid is slightly more difficult and more expensive to repair. The all-ceramic hybrid designs are the most difficult and most expensive to repair.

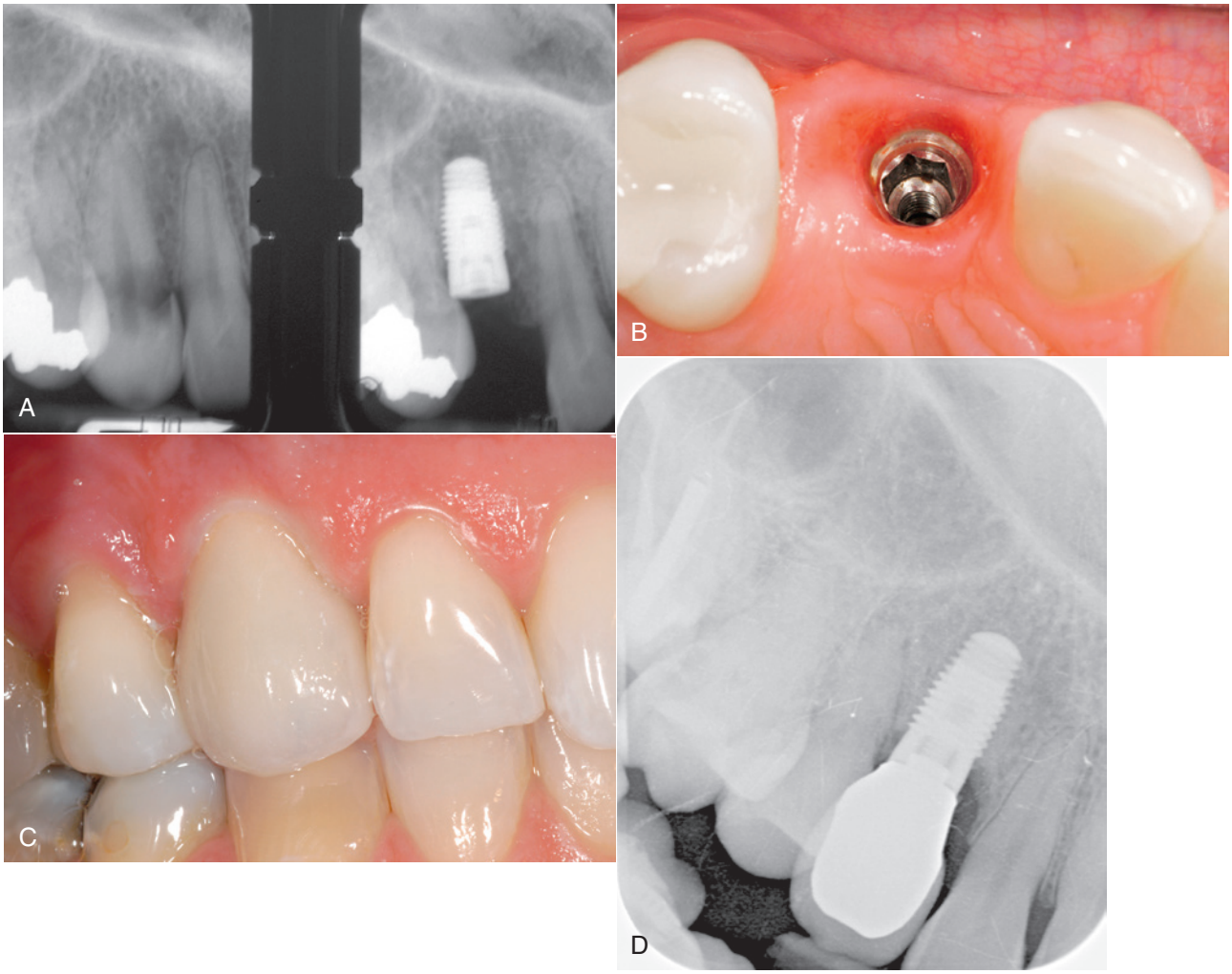
Options for the Partially Edentulous Patient

The options for partially edentulous patients can be divided into two different categories: (1) a single missing tooth or (2) two or more missing adjacent teeth. Multiple options exist for restoration in each of these situations (Figs. 14.34 to 14.37). The single missing tooth can be restored using either a cement-retained crown on an abutment or a screw-retained crown seated and screwed directly to the implant platform. The cement-retained crown can be fabricated as a full cast gold, porcelain fused to metal, or all-ceramic crown. The abutment to which the crown is cemented can be either a prefabricated stock abutment or a custom abutment made from either titanium or zirconium. The zirconium abutment and all-ceramic crown combination is typically used in the anterior region to maximize esthetics.

Two or more adjacent missing teeth can be replaced with cement-retained or screw-retained individual crowns or splinted crowns. In patients missing more than two adjacent teeth, the implants can serve as abutments for a fixed partial denture (e.g., two implants to support a three-unit fixed partial denture); again, this can be cement retained or screw retained. Both titanium and zirconium can be used for the framework of the fixed partial denture. In some clinical situations the prosthesis may be replacing not only missing teeth but also missing bone and soft tissue. As in the completely edentulous patient, a hybrid prosthesis can also be used effectively in the partially edentulous patient. Implants can be used to assist in retaining a removable partial denture. This option allows increased retention and can eliminate unsatisfactory framework clasps in the patient who has concerns about esthetics.

Prosthetic Complications

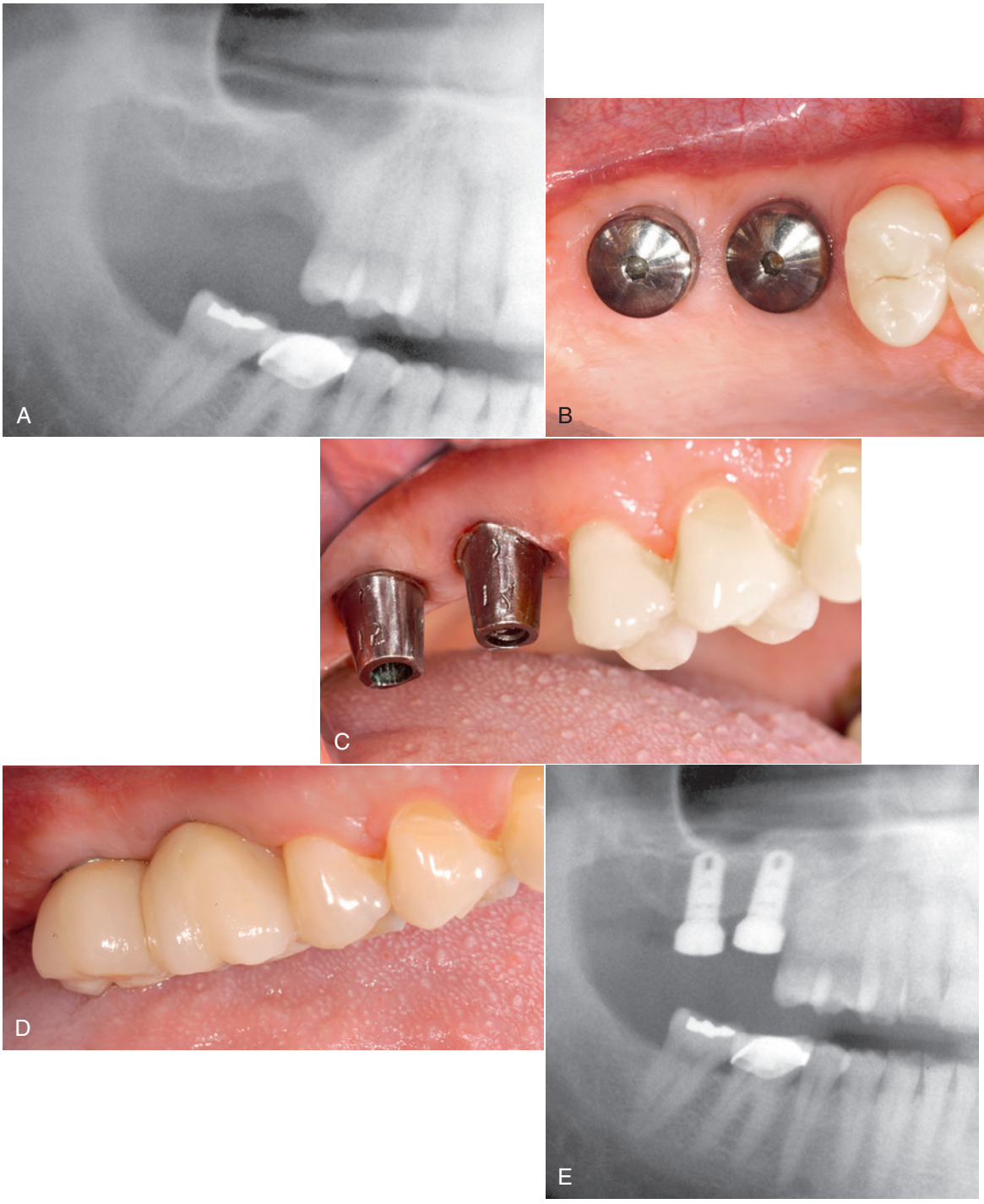
As with any dental procedure, implant prosthetic complications do occasionally occur. The cause of most prosthetic complications



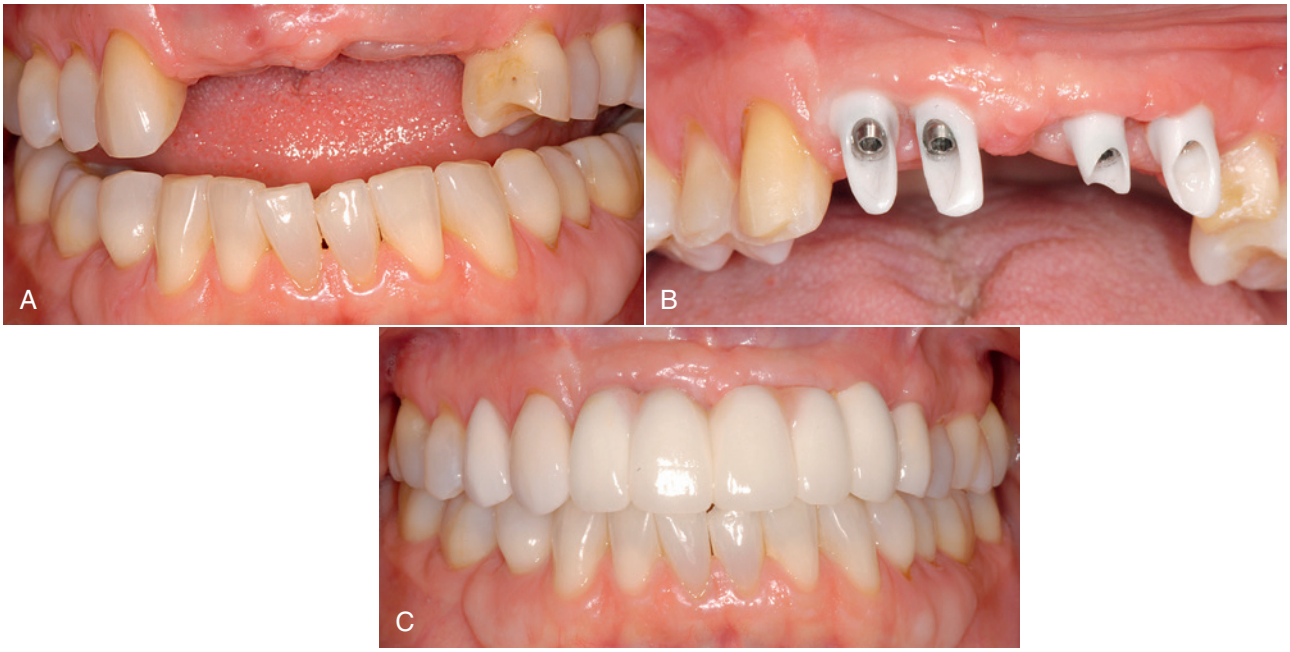
• **Fig. 14.34** Single tooth replacement. (A) Radiograph showing nonrestorable tooth before extraction *(left)* and after *(right)* extraction with implant in place. (B) Implant after the uncovering and healing period and ready for restoration. (C) Final result. (D) Final radiograph.

can be attributed to a mechanical overload of the implant–prosthetic complex or in response to a noxious biologic insult. The complications can easily be divided into four categories:

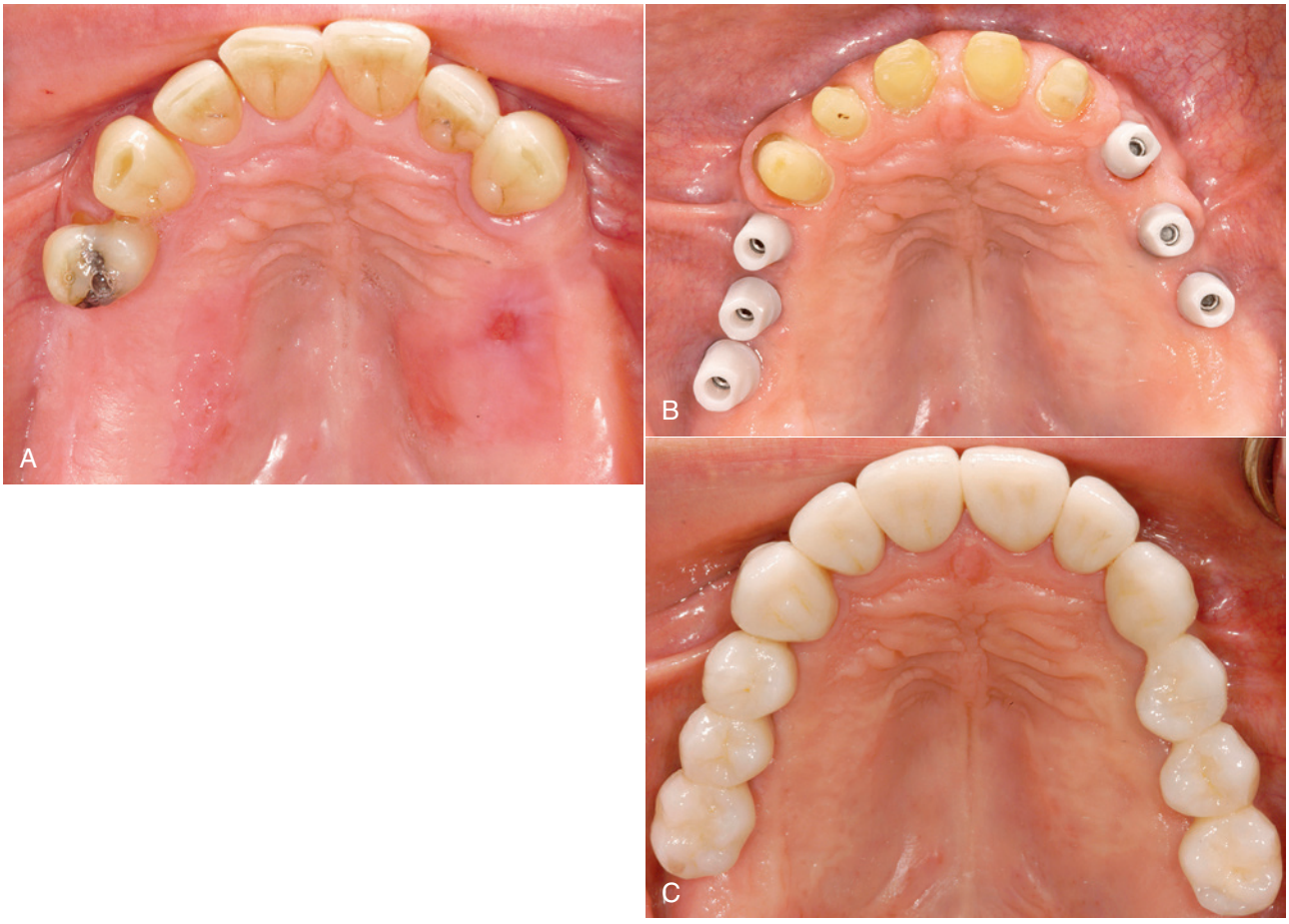
- *Peri-implant complications:* If the load-bearing capacity of the implant-bone complex is exceeded by the applied load, then either a mechanical complication or, worse, a biologic response ensues. If forces are not managed, the stresses can be transferred through the implant-prosthetic complex and cause bone loss around the implant body. If left unattended, this can continue until the implant eventually fails. Secondarily, if the soft tissue interface is violated (e.g., retained cement, lack of hygiene), the same sequela could occur.
- *Component complications:* Component complications (e.g., screws, abutments, bars, or attachments) are almost always associated with excessive mechanical overload. In most cases the overload is too great, transferred at an angle that is destructive to the implant-prosthetic complex, or both. Complications can be as simple as a component coming loose or as detrimental as fracturing of the component. On rare occasions a manufacturing error may result in a component being mechanically compromised.
- *Structural complications:* Structural complications typically include insults to the metal, porcelain, acrylic, resin, or denture teeth. The complication can sometimes be simple and easily adjusted or repaired. However, in some cases, structural failure can be catastrophic and require the prosthesis to be remade.
- *Complex concerns:* Implant dentistry is characterized by clinical variability. An infinite range of clinical scenarios seems to exist. Often the patient is seeking implantation as a last resort and is in desperation. Frequently patients present with failing dental rehabilitation efforts and are now searching for restorative solutions that are far more complex. Many patients present after being edentulous for many years and have experienced profound bone loss and can no longer function with conventional dentures. Trauma patients and patients with craniofacial or developmental anomalies also present with complex prosthetic needs. Chapter 15 presents some of the more advanced cases and their treatment modalities.



• **Fig. 14.35** Replacement of two adjacent posterior maxillary teeth. (A) Pretreatment radiograph. (B) Six months after implant placement and 3 weeks after uncovering placement of healing abutment. (C) Final abutment in place for cement-retained porcelain-fused metal (PFM) crowns. (D) Final cement-retained PFM crown restoration. (E) Final radiograph.



• **Fig. 14.36** Replacement of five anterior maxillary teeth. (A) Pretreatment view. (B) Four computer-aided design and computer-aided manufacturing custom zirconia abutments in place for a cement-retained fixed partial denture. (C) Final result.



• **Fig. 14.37** Restoration of bilateral posterior edentulous maxilla. (A) Pretreatment view. (B) Six zirconia abutments in place for two three-unit fixed partial dentures and five natural teeth prepared for individual all-ceramic crowns. (C) Final restorations in place.

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15

Implant Treatment: Advanced Concepts and Complex Cases

MYRON R. TUCKER, RICHARD E. BAUER, TROY R. EANS, AND MARK W. OCHS

CHAPTER OUTLINE

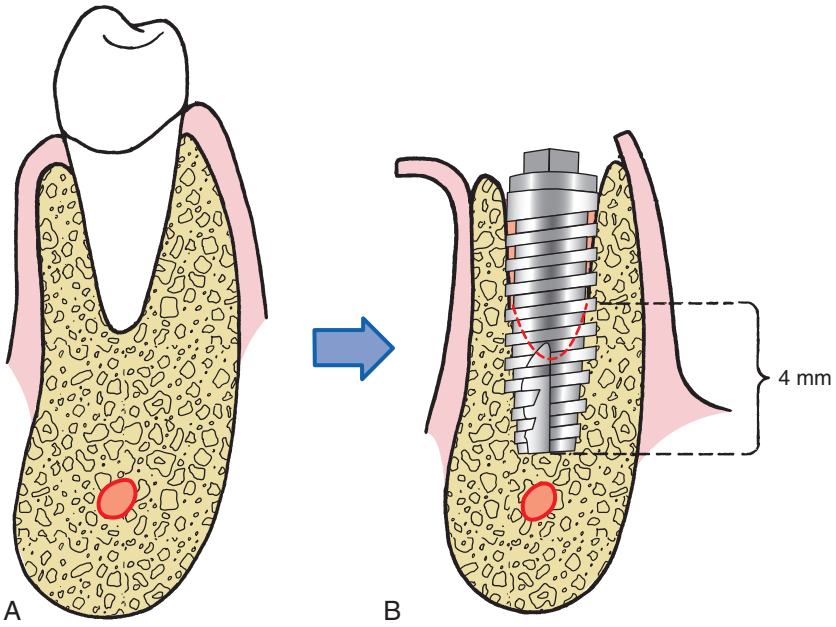
Chapter 14 focuses primarily on the clinical evaluation and surgical, as well as prosthetic, considerations for basic implant treatment. The techniques described in that chapter primarily focus on clinical situations where adequate bone and soft tissue exist and implants can be placed into a well-healed area of bone without jeopardizing anatomic structures such as the maxillary sinus or the inferior alveolar nerve. There are situations where placement of implants becomes more complex. In some cases, it may be advantageous to place an implant at the time of extraction. In many cases the bone and soft tissue present are inadequate for implant placement and require augmentation to facilitate implant placement. This chapter focuses on considerations for types of cases that require immediate implant placement, as well as cases where preparatory bone and soft tissue augmentation may be required before implant placement. These types of surgical procedures are performed by surgeons with advanced training and experience in bone grafting and implant procedures.

Immediate Postextraction Placement of Implants

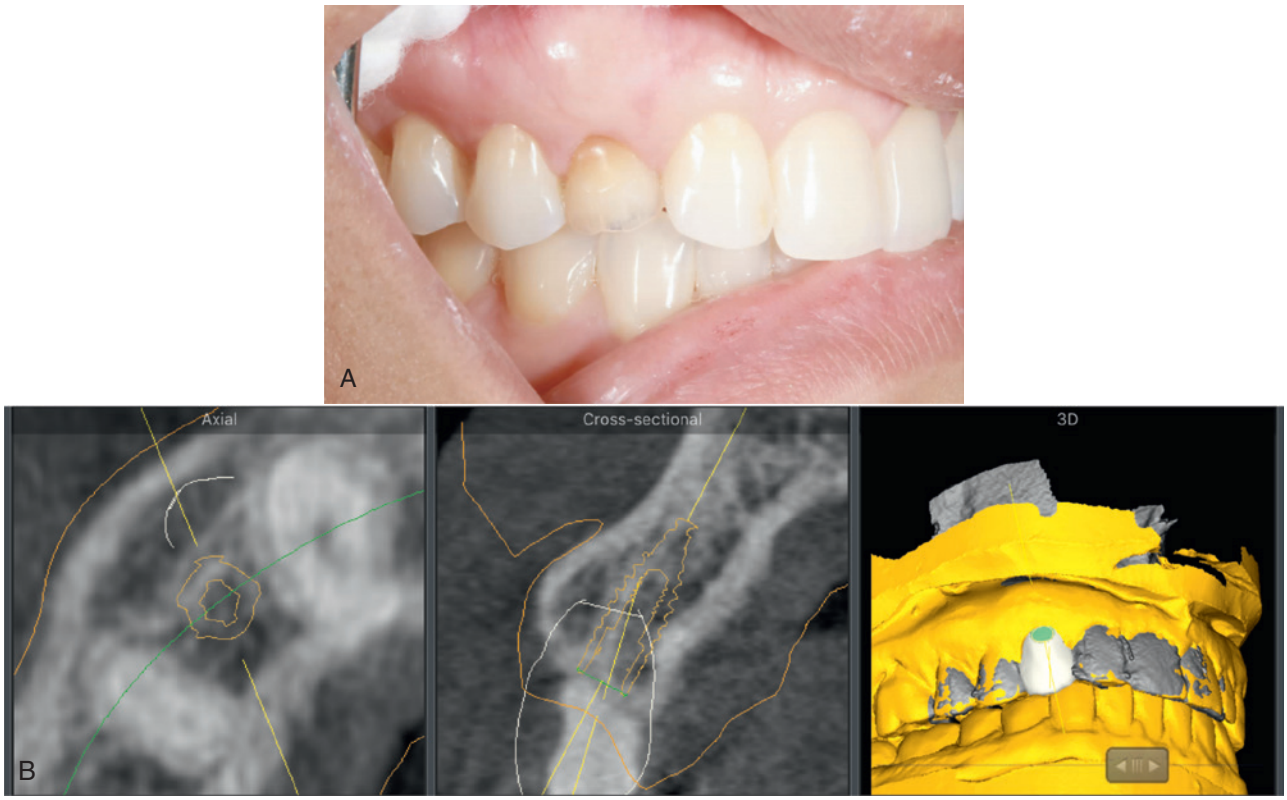
When implant placement is planned before tooth extraction, consideration should be given to the most desirable time for implant placement. The implant may be placed immediately (i.e., at the time of extraction), early (i.e., 2 months after extraction), or late (i.e., more than 6 months after extraction). Each of these times has its indications, advantages, and disadvantages.

The primary advantage of immediate placement is that this allows the overall shortest healing time and combines tooth extraction with surgical implant placement. Placing a provisional restoration at the same procedure may provide the best opportunity for maintenance of soft tissue anatomy and the best immediate and long-term esthetic results. The primary disadvantage of immediate placement is related to the difference in the anatomy of the root or roots of the extracted tooth compared with the shape and size of the implant. This is particularly true of a multirooted tooth that is being replaced by an implant. Even in the case of an incisor, the difference in the shape of the root and that of the implant creates some difficulty in implant placement. Another disadvantage is that if the implant is exposed to excessive occlusal forces, the immediate and long-term stability of the implant can be jeopardized.

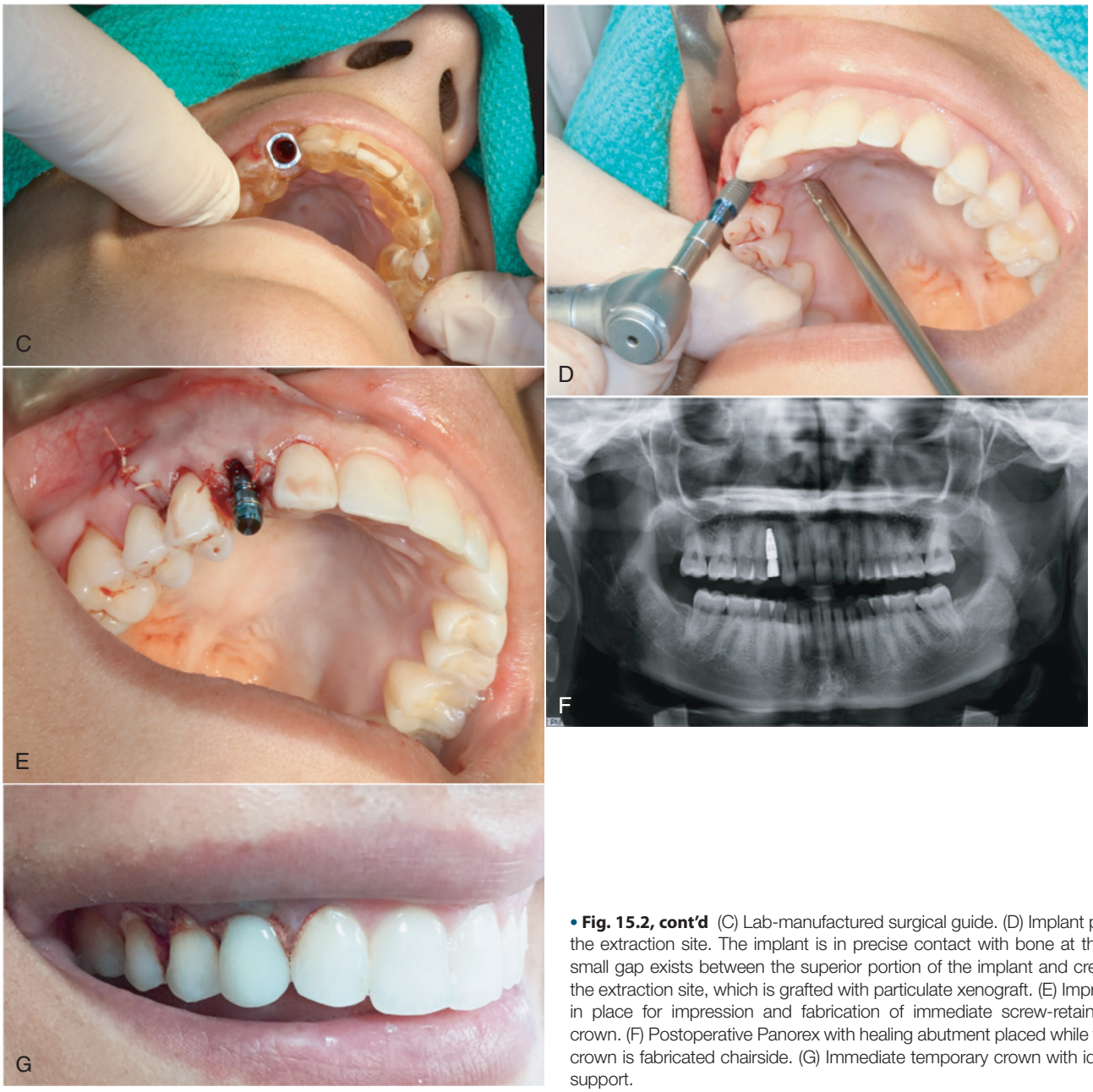
Immediate placement can be considered if the tooth to be removed is not infected and can be removed without the loss of alveolar bone. A critical component in the success of this technique is to complete the extraction of the tooth with minimal bone removal and without distorting or weakening the bony support. An atraumatic extraction technique using periotomes will help minimize damage to bone and help facilitate implant placement. Initial implant stability at the time of placement is also critical to long-term success. When the implant is placed, at least 4 mm of the implant apex should be precisely seated in firm bone to provide this initial stability (Fig. 15.1). Surgical guides are extremely helpful in placing the implant because drilling the implant site at the correct angulation can sometimes be difficult because the drill can be easily deflected when bouncing off the wall of the socket (Fig. 15.2). The implant should be countersunk slightly below the height of crestal bone to allow for resorption of bone resulting from extraction. In the esthetic zone (maxillary anterior), the platform of the implant is ideally placed 3 mm below the free gingival margin. This allows for development of optimal emergence contour of the final restoration



• **Fig. 15.1** (A–B) Implants placed in fresh extraction sockets must have 4 mm of precise fit along the apical aspect of implant. Implants should be countersunk slightly below the crest of bone. Gaps between the implant and facial socket wall are most often grafted with autogenous or allogeneic bone, bone morphogenetic protein, or both.



• **Fig. 15.2** Guided surgery of immediate dental implant with immediate provisionalization. (A) Retained primary right maxillary cuspid. (B) Presurgical virtual planning for computer-aided design and computer-aided manufacturing processing of a static surgical guide.



• **Fig. 15.2, cont'd** (C) Lab-manufactured surgical guide. (D) Implant placement into the extraction site. The implant is in precise contact with bone at the apex, but a small gap exists between the superior portion of the implant and crestal aspect of the extraction site, which is grafted with particulate xenograft. (E) Impression coping in place for impression and fabrication of immediate screw-retained temporary crown. (F) Postoperative Panorex with healing abutment placed while the provisional crown is fabricated chairside. (G) Immediate temporary crown with ideal soft tissue support.

and soft tissue maintenance. In general the implant is also positioned 1 mm palatal to the center of the extracted tooth root. This accounts for anticipated facial bone and soft tissue remodeling that decreases the facial crestal volume.

The gap between the implant and the residual tooth socket must be evaluated and managed according to its size. If the gap is less than 1 mm and the implant is stable, often no treatment modification is needed. If the gap is greater than 1 mm, grafting with a particulate bone material may be indicated. At present the need for this is controversial. In most cases, with flapless, atraumatic extraction techniques, primary closure may not be possible or desirable. In this situation, a resorbable collagen pellet may be placed over the implant and held in place with a figure-of-eight suture. The surgeon may consider extending the time allowed for integration before loading.

In isolated cases, restoration at the time of implant placement may be considered. It is extremely important to ensure that the restoration is in ideal firm contact with adjacent teeth, which will help to reduce unfavorable loading on the implant until it is osseointegrated.

Bone Grafting and Graft Substitutes

In many cases, areas to be restored with implants have insufficient bone for implant placement. This may be a result of extraction and bone atrophy, sinus pneumatization, previous trauma, congenital defects, or removal of pathologic lesions. In these cases, bone will need to be augmented to provide adequate support for implant placement. Several potential sources of graft material can be considered, depending on the volume and configuration of bone needed.

Autogenous Grafts

Autogenous bone can be harvested from several anatomic areas. Intraorally, bone can be harvested from the mandibular symphysis, ramus, or maxillary tuberosity areas. Bone in the tuberosity is primarily cancellous, whereas in the ramus–posterior body area of the mandible, the bone is primarily cortical. The symphysis provides the best intraoral source for a reasonable volume of cortical and cancellous bone (Fig. 15.3). When more bone is required for situations such as atrophic edentulous mandible or bilateral sinus lifts, an extraoral site should be considered if autogenous bone is to be used. The most common site of graft harvest is the anterior iliac crest. Other areas where bone is sometimes harvested include the tibia, the fibula, and the calvarium.

Allografts

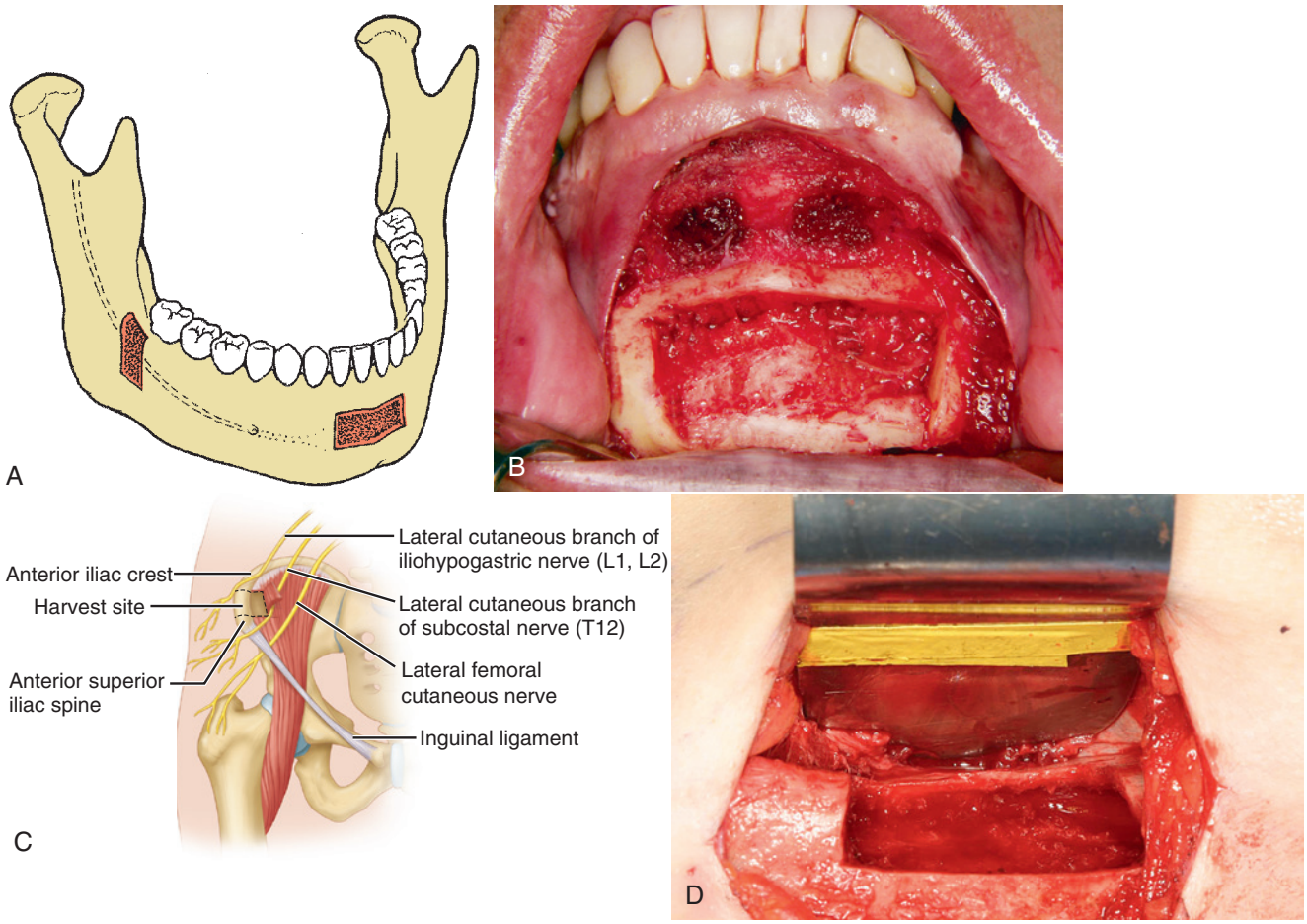
Allogeneic bone grafts procured from cadavers are processed to achieve sterility and decrease the potential for immune response. The sterilization process destroys the osteoinductive nature of the graft; however, the graft provides a scaffold, allowing bone ingrowth (osteoconduction). Bony incorporation, followed by remodeling and resorption, occurs during the healing phase. Granular forms of allogeneic graft material provide increased surface area and improved adaptation within the graft and are the most commonly used for augmenting alveolar ridge contour defects. The advantages of allogeneic bone grafting include the avoidance of an additional donor site, unlimited availability, and the fact that patients can undergo this type of procedure in an outpatient setting. The disadvantage is that a significant amount of grafted bone is resorbed, which results in a much smaller volume of bone for implant placement.

Xenografts

Xenografts are derived from the inorganic portion of bone harvested from a species that is genetically different from the graft recipient. The most common source of xenografts is bovine bone. The advantages and disadvantages are similar to those of allografts, including significant postgrafting resorption.

Bone Morphogenetic Proteins

One of the most exciting recent advancements in bone grafting has been the extensive research related to bone morphogenetic proteins (BMPs). BMPs are a family of protein factors that have been isolated and applied to reconstruction of the maxillofacial skeleton. These proteins have the ability to enhance bone graft



• **Fig. 15.3** Sites of autogenous bone graft harvest. (A) Graft sites from the posterior body or ramus and symphysis regions. (B) Clinical photograph of harvest from symphysis area. (C) Anatomy of iliac crest harvest. (D) Clinical photograph of iliac crest harvest. (C, From Bagheri SC, Jo C. *Clinical Review of Oral and Maxillofacial Surgery.* St. Louis: Mosby; 2008.)

healing and, in many cases, substitute for other graft materials. Recombinant human BMP 2 (rhBMP-2) has been isolated and has now been produced and packaged for use in grafting procedures. The BMP is placed on carriers, usually absorbable collagen sponges, to facilitate placement in the graft site. BMP can be positioned around implants within the extraction sites, aiding in osseointegration. In larger defects, the BMP is usually combined with osteoconductive allogeneic materials to expand the graft volume and to help place, shape, and contain the graft material. BMP with a collagen sponge carrier can be used for sinus lifting and reconstruction of non–load-bearing bony defects (Fig. 15.4). The obvious advantages include eliminating the need for donor site surgery and improved bone formation at the site of augmentation. The primary disadvantages include significant postoperative edema and the cost of the BMP.

Two problems associated with any type of grafting include containment and shaping of the graft material and prevention of fibrous tissue ingrowth during the healing phase. Placement of particulate grafts to augment alveolar ridges often requires some type of containment device or material to facilitate the ideal ridge size and shape. Materials used to contain and shape the graft can also be effective in eliminating the unfavorable invasion of soft tissue during healing.

Guided bone regeneration is a process that allows bone growth while retarding the ingrowth of fibrous connective tissue and epithelium. Many bone defects will regenerate with new bone if the invasion of connective tissue from adjacent soft tissue can be prevented. Guided bone regeneration involves using a barrier that is placed over the bony defect to prevent fibrous tissue ingrowth while the bone underlying the barrier has time to grow and fill the defect (Fig. 15.5). This technique is particularly useful in the treatment of buccal dehiscence, where labiobuccal (horizontal) augmentation of bone is required. Guided bone regeneration can be performed simultaneously with implant placement or before stage I. A variety of materials may serve as barriers to fibrous tissue ingrowth. Expanded polytetrafluoroethylene (Gore-Tex) is the most extensively tested material. Resorbable materials are also now available, eliminating the necessity of removal. Thin, malleable titanium mesh is also a commonly used material facilitating maintenance of graft shape while eliminating extensive fibrous ingrowth. Titanium mesh trays can be created by trimming and contouring flat titanium mesh at the time of surgery, or they can be fabricated prior to surgery using diagnostic mounted dental casts or computer-aided design and computer-aided manufacturing technology.

Mandibular Augmentation

Augmentation grafting adds strength to an extremely deficient mandible and improves the height and contour of available bone for implant placement in denture-bearing areas. Superior border augmentation with a bone graft is often indicated when severe resorption of the mandible results in inadequate height and contour and potential risk of fracture or when the treatment plan calls for placement of implants in areas of insufficient bone height or width. Neurosensory disturbances from inferior alveolar nerve dehiscence at the superior aspect of the mandible also can be improved with superior border grafting. Sources of graft material include autogenous bone, allogeneic bone, or both, often combined with BMP (off-label use). Historically, autogenous bone has been the most biologically acceptable material used in mandibular augmentation. Disadvantages of the use of autogenous bone include the need for donor site surgery and the possibility of the significant resorption that occurs after grafting. The use of allogeneic bone eliminates the need for a second surgical site and has been shown to be useful in augmenting small areas of deficiency in the mandible. Use of allogeneic bone seems to be most effective in augmenting the width of the alveolar ridge and is much less effective in improving the height (vertical augmentation) of a deficient mandible. Current techniques for superior border augmentation of the mandible frequently involve some combination of block grafting, supplemented with an allogeneic material such as freeze-dried bone mixed with BMP often contained in some type of mesh tray (Fig. 15.6).

Maxillary Augmentation

Severe resorption of the maxillary alveolar ridge presents a significant challenge to the prosthetic reconstruction of the dentition. When moderate to severe maxillary resorption does occur, the larger denture-bearing area of the maxilla may allow prosthetic rehabilitation without bony augmentation. In certain cases a severe increase in interarch space, loss of palatal vault, interference from the zygomatic buttress area, and absence of posterior tuberosity notching may make it difficult to construct proper dentures; augmentation should then be considered.

Onlay Bone Grafting

Bone grafting of the edentulous atrophic maxilla with an autogenous rib was first described by Terry in 1984. Maxillary onlay bone grafting is indicated primarily in the presence of severe resorption of the maxillary alveolus that results in the absence of a clinical alveolar ridge and loss of adequate palatal vault form. Maxillary onlay grafting is usually accomplished by using some combination of autogenous bone (corticocancellous blocks or particulate marrow), allogeneic bone, and BMP (off-label use), often contained in some type of mesh tray (see Fig. 15.5). When blocks of corticocancellous bone are used, they can be secured to the maxilla with small screws, eliminating mobility and decreasing resorption (Fig. 15.7). Cancellous bone is then packed around the grafts to improve contour. Implants can be placed at the time of grafting in some cases, but placement is often delayed to allow initial healing of the grafted bone.

Sinus Lift

Rehabilitation of the maxilla using implants is frequently problematic because of the extension of the maxillary sinus into the alveolar ridge area. In many cases the actual size and configuration of the maxilla are satisfactory in terms of the height and width of the alveolar ridge area. However, extension of the maxillary sinuses into the alveolar ridge may prevent placement of implants in the posterior maxillary area because of insufficient bony support. The sinus lift is a bony augmentation procedure that places graft material inside the sinus cavity but external to the membrane and augments the bony support in the alveolar ridge area.

When only a few millimeters of augmentation are needed in conjunction with simultaneous implant placement, an indirect sinus lift is effective. This procedure relies on the lack of density found in maxillary cancellous bone. The initial drill is used to locate the angulation and position of the planned implant. The depth is drilled just short of the sinus floor. Osteotomes are then used to enlarge the site progressively. The osteotome is cupped on

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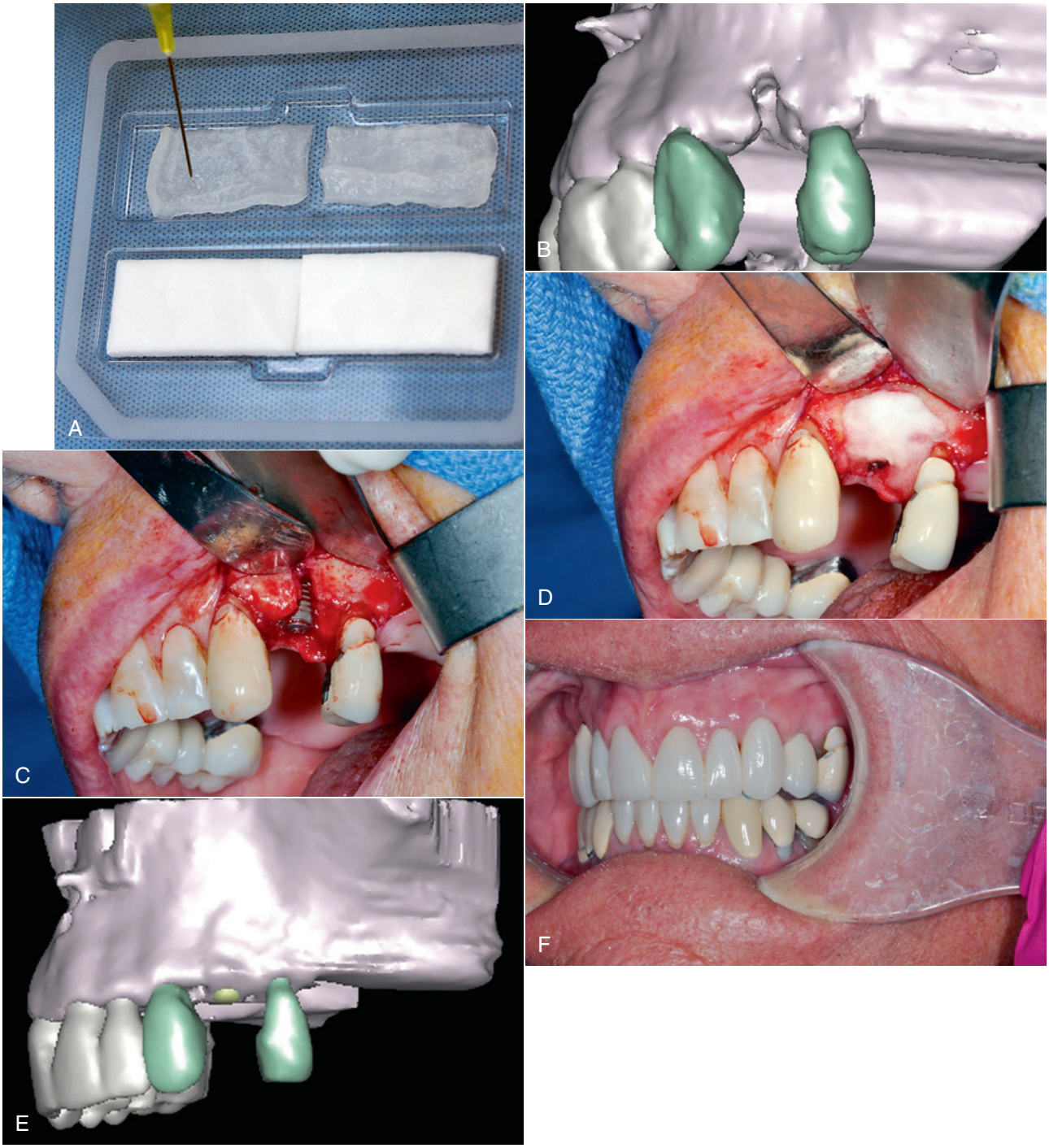
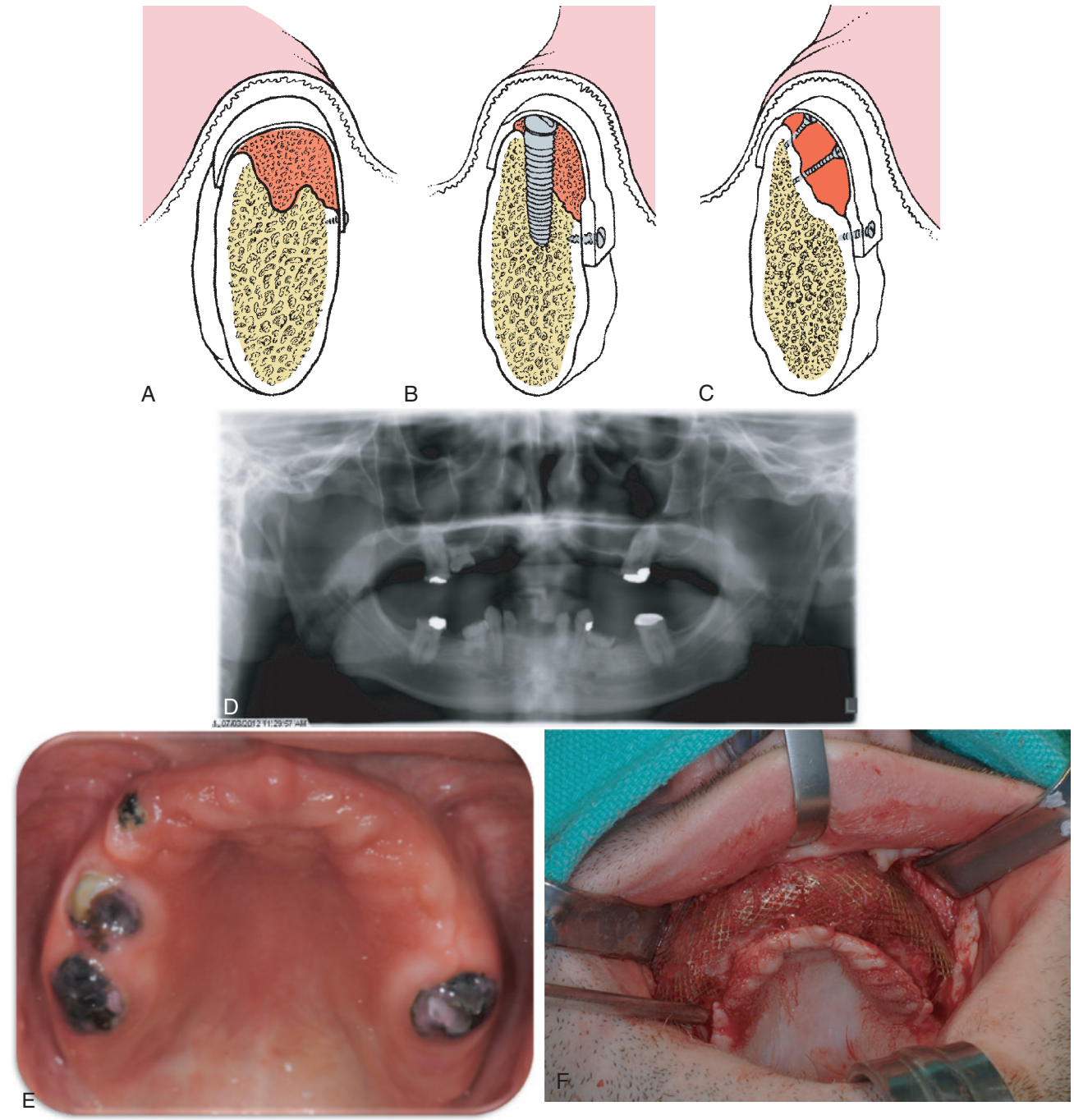
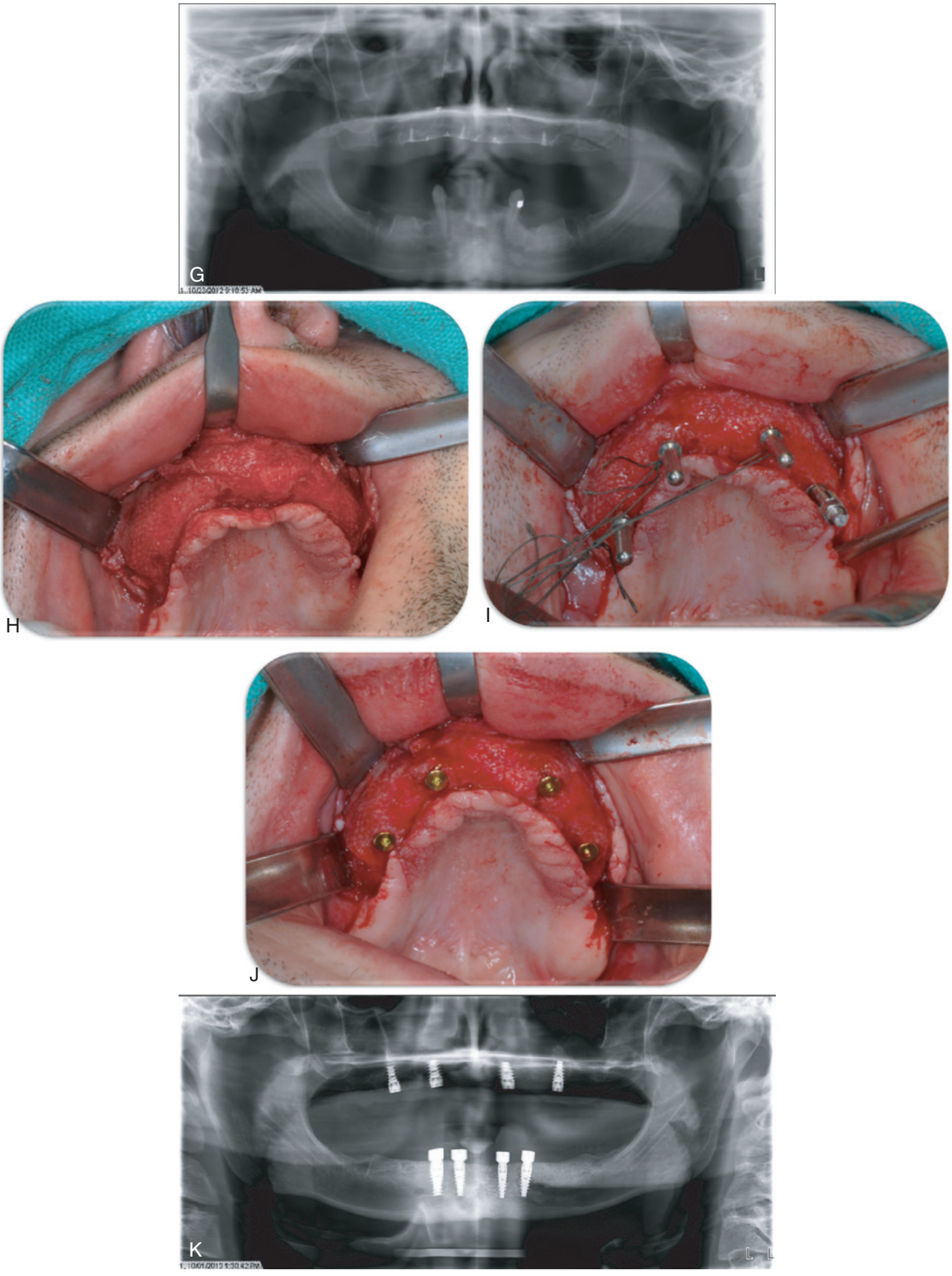


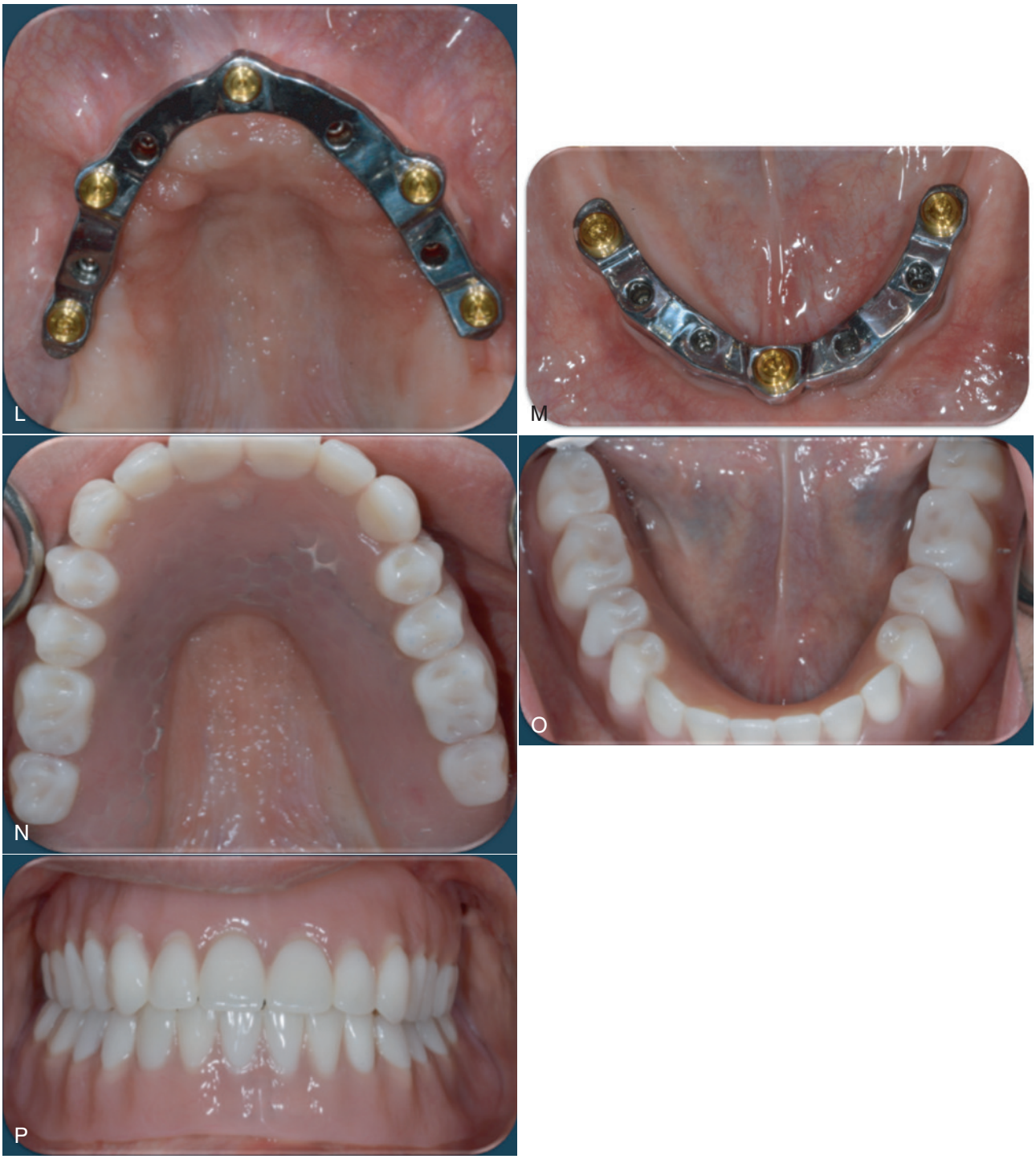
• **Fig. 15.4** Bone morphogenetic protein (BMP). (A) Kit containing BMP in liquid form and collagen sponges. (B) Three-dimensional computed tomography (CT) showing edentulous space with facial wall defect. (C) Implant placed. (D) Allogeneic bone graft material combined with BMP on collagen sponge covering bony defect. (E) Three-dimensional CT showing excellent postoperative bone regeneration. (F) Restored implant.



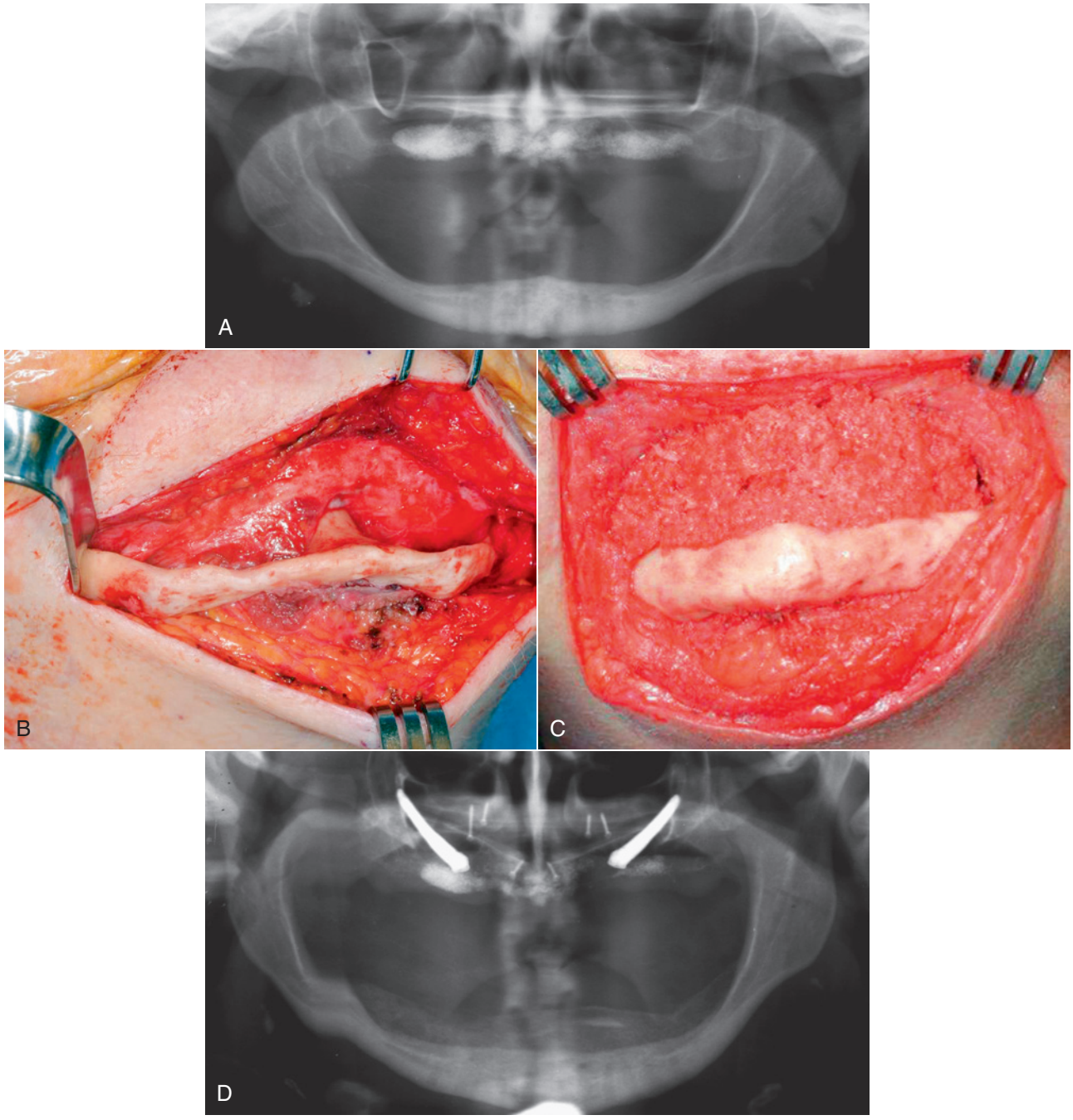
• **Fig. 15.5** Various applications of guided bone regeneration. (A) Membrane and "filler material" such as allogeneic bone are used to augment the ridge. (B) Same as in (A), except that an implant is placed simultaneously. (C) The membrane is supported by "tenting" screws that preserve the space beneath the graft to allow bone fill. (D) Panorex of patient with ectodermal dysplasia. (E) Intraoral photo. (F) Maxillary augmentation with bone morphogenetic protein and titanium mesh. *Continued*



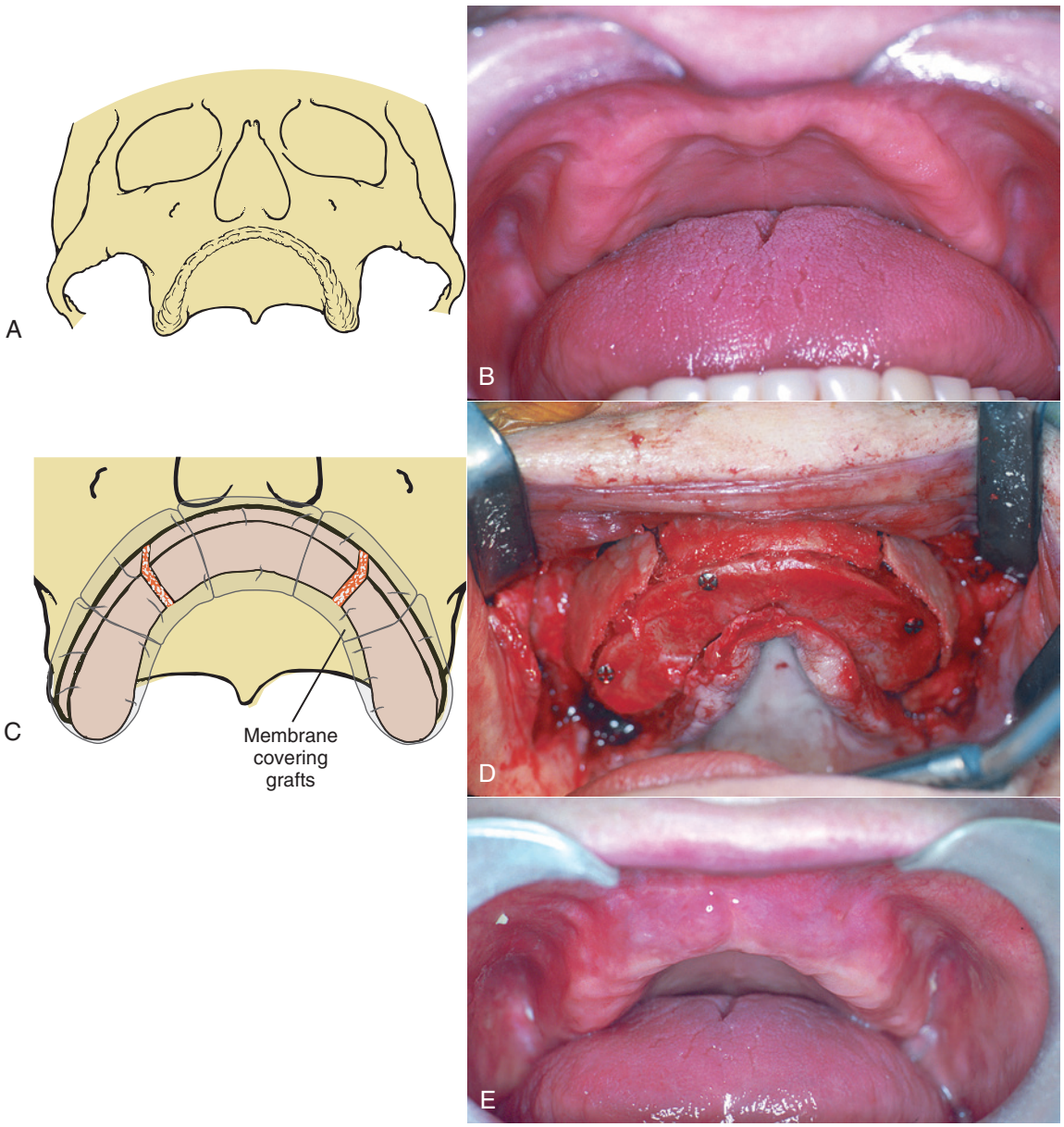
• **Fig. 15.5, cont'd** (G) Postoperative Panorex of maxillary augmentation. (H) Surgical reentry 9 months after the grafting procedure. (I) Four direction indicators during implant placement at the time of titanium mesh removal. (J) Four implants placed into the regenerated bone with cover screws in place. (K) Post-implant placement Panorex.



• **Fig. 15.5, cont'd** (L) Maxillary implant supported milled titanium bar with attachments. (M) Mandibular implant-supported milled titanium bar with attachments. (N) Maxillary metal-reinforced overdenture. (O) Mandibular metal-reinforced overdenture. (P) Final prosthesis in place.



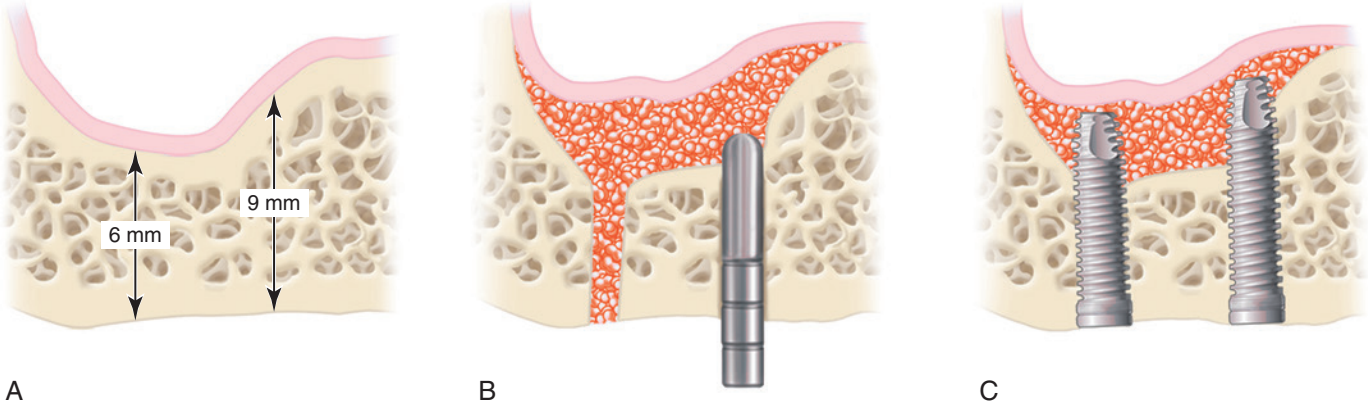
• **Fig. 15.6** Augmentation of atrophic edentulous mandible. (A) Preoperative radiograph. (B) Exposure of atrophic mandible through an extraoral approach. (C) Bone graft in place. Bone graft was a combination of bone morphogenetic protein, stem cells harvested by aspiration of iliac crest marrow, and freeze-dried bone. (D) Six-month postoperative radiograph. (Maxillary bone graft and zygomaticus implants were placed at the time of mandibular grafting.) Note that the bone graft area is not as dense as underlying bone. When implants are placed and stress is applied to grafted bone, the density will increase.



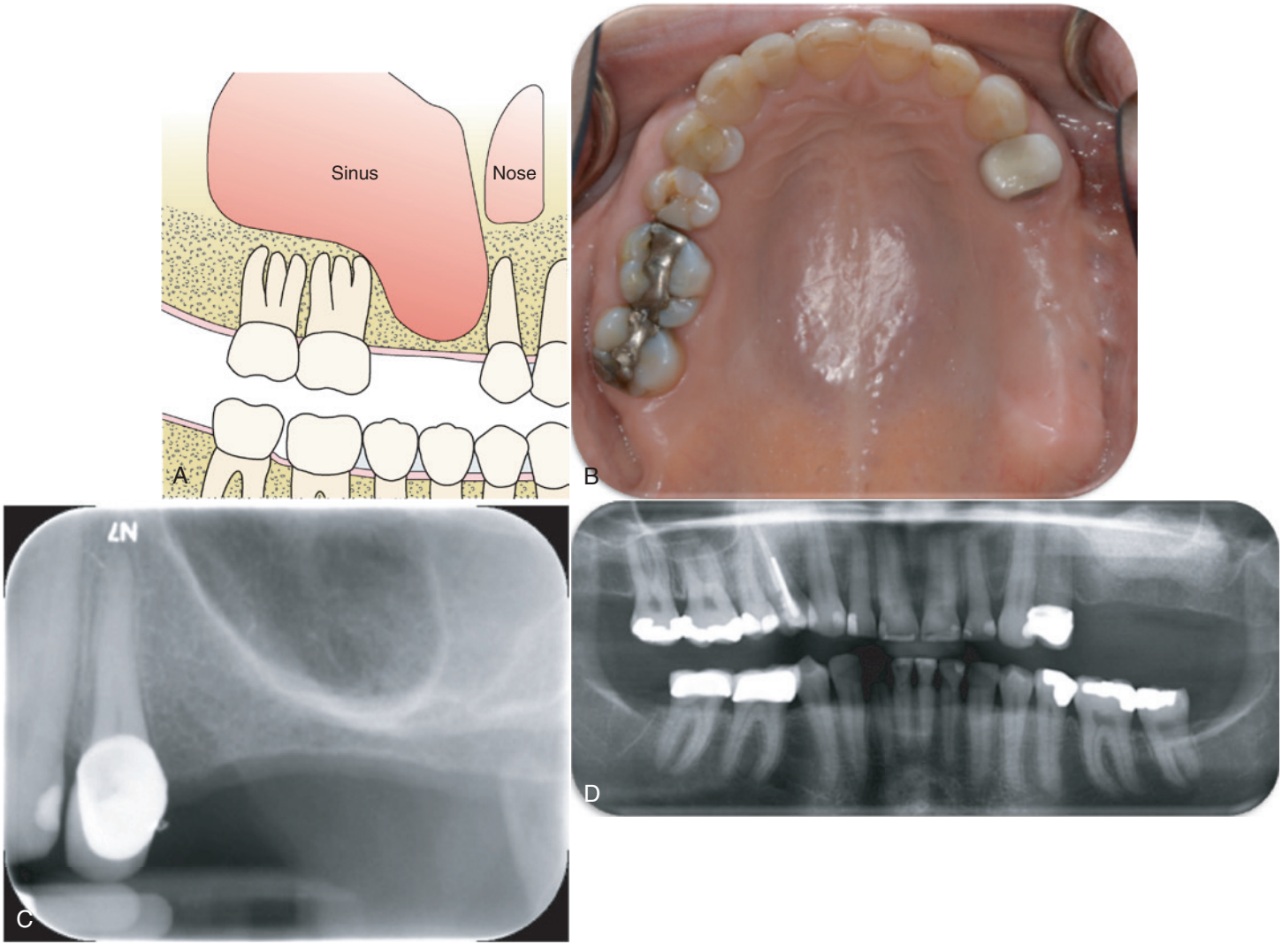
• **Fig. 15.7** Iliac crest onlay bone reconstruction of maxilla. (A) Diagram of atrophic maxilla. (B) Clinical photograph illustrating inadequate alveolar ridge for reconstruction. (C) Three segments of bone are secured in place. (D) Stabilization of the onlay grafting with rigid fixation. Small defects are filled with cancellous bone and bone morphogenetic protein. A resorbable membrane is then placed over the graft prior to tissue closure. (E) Postoperative result demonstrating improved alveolar ridge height and contour.

the end and compresses the walls of the osteotomy site; it also scrapes bone from the sides of the wall, pushing it ahead. The bone of the sinus floor is pushed upward, elevating the sinus membrane and depositing the bone from the lateral wall and apex of the osteotomy into the sinus below the membrane (Fig. 15.8). If needed, additional graft material can be introduced through the implant site.

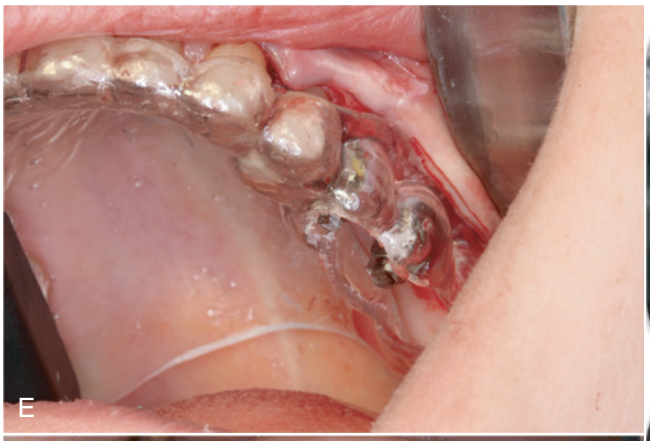
When more bony augmentation is needed, an open approach to the sinus is necessary. In this technique, an opening is made in the lateral aspect of the maxillary wall, and the sinus lining is carefully elevated from the bony floor of the sinus (Fig. 15.9). After elevation of the sinus membrane, the graft material is placed in the inferior portion of the sinus, below and external to the sinus membrane. Allogeneic, autogenous, xenogeneic bone, BMP, or a combination of these materials can be used as a graft source. Perforation of the sinus membrane can occur during exposure of the maxillary sinus floor. Perforations are usually covered with redundancy of the elevated membrane and a "patch" of resorbable membrane material. These measures allow placement of the graft material with protection from a direct sinus communication. If insufficient bone is available to provide initial implant stability, the graft is allowed to heal for 3 to 6 months, after which the first stage of implant placement can begin in the usual fashion described in Chapter 14. If enough bone is available to obtain initial implant stability (usually 4 to 5 mm), then implant placement can be accomplished simultaneously with sinus grafting. This procedure can be performed as outpatient surgery. A properly relieved removable prosthesis can usually be worn after surgery, during the healing period.

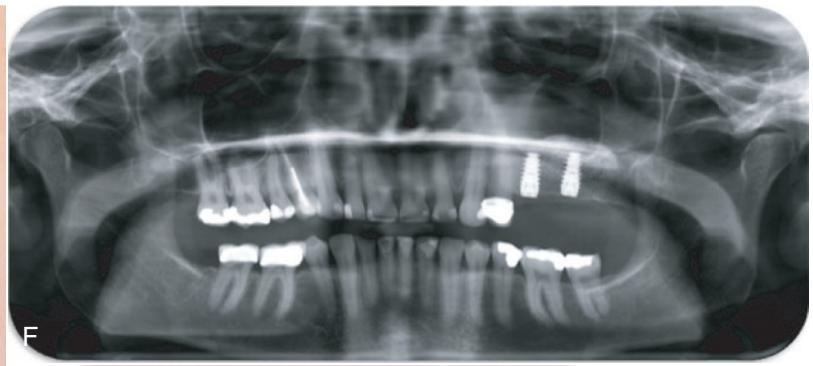


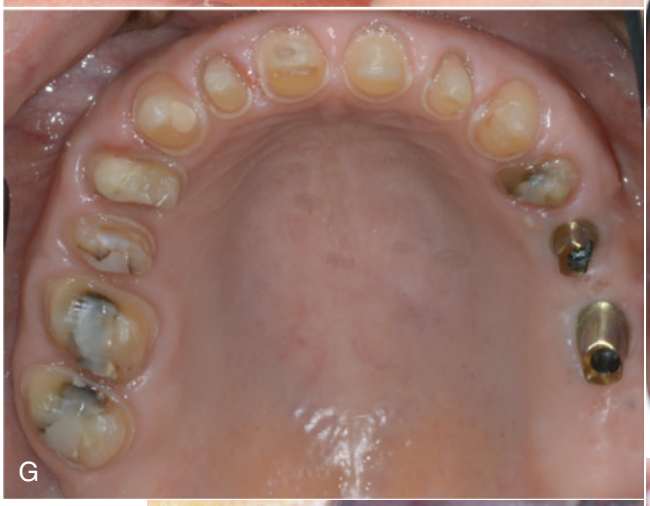
• **Fig. 15.8** Indirect sinus elevation procedure. (A) Pneumatized sinus with adequate bone for primary stability. (B) After drilling pilot holes, osteotomes are used to enlarge the osteotomy while placing graft material. (C) The pressure created by the graft material as it is inserted into the osteotomy expands the intact sinus membrane and elevates the floor of the sinus, allowing implant placement.

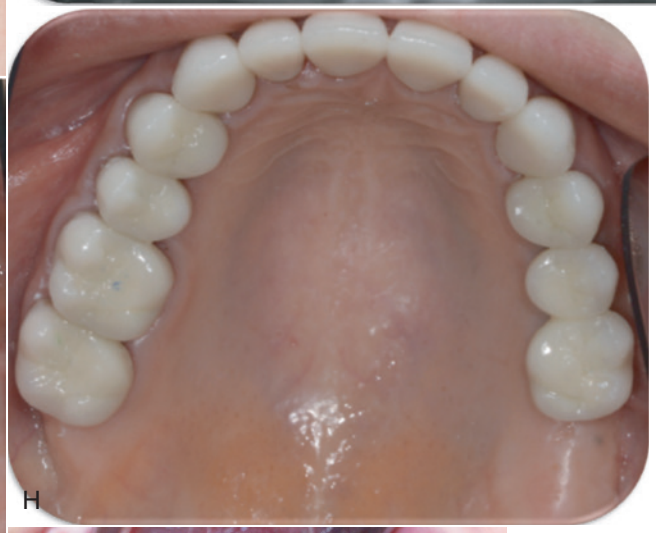


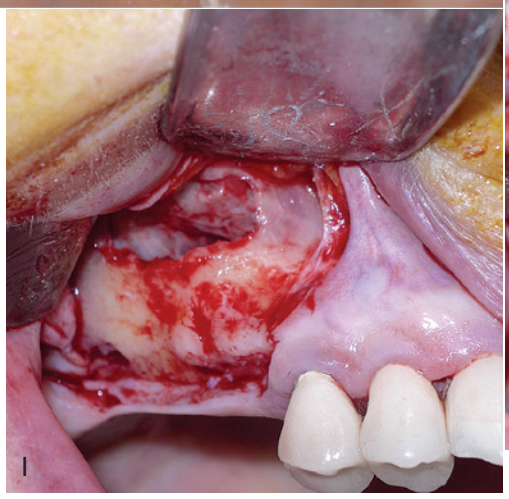
• **Fig. 15.9** Sinus lift procedure. (A) Diagram illustrating pneumatization of the maxillary sinus into the alveolar ridge with inadequate bone support for reconstruction. (B) Pretreatment image of a patient missing teeth #13 and #14. (C) Pneumatization of the maxillary right sinus. (D) Postoperative Panorex showing left maxillary sinus lift using a combination of particulate allogenic and xenograft via a lateral window approach.

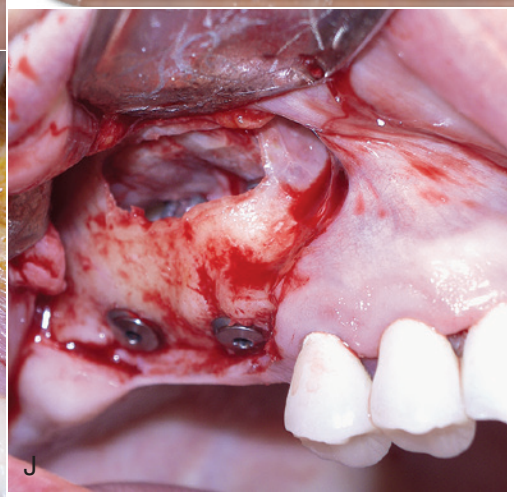




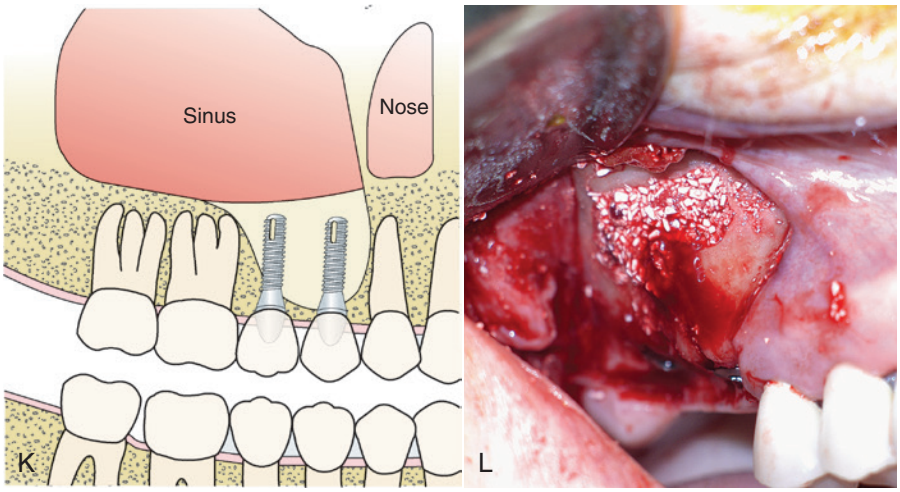








• **Fig. 15.9, cont'd** (E) Implant placement using a surgical stent as a secondary procedure 5 months after the sinus augmentation was completed. (F) Postsurgical Panorex showing implant placement into the augmented left maxillary sinus. (G) Intraoral photo of prepared teeth and custom titanium implant abutments. (H) Final restorations in place. (I) Lateral bone window provides access; the sinus membrane is elevated and when enough native ridge is present for stability the implants can be placed at the time of sinus elevation. (J) Implants are placed through the native ridge and into the sinus. *Continued*



• **Fig. 15.9, cont'd** (K) Diagram depicting elevation of the sinus membrane, implant placement, and grafting of area around implants below the sinus membrane. (L) Graft (a combination of autogenous bone and allograft material) in place.

Alveolar Ridge Distraction

Trauma, congenital defects, and resection of bony pathologic conditions often create a bone defect inadequate for immediate reconstruction with implants. Considerable soft tissue defects, including loss of attached gingiva, keratinized tissue, or mucosa, frequently accompany the bony discrepancy. Distraction osteogenesis has been used to correct these alveolar deficiencies. Distraction osteogenesis involves cutting an osteotomy in the alveolar ridge (Fig. 15.10). An appliance is then screwed directly into the bone segments. After an initial latency period of 5 to 7 days, the appliance is gradually activated to separate the bony segments at approximately 1 mm per day. The gradual tension placed on the distracting bony interface produces continuous bone formation. In addition, adjacent tissue, including mucosa and attached gingiva, expands and adapts to this gradual tension. Because the adaptation and tissue genesis involve a variety of tissue types in addition to bone, this concept should also include *distraction histiogenesis*, in which the distracted segment and newly generated bone (termed *regenerate*) is allowed to heal for 3 to 4 months. The distraction appliance is then removed, and implants are usually placed at the time of distractor removal. Additional bone augmentation may still be required. Horizontal distraction of the alveolus to increase width followed by implant placement has also been completed successfully.

Diagnostic Imaging and Virtual Treatment Planning

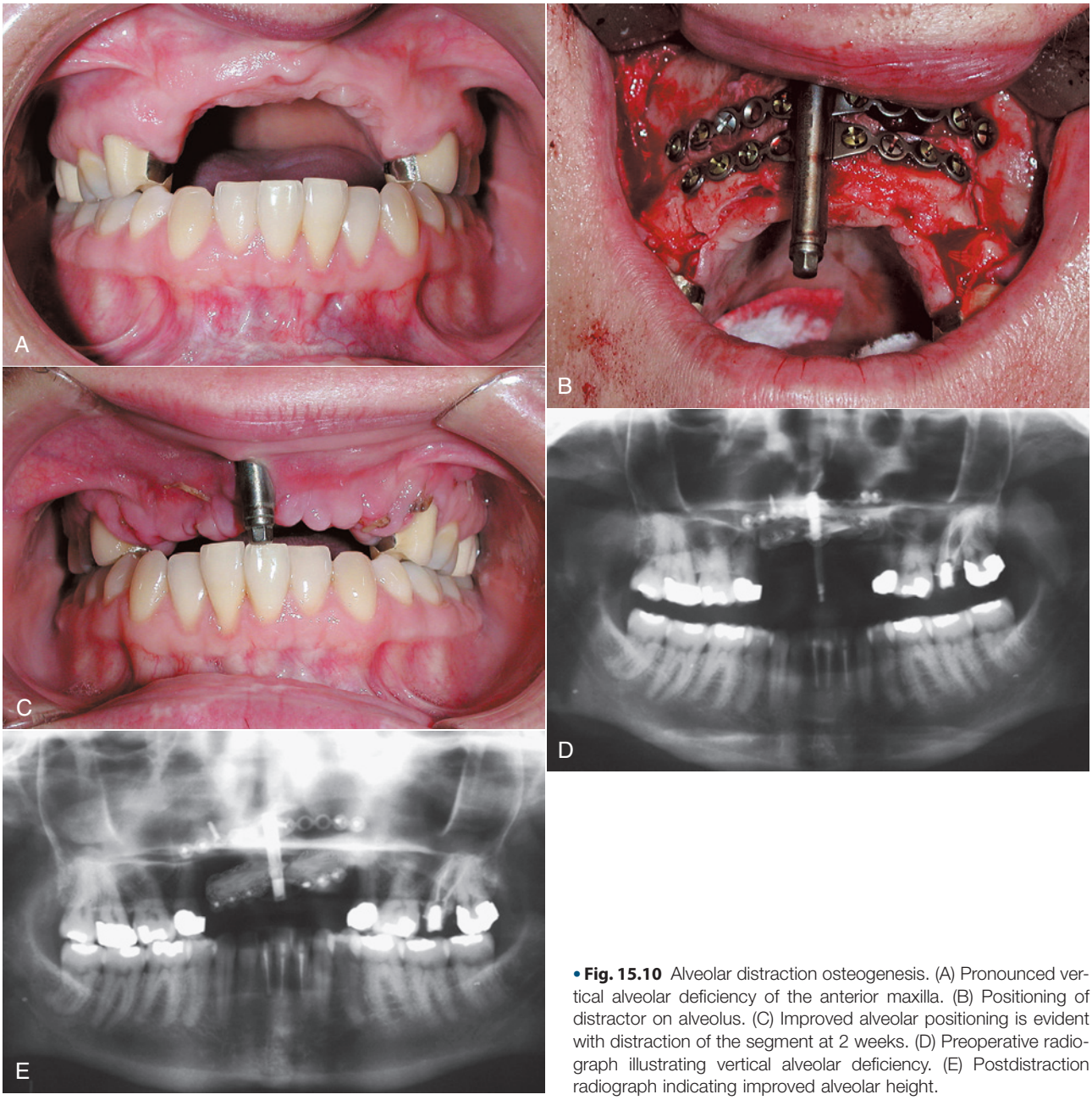
The increasing availability and use of computed tomography and cone-beam computed tomography scanning, along with significant software advances, have dramatically changed the way implant cases are planned from both surgical and prosthetic standpoints. Cone-beam computed tomography scans with three-dimensional reconstruction allow detailed visualization of the bony anatomy in all three planes of space. Cross-sectional viewing of the bony anatomy allows detailed analysis of all important anatomic structures, including ridge size and shape, position of the maxillary sinus in relation to the ridge, and location of the inferior alveolar nerve or adjacent tooth roots. (Fig. 15.11; see also Fig. 14.10). Proprietary software that facilitates the integration of the desired final prosthetic result with the underlying bony anatomy is available. By using computer technology to "virtually visualize" underlying bone anatomy along with the planned final prosthetic result, the need for bone grafting, as well as the position and angulation of implant placement can be planned with extreme precision (Fig. 15.12). By using rapid prototyping technology, a surgical guide can then be created with laser polymerization of resin. Guide cylinders that exactly match the size of surgical drills used for implant site preparation can be imbedded in the surgical guide. The guide, which is securely fixed to either the maxilla or the mandible, dictates the exact position, angulation, and depth of each implant. In some cases, it is possible to place implants through the surgical guide, which can provide an index for the internal or external retention configurations of the implant. This allows the prosthetic provisional restoration to be constructed before surgery and delivered immediately at the time of implant placement.

Computer-assisted surgical treatment planning has become prominent in medicine and dentistry. The obvious next step is to implement computer-assisted surgery, or surgical navigation, to ensure accuracy and efficiency as well as reproducible outcomes. Surgical navigation has been used with positive outcomes in the hospital setting for years. Adapting this technology for intraoral dental surgical purposes has posed a number of new challenges. The primary concerns revolve around the equipment necessary to execute intraoral navigation. Bulky handpieces and reliable and reproducible calibration have been on the forefront of adapting this technology. Dynamic navigation in implant dentistry is evolving and will continue to become a key component in successful patient outcomes.

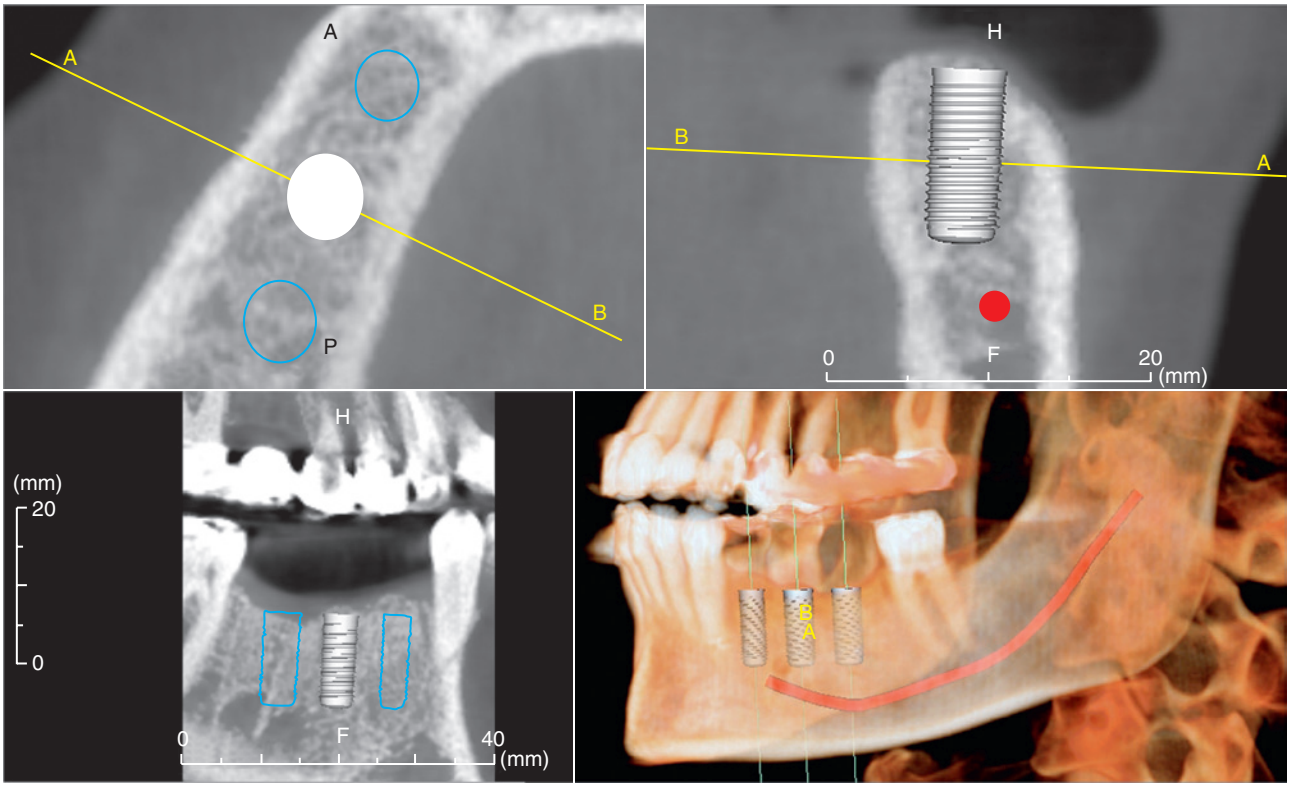
Special Implants

Zygomatic Implants

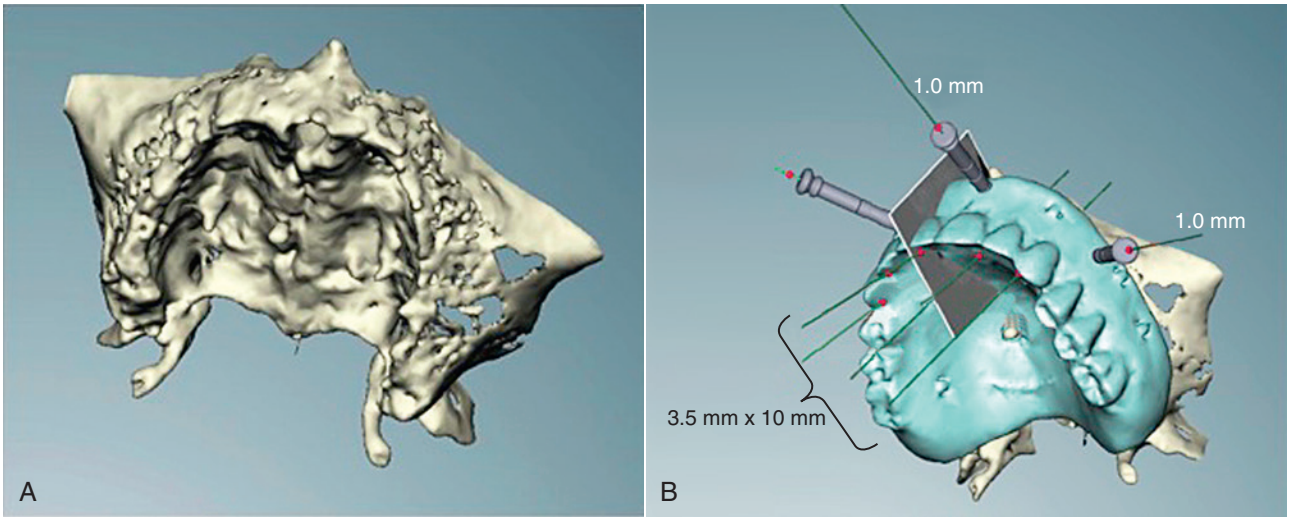
The implications of pneumatization of the maxillary sinus and the possible need for grafting are discussed earlier in this chapter. There are some situations where grafting of the sinus floor may not be



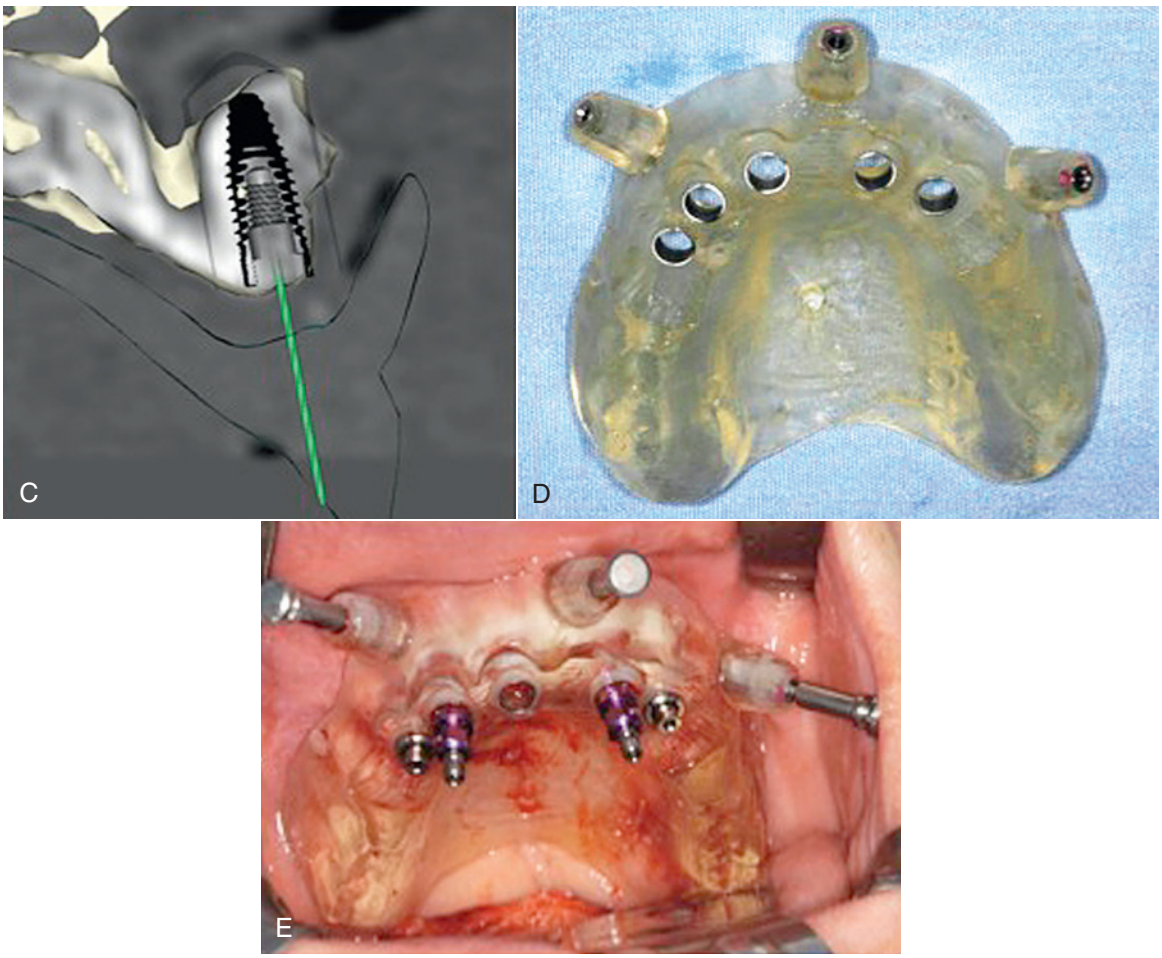
• **Fig. 15.10** Alveolar distraction osteogenesis. (A) Pronounced vertical alveolar deficiency of the anterior maxilla. (B) Positioning of distractor on alveolus. (C) Improved alveolar positioning is evident with distraction of the segment at 2 weeks. (D) Preoperative radiograph illustrating vertical alveolar deficiency. (E) Postdistraction radiograph indicating improved alveolar height.



• **Fig. 15.11** Cone-beam computed tomography image showing three-dimensional reconstruction and cross-sectional views of the mandible, identifying the site of planned implant placement and the relationship to the inferior alveolar nerve.



• **Fig. 15.12** Computer-assisted virtual treatment planning. (A) Three-dimensional view of the maxilla created from cone-beam computed tomography data. (B) "Virtual" prosthesis placed over the maxillary anatomy. The ideal position and angulation of implant placement can be determined. Individual cross-sections can be evaluated.



• **Fig. 15.12, cont'd** (C) Cross-sectional view of the anterior maxilla with virtual implant placed to view the position, angulation, and adequacy of bone support in this area. (D) Computer-designed surgical guide dictating exact placement of implants. (E) Surgical guide rigidly fixed with anchor pins into position at the time of surgery to ensure precise placement of implants.

feasible. Such cases may include patients with compromised health or individuals who are reluctant to undergo staged surgery requiring multiple surgeries and prolonged treatment times. In these cases the use of a zygomaticus implant can be considered. The implant was originally developed in the early 1990s by Brånemark, with several subsequent modifications. The implants are extremely long, ranging from 35 to 55 mm. The implants are placed intraorally, with exposure to the crest of the alveolar ridge and the body of zygoma and visual access to the maxillary sinus. After the membrane is reflected, the implant traverses the maxillary sinus, with the tip engaging the body of the zygoma and the external hex fixture emerging in the second premolar or first molar area of the maxilla (Fig. 15.13). The portion of the implant embedded just medial to the alveolar crest or zygomatic bone undergoes osseointegration similar to other implants. The posterior zygomatic implants are usually combined with four anterior implants, all supporting a fixed prosthesis (see Fig. 15.18).

Extraoral Implants

Recognizing the success of implants for oral applications, maxillofacial prosthodontists and surgeons have expanded use of titanium fixtures to extraoral application. Extraoral implants are currently used to anchor prosthetic ears, eyes, and noses for patients with defects resulting from congenital conditions, trauma, or pathologic conditions (Fig. 15.14).

Complex Cases

Complex cases often require the combination of many components of advanced imaging, treatment planning, and surgical and prosthetic treatment techniques. The following are five examples of cases requiring the combination of several treatment options:

- Missing anterior teeth, requiring grafting and implant placement (Fig. 15.15)
- Edentulous spaces in maxilla and mandible augmented with autogenous grafting (Fig. 15.16)
- Maxillary defect from central giant cell granuloma resection reconstructed with BMP, allogenic bone graft, and a titanium mesh crib (Fig. 15.17)
- Failed maxillary and mandibular dentition with moderate atrophy of the mandible treated with conventional maxillary denture and mandibular overdenture (Fig. 15.18)
- Severely atrophic edentulous mandible treated with anterior iliac crest bone grafting (Fig. 15.19)
- Nonrestorable maxillary dentition restored with conventional anterior implants and posterior zygomaticus implants (Fig. 15.20)

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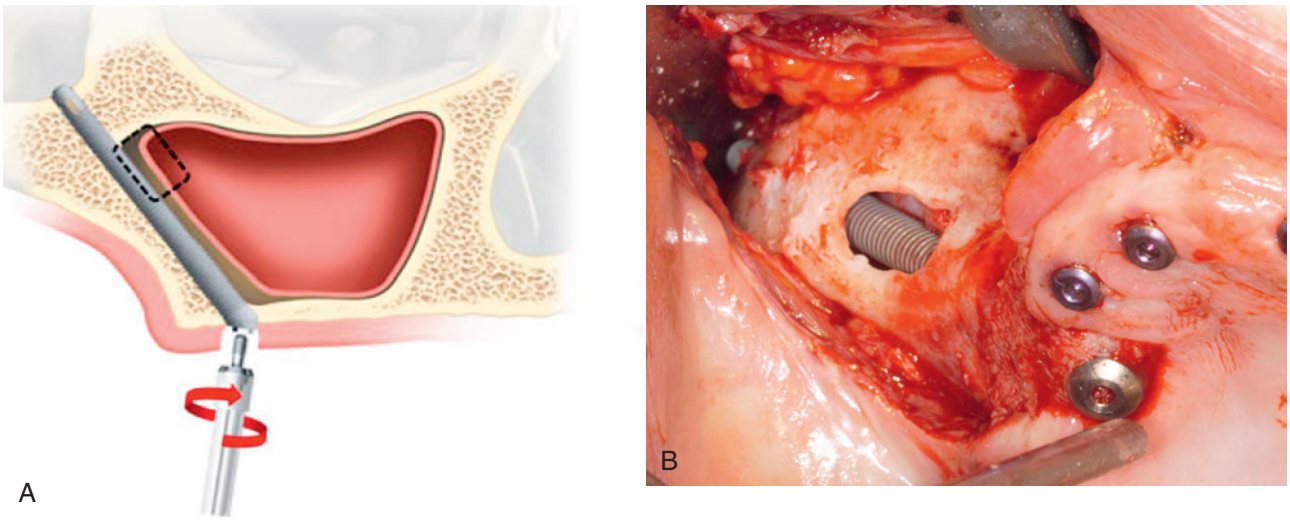
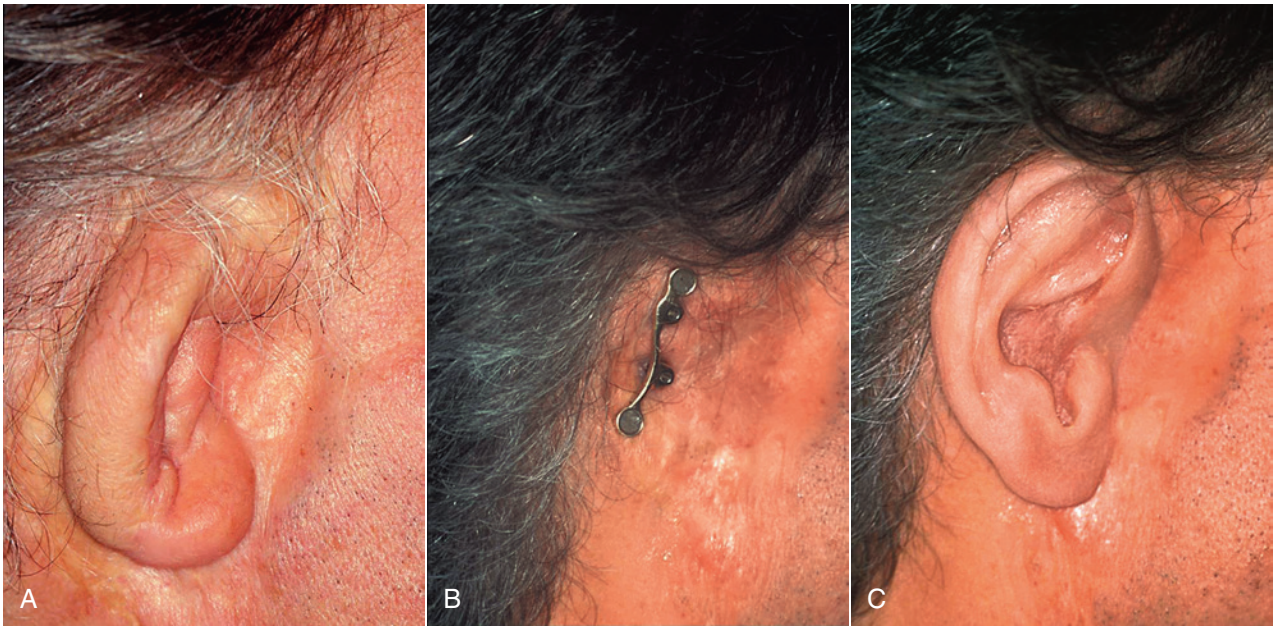
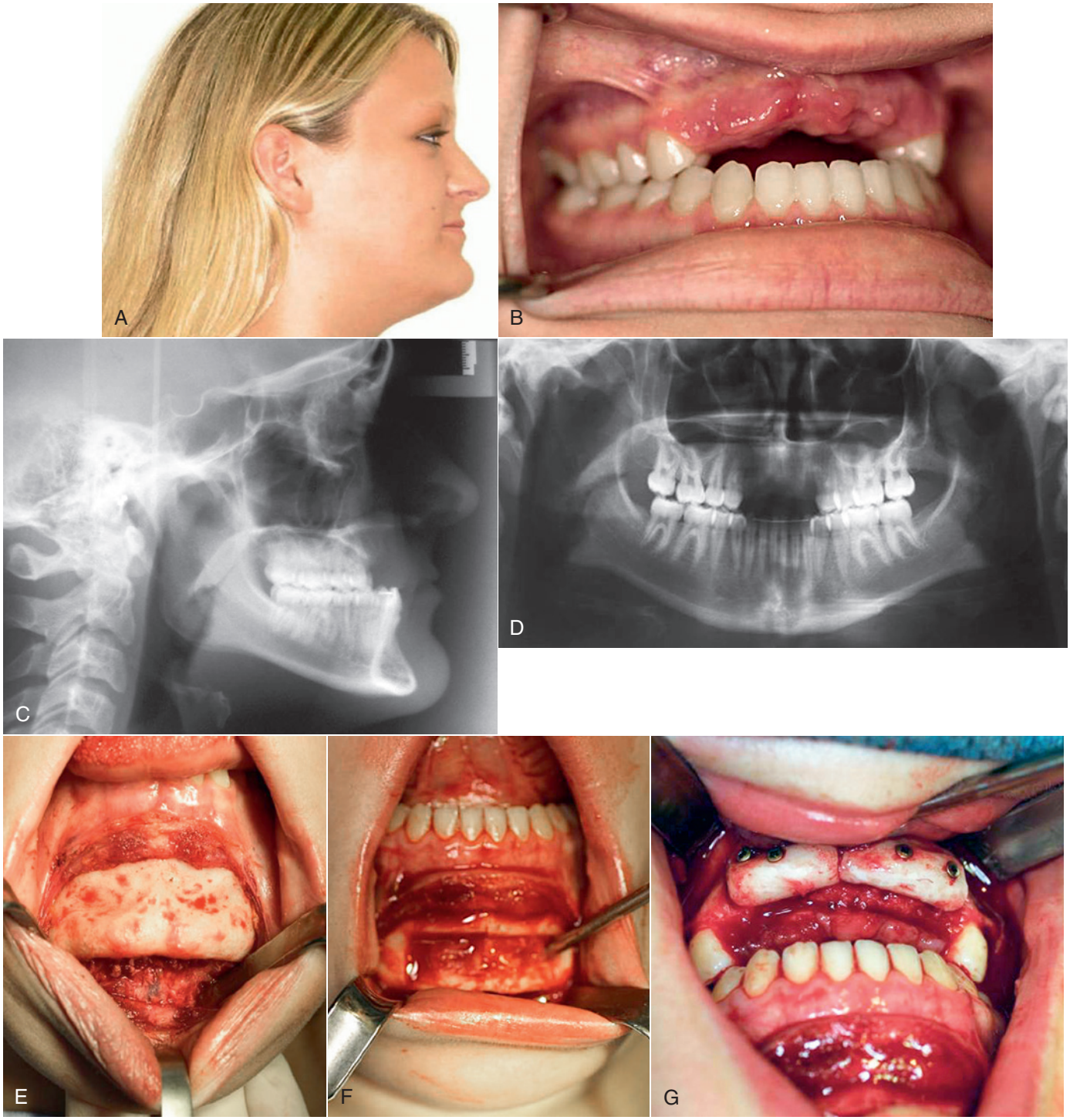


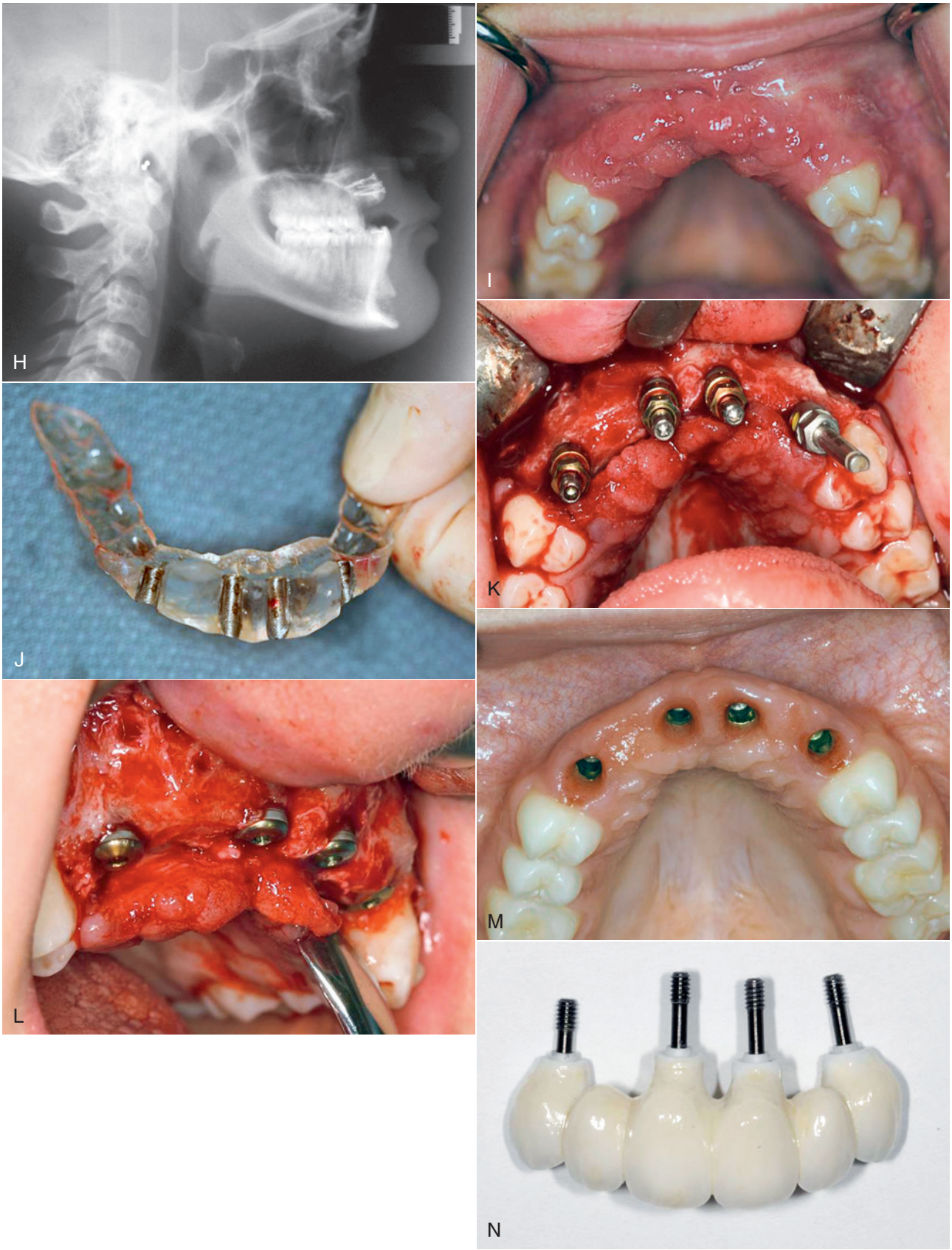
• **Fig. 15.13** Zygomaticus implant. (A) Diagram showing placement of zygomatic implant. The implant engages the body of the zygoma, medial alveolar ridge, and lateral aspect of the maxilla. (B) Clinical image of placement of the zygomatic implant. (A, Courtesy Nobel Biocare USA, Yorba Linda, CA.)



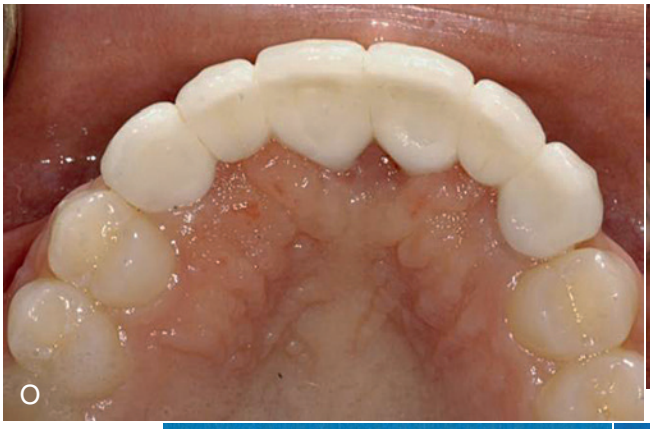
• **Fig. 15.14** (A) Congenitally absent ear with unsatisfactory autogenous reconstruction. (B) Endosseous implants placed into temporal bone with framework. (C) Implant-supported prosthetic ear. (Courtesy Dr. Peter Larsen.)

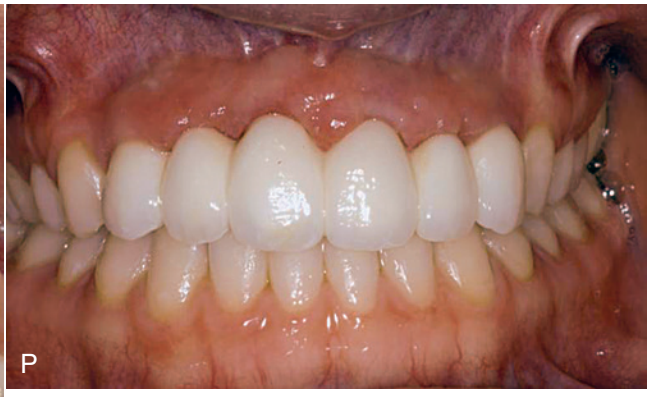


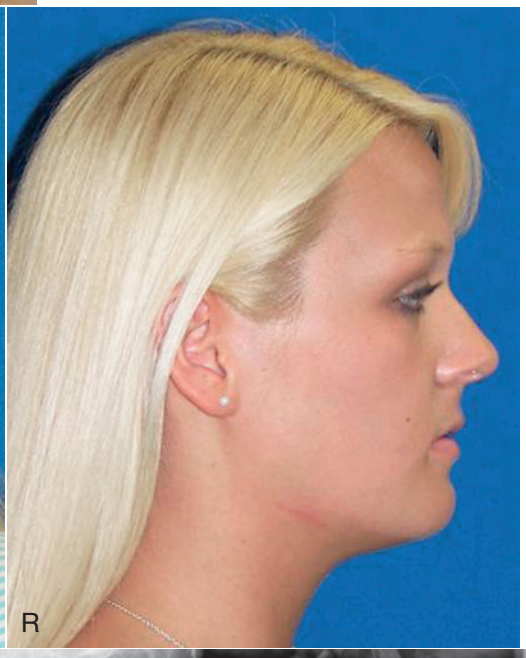
• **Fig. 15.15** Missing anterior teeth, requiring grafting and implant placement. (A) Preoperative patient profile. Note the midface deficiency. (B) Anterior maxilla after extraction of nonrestorable teeth. (C) Lateral cephalometric radiograph. Note the maxillary deficiency compared with the mandible. (D) Panoramic radiograph. (E) Surgical exposure of mandibular symphysis. (F) Bone harvest from mandibular symphysis. (G) Fixation of symphyseal bone harvest to the facial wall of the anterior maxilla. *Continued*

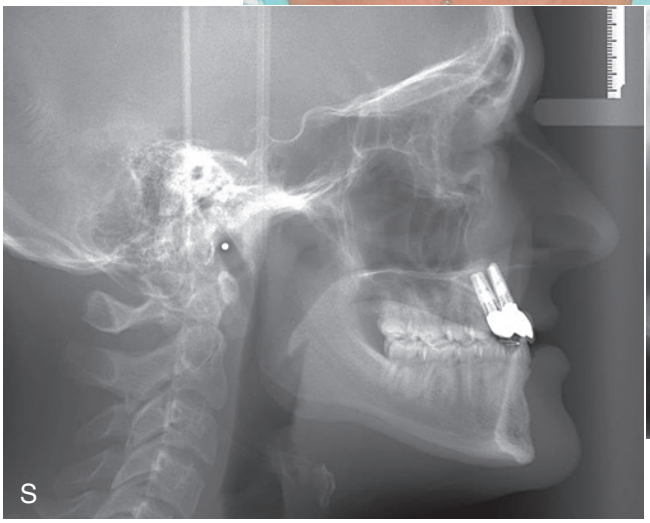


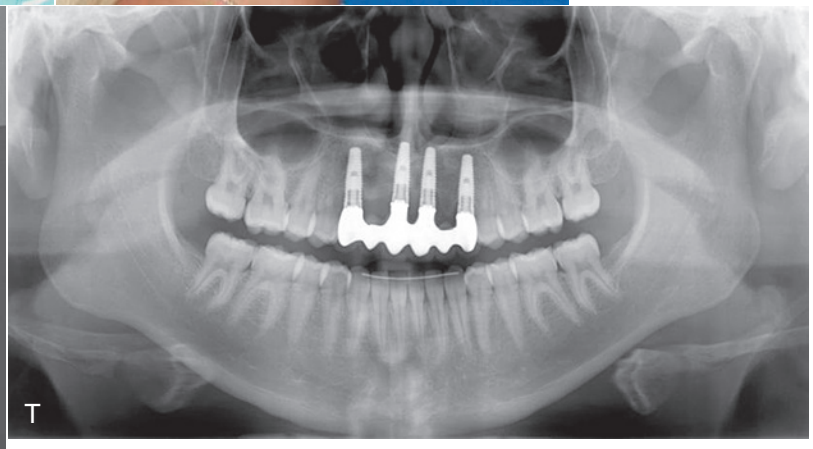
• **Fig. 15.15, cont'd** (H) Lateral cephalometric radiograph with the bone graft in place. (I) Occlusal view of the maxillary arch after grafting. (J) Surgical guide for implant placement. (K) Implants placed. (L) Implant cover screws placed for a two-stage healing process. (M) Healing abutment removed 6 months after implant placement. (N) An implant-supported, all-zirconia, screw-retained, fixed partial denture.



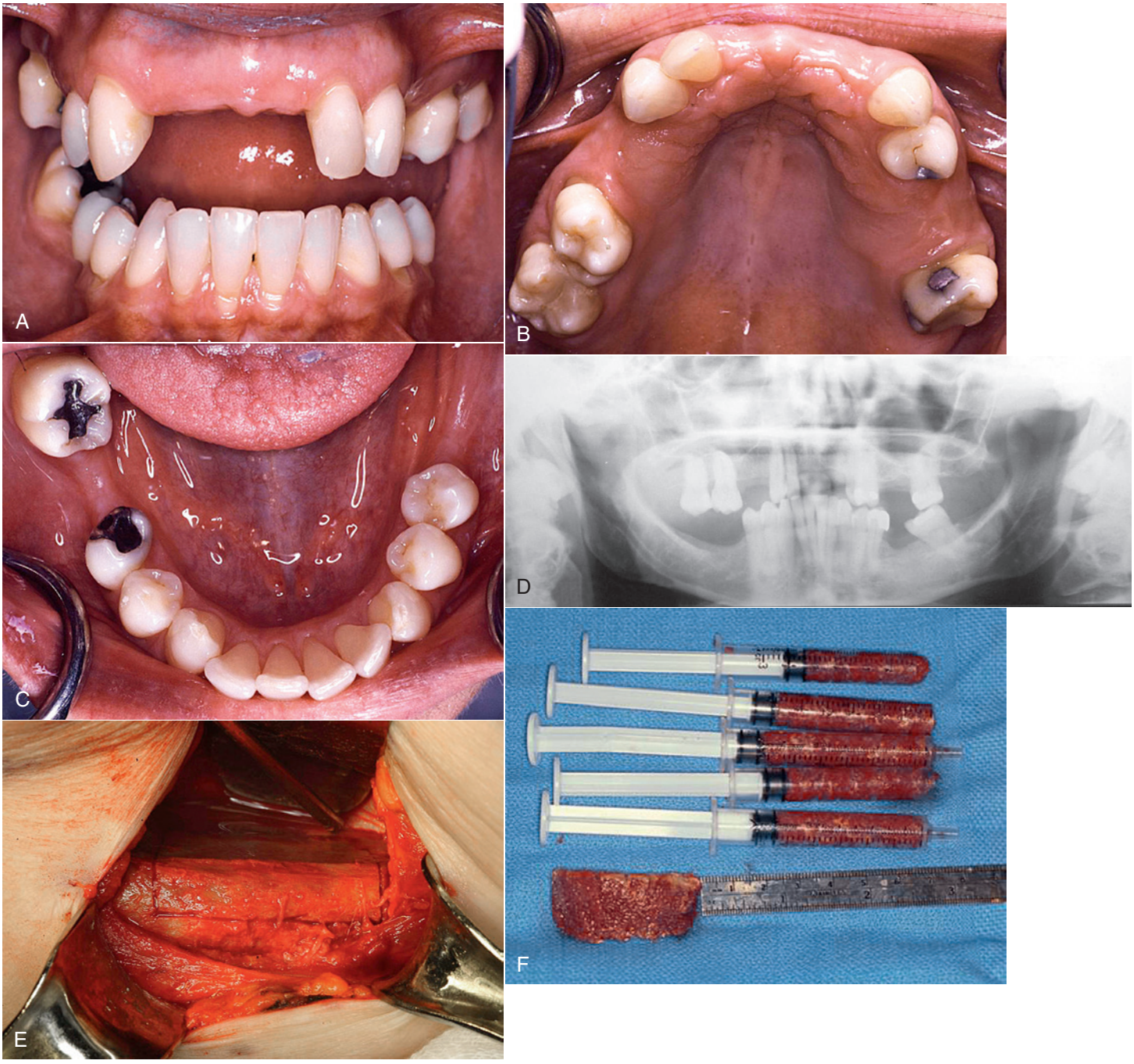




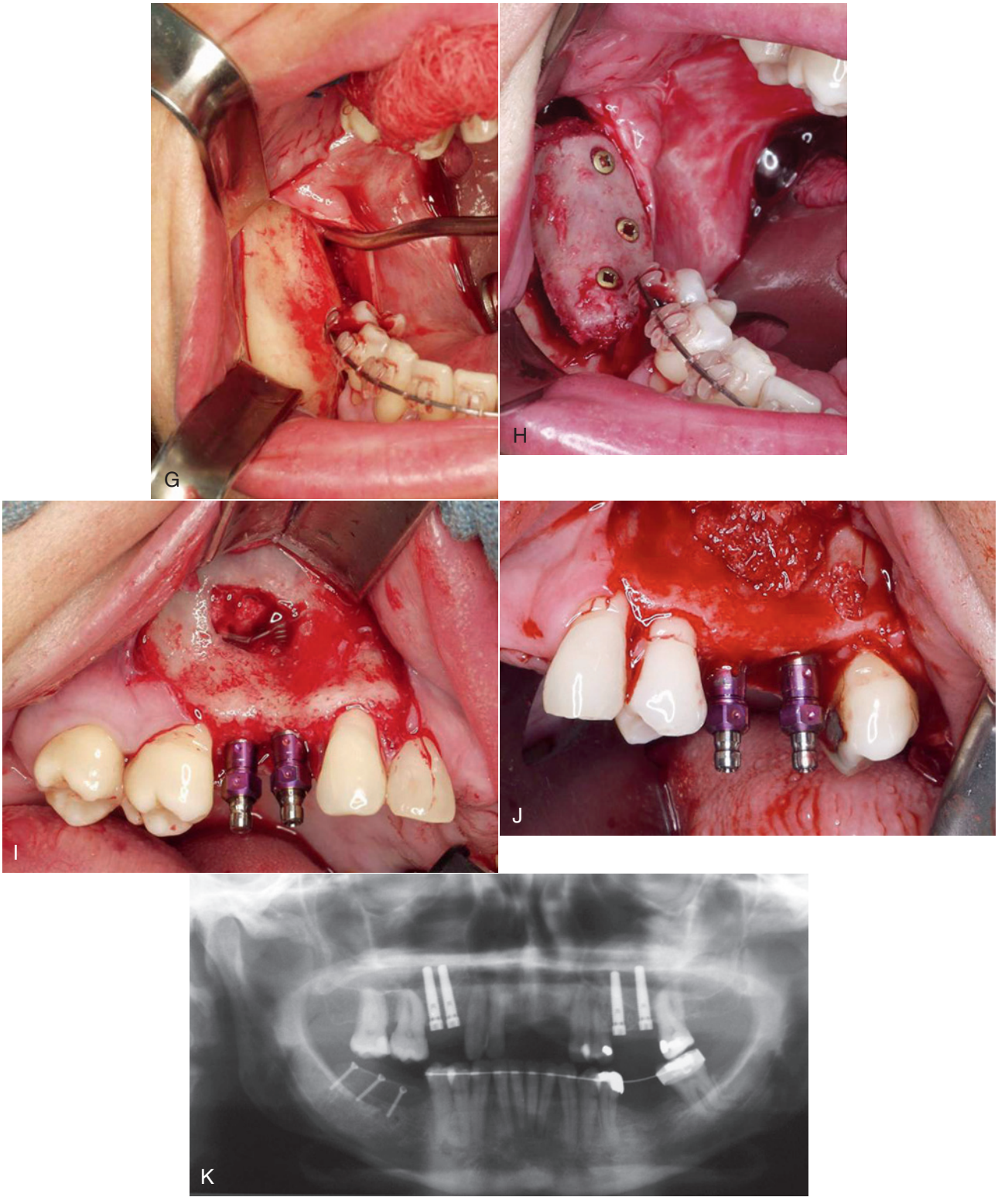




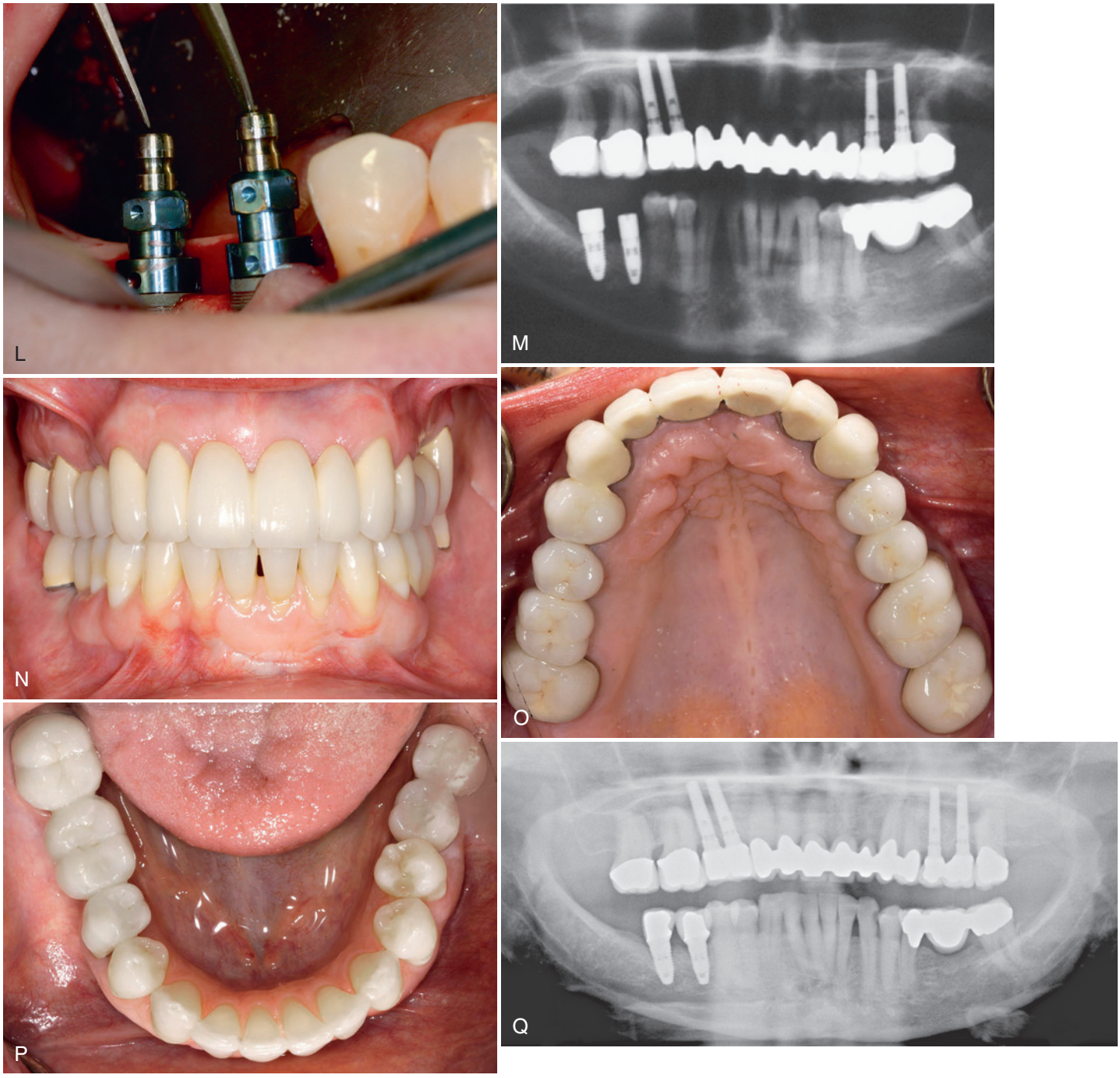
• **Fig. 15.15, cont'd** (O) Occlusal view of the final prosthesis in place. (P) Final prosthetic result. (Q) Final full-face photo. (R) Final profile photo. (S) Final lateral cephalometric radiograph. (T) Final panoramic radiograph.



• **Fig. 15.16** Edentulous spaces in maxilla and mandible augmented with autogenous grafting. (A) Preoperative frontal view. (B) Preoperative occlusal view of maxilla. (C) Preoperative occlusal view of mandible. (D) Preoperative panoramic radiograph. Note the pneumatized maxillary sinuses and atrophic posterior mandibular anatomy. (E) Iliac crest exposure and initiation of cortical bone harvest. (F) Cortical and cancellous bone harvested from iliac crest.



• **Fig. 15.16, cont'd** (G) Surgical exposure of atrophic posterior mandible. (H) Fixation of the cortical bone graft. (I) Simultaneous implant placement and sinus lift prior to placement of the bone graft. (J) Completion of the graft placement in the maxillary sinus. (K) Panoramic radiograph after grafting. *Continued*



• **Fig. 15.16, cont'd** (L) Mandibular implant placement. (M) Radiograph after placement of mandibular implants. (N) Frontal view of the completed prosthetics. (O) Occlusal view of the completed maxillary prosthetics. (P) Occlusal view of the completed mandibular prosthetics. (Q) Final radiograph.

• **Fig. 15.17** Maxillary defect from central giant cell granuloma resection reconstructed with bone morphogenetic protein (BMP), allogenic bone graft, and a titanium mesh crib. (A) Patient after resection of central giant cell granuloma with significant maxillary defect. (B) Postresection Panorex. (C) Preformed titanium mesh crib prepared and sterilized prior to surgery. (D) Fine titanium mesh contoured to an ideal alveolar ridge form and packed with BMP on absorbable collagen sponges (ACSs) with particulate bone. (This type of alveolar ridge reconstruction is an extended application or "off-label" use of the BMP.) (E) Packaging of the BMP. (F) View of the ACSs that have been impregnated with the sterilely reconstituted recombinant human BMP 2. After 15 minutes, the BMP becomes adherent to the moistened collagen sponges.

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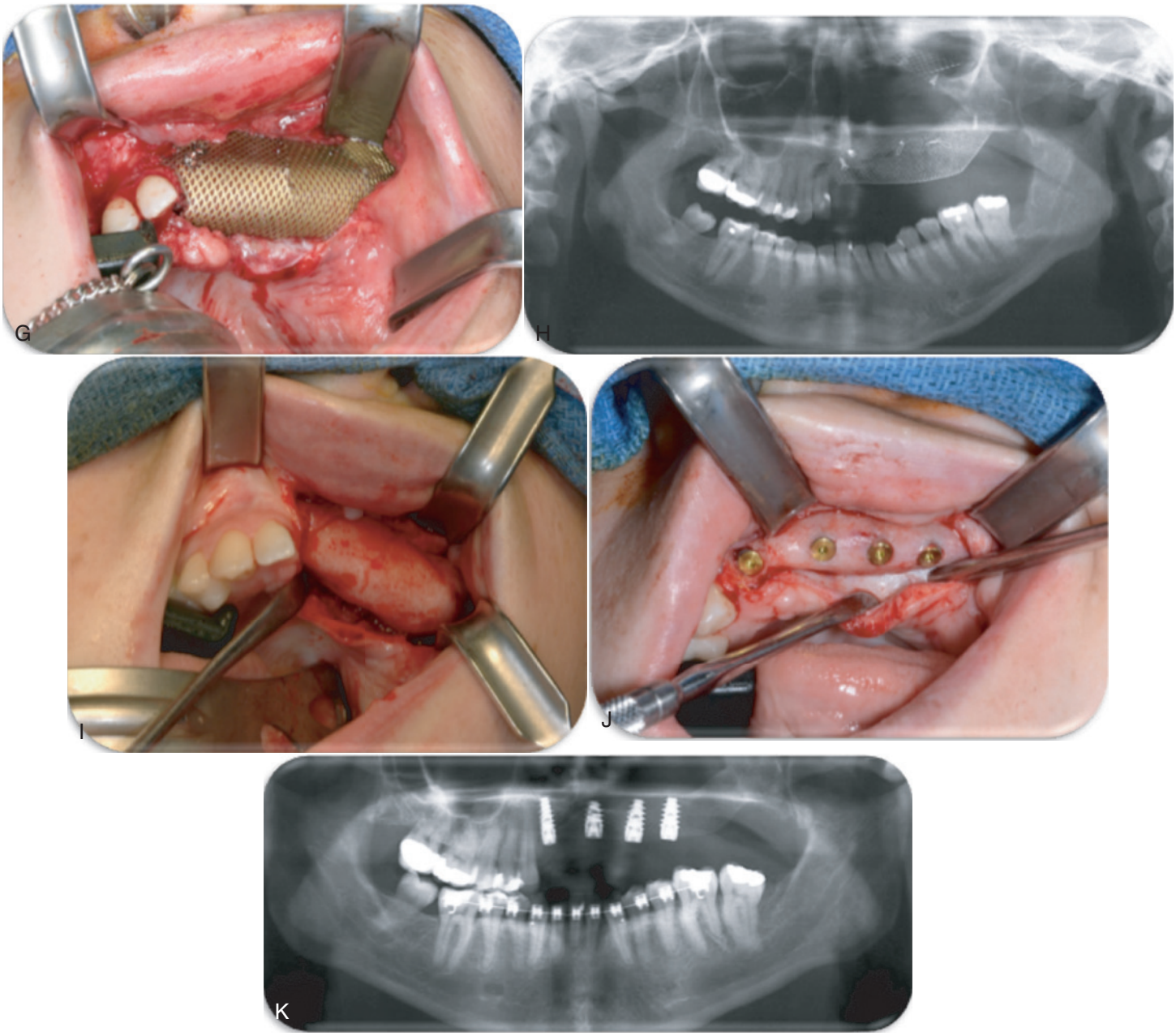
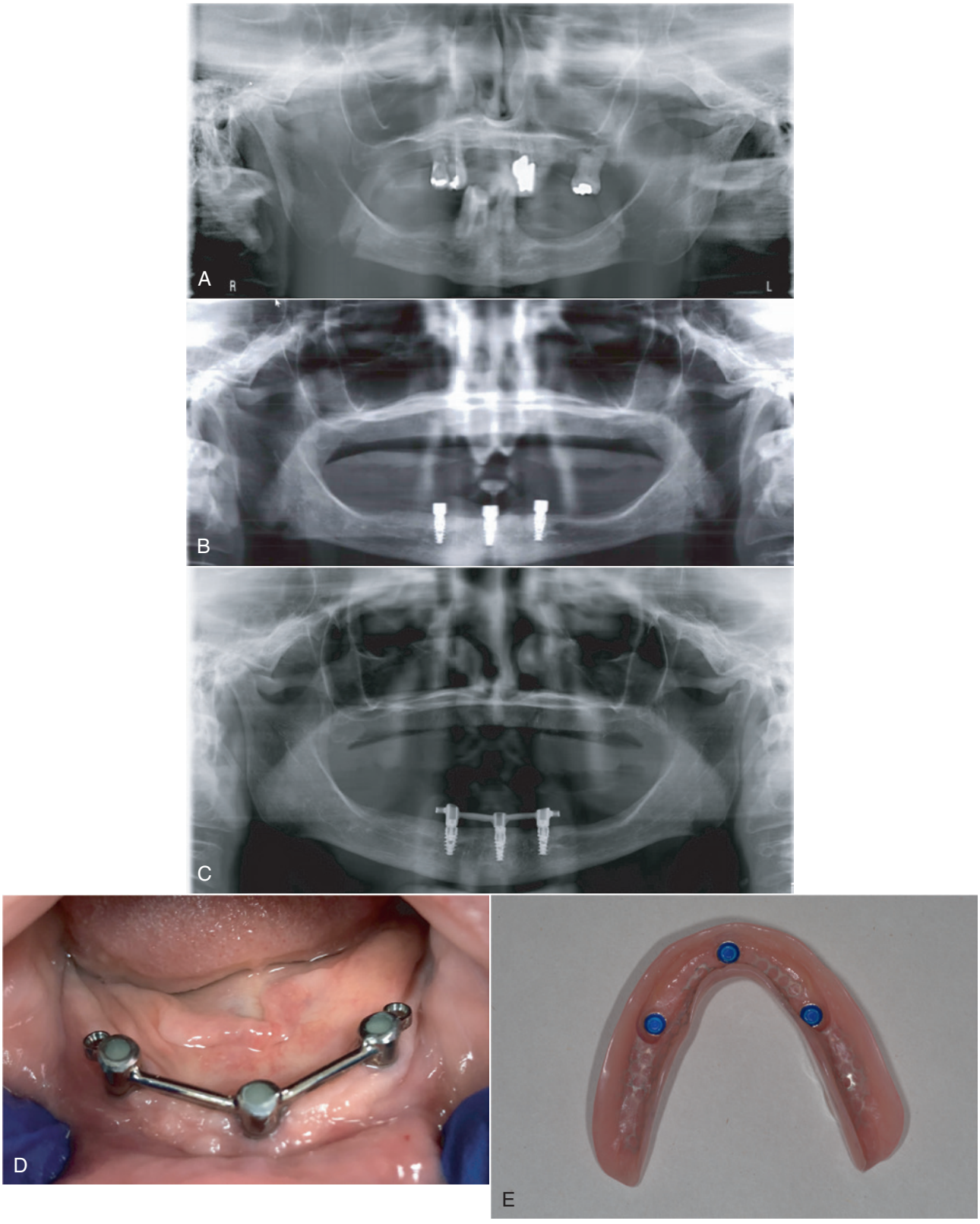
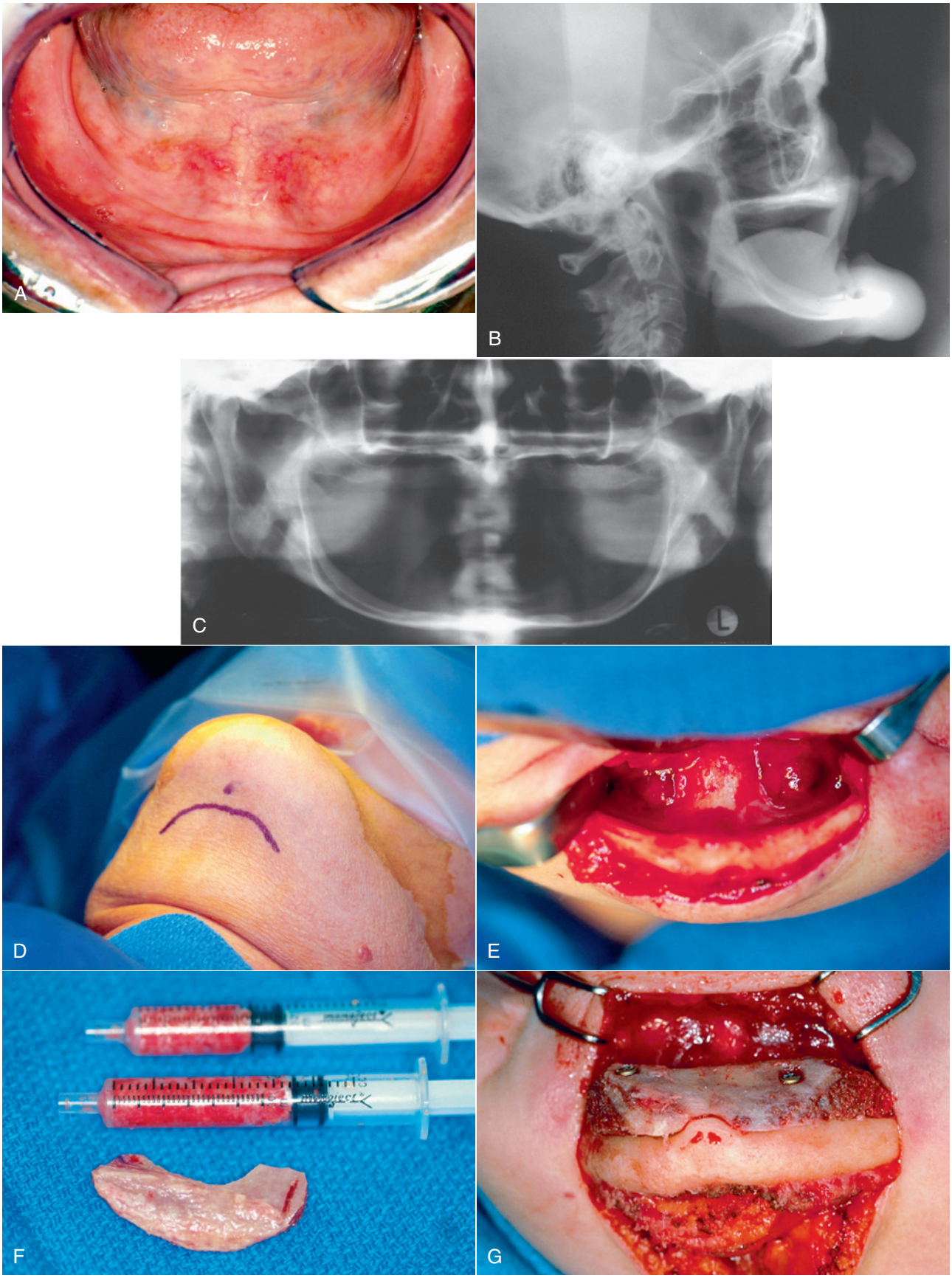


• **Fig. 15.17, cont'd** (G) The "titanium crib" is secured to the native ridge with 1.2-mm self-drilling screws. (H) Panorex image after the grafting procedure. Titanium crib and graft reestablishing normal alveolar ridge height. (I) View of the regenerated ridge at surgical reentry 9 months after grafting. (J) Placement of four dental implants into the regenerated ridge. (K) Panorex after implant placement. (L) Tissue healing under a temporary fixed prosthesis. (M) Screw retained zirconia hybrid framework with pink porcelain to replace gingival tissues.

• **Fig. 15.17, cont'd** (N) Individual cement-retained zirconia crowns. (O) Framework in place. (P) Final prosthesis in place with cement-retained crowns.



• **Fig. 15.18** Failed maxillary and mandibular dentition with moderate atrophy of the mandible treated with conventional maxillary denture and mandibular overdenture. (A) Pretreatment Panorex. (B) Placement of three mandibular implants. (C) Panorex of titanium bar splinting three implants. (D) Implant-supported milled titanium bar with attachments. (E) View of the intaglio surface of the metal-reinforced final overdenture with attachments.



• **Fig. 15.19** Severely atrophic edentulous mandible treated with anterior iliac crest bone grafting. (A) Initial clinical image of severely atrophic mandible. (B) Lateral cephalometric radiograph. (C) Panorex showing extreme atrophy of entire mandible. (D) Extraoral approach for bone grafting. (E) Exposure of anterior mandible. (F) Autogenous bone harvested from the iliac crest. The graft includes a corticocancellous block as well as additional marrow. (G) Grafts in place.

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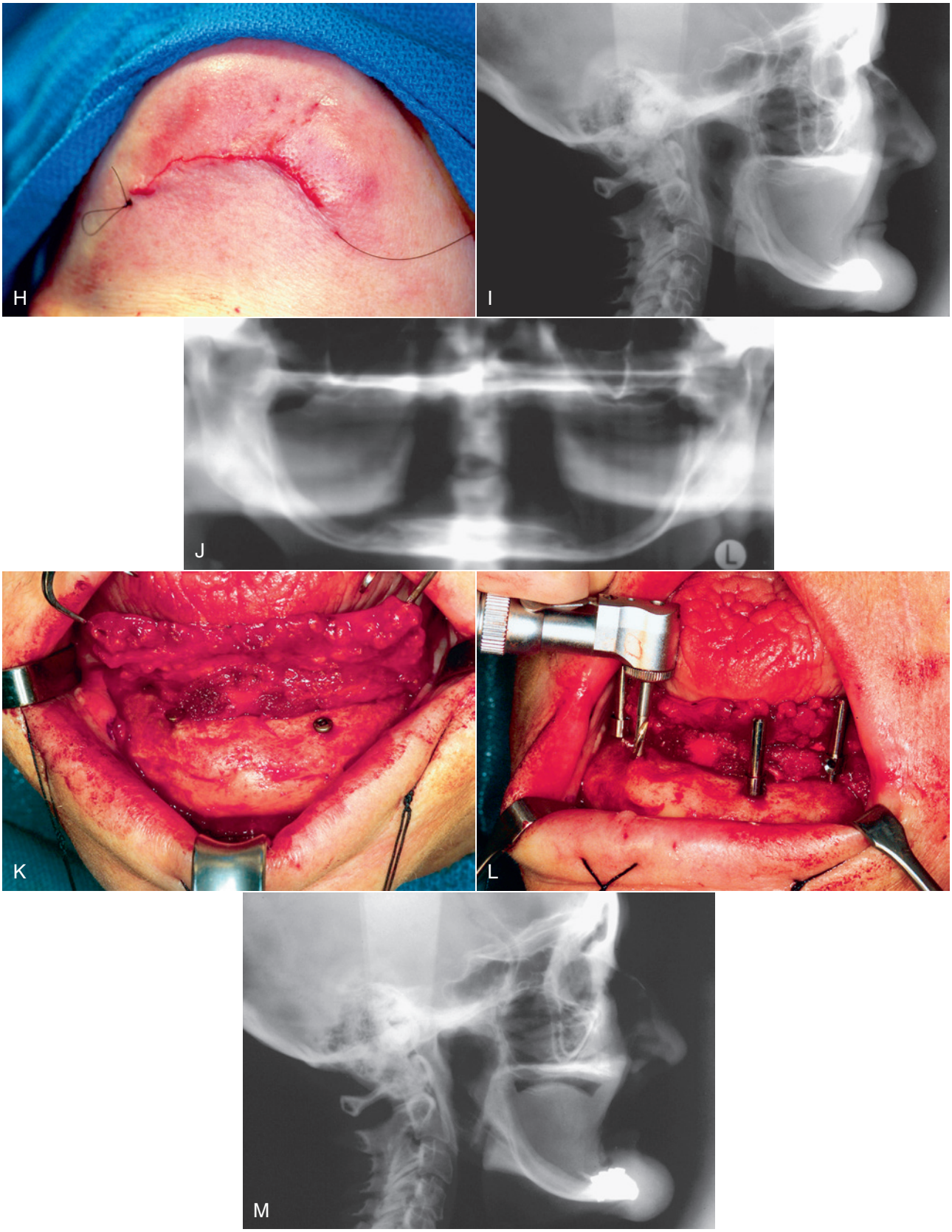
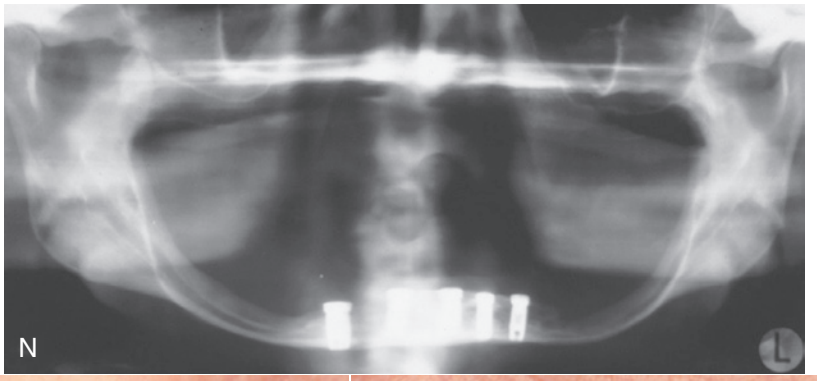
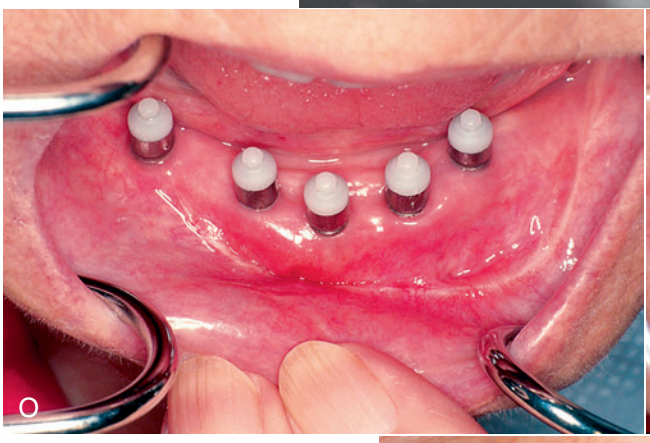
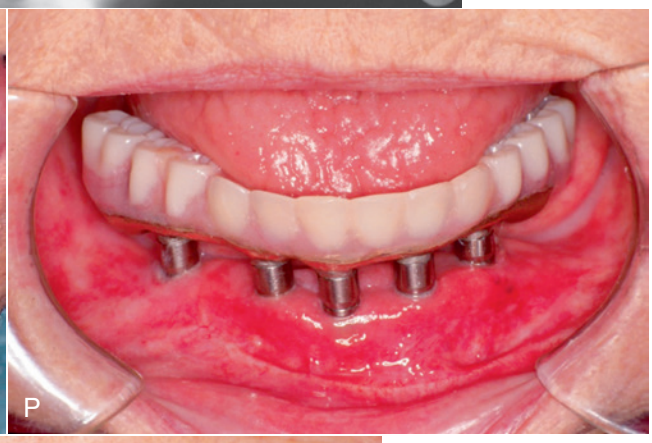
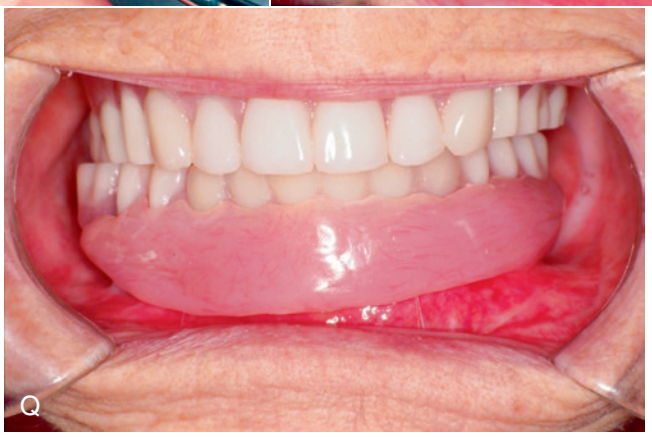


• **Fig. 15.19, cont'd** (H) Wound closure. (I) Cephalometric radiograph after grafting. (J) Panorex radiograph after graft placement. (K) Intraoral exposure of anterior mandible at time of implant placement. (L) Placement of implants. (M) Cephalometric radiograph after implant placement.

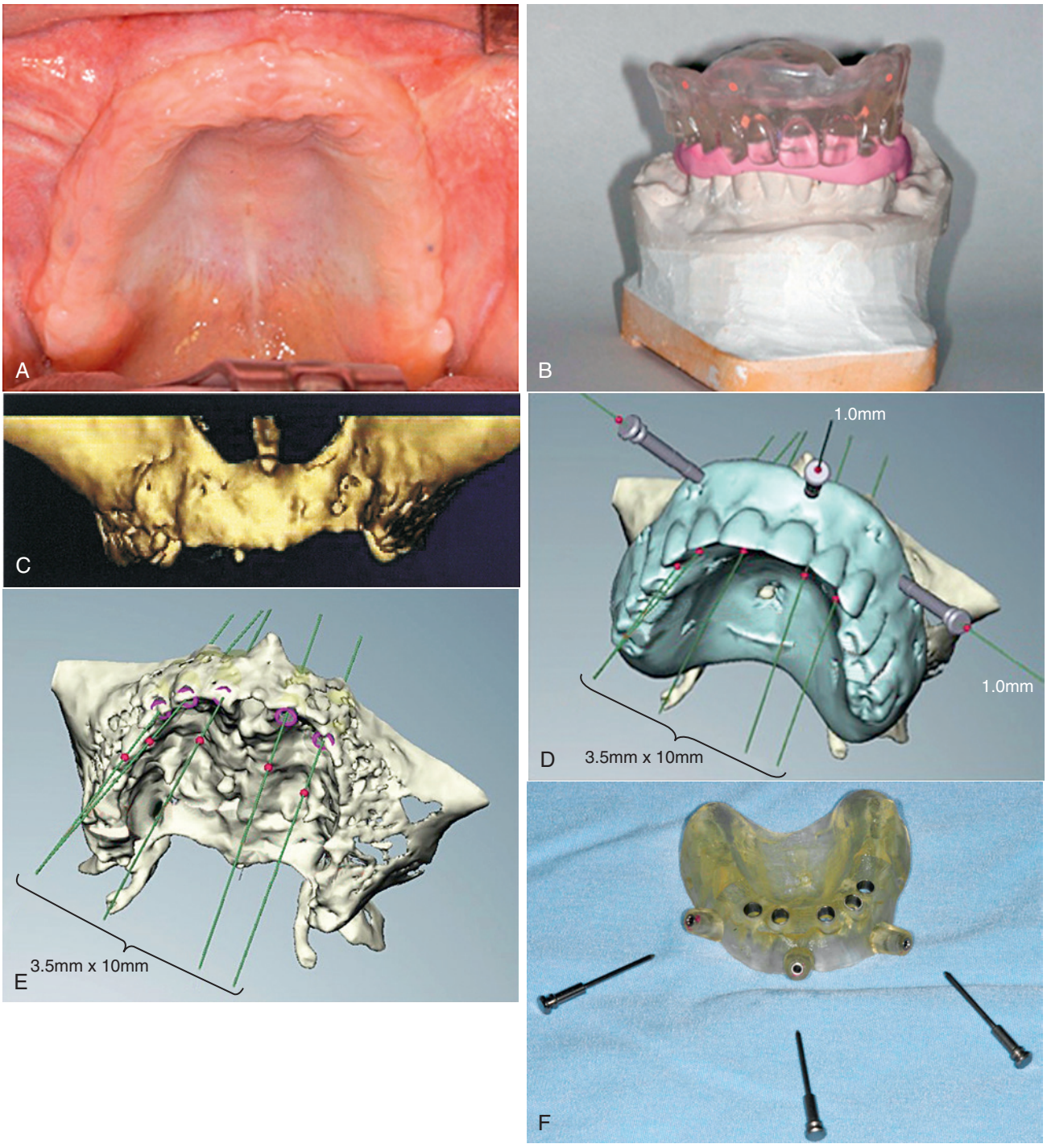




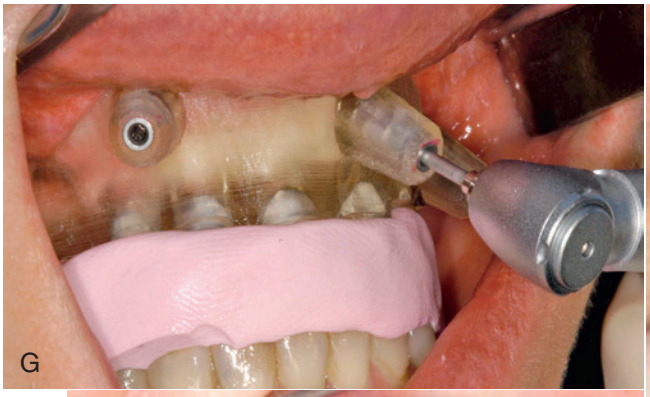


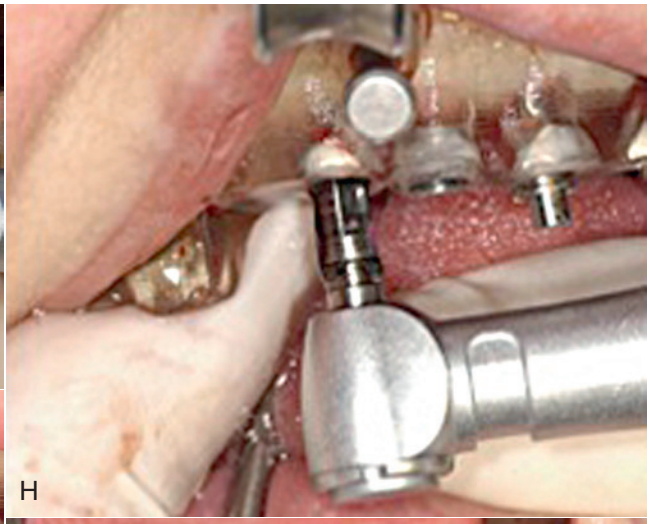


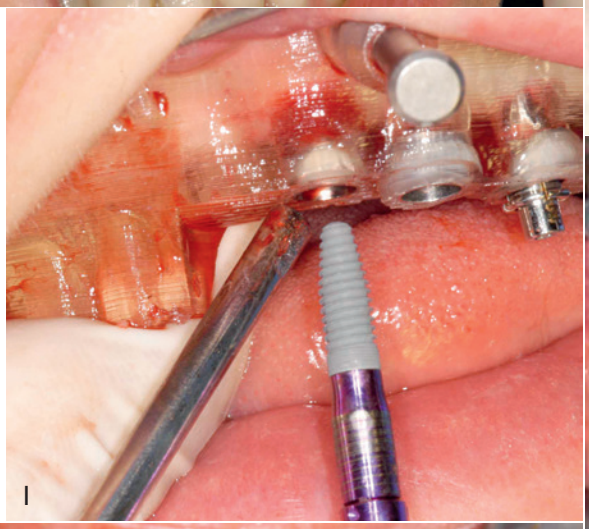
• **Fig. 15.19, cont'd** (N) Panorex after implant placement. (O) Implants uncovered, ready for restoration. (P) Prosthesis totally supported by implants. The prosthesis is elevated due to increased interarch space resulting from maxillary and mandibular atrophy. (Q) Prosthetic overlay to fill space between mucosa and prosthesis and to add support to lower lip area.

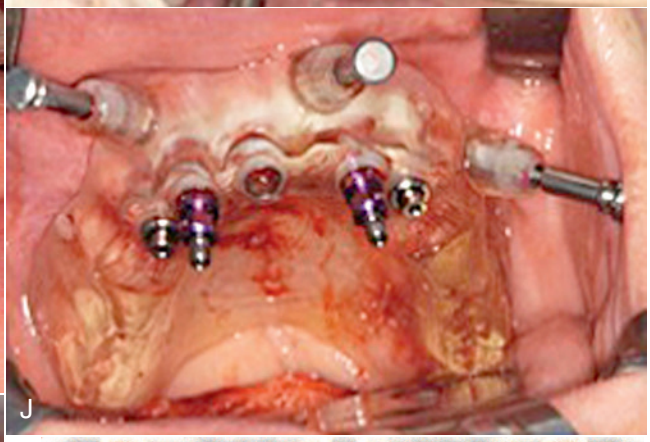


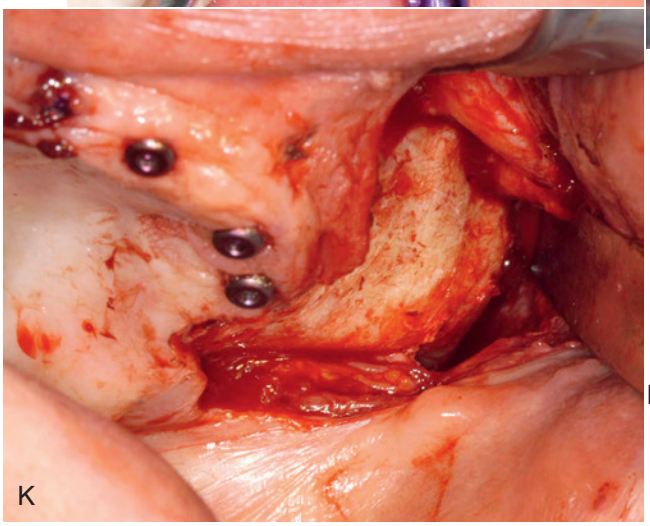
• **Fig. 15.20** Nonrestorable maxillary dentition restored with conventional anterior implants and posterior zygomaticus implants. (A) Occlusal view of edentulous maxilla. (B) Radiographic guide (duplicated from the approved transitional denture) and bite registration. (C) Three-dimensional reconstruction of edentulous maxilla. (D) Virtual planning for implant placement in edentulous maxilla with the simulated prosthesis in place. (E) Virtual implant placement. (F) Surgical guide and fixation pins.

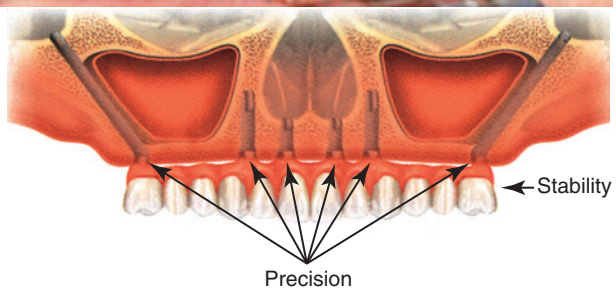








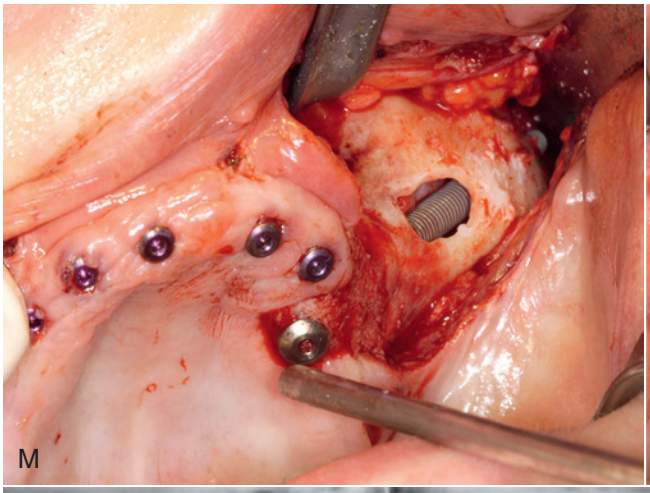


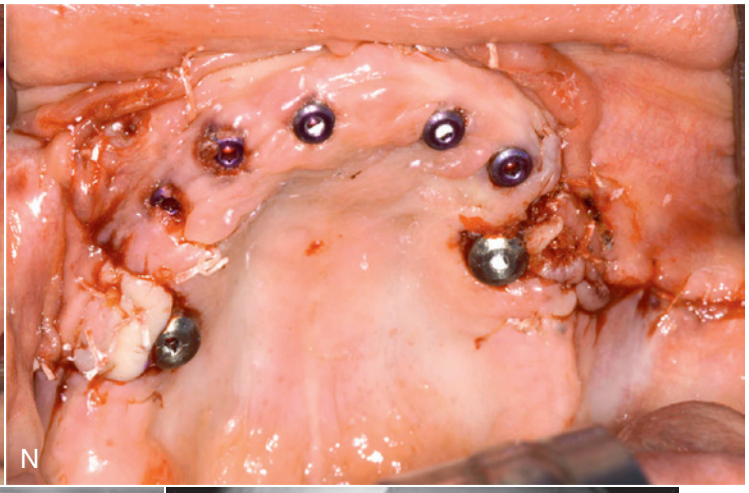


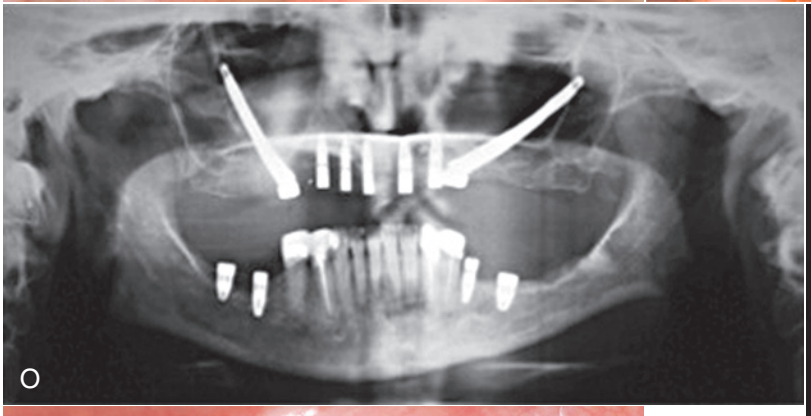
L

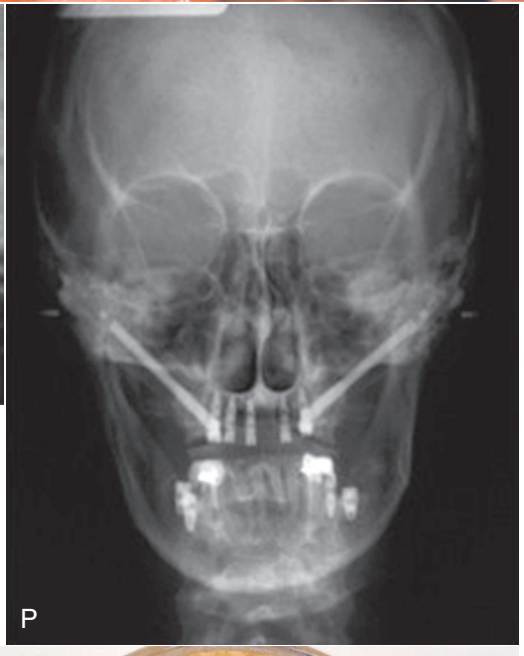
Stability in the bridge framework
Precision in the connecting screw joints

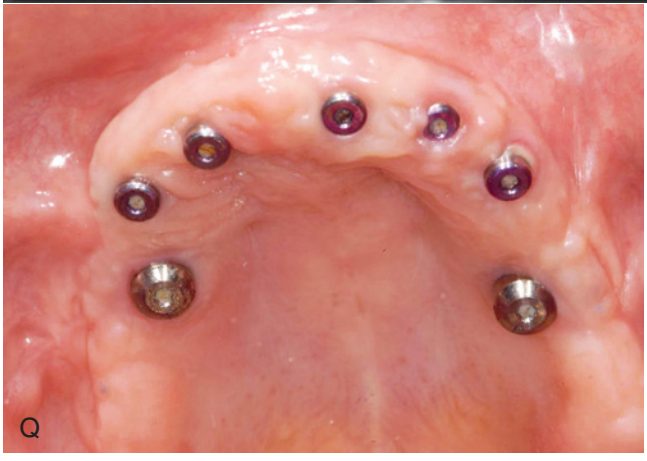
• **Fig. 15.20, cont'd** (G) Surgical guide in place with bite registration and insertion of fixation pins. (H) Surgical guide in place with mixture mounts. (I) Implant drill preparing osteotomy. (J) Placement of the implant. (K) Surgical exposure for placement of the zygomaticus implant. (L) Diagram of the intended surgery—a combination of zygomaticus implants and endosseous implants. *Continued*

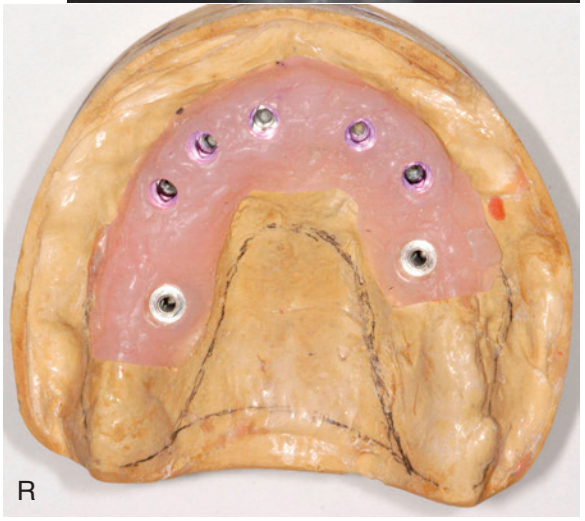




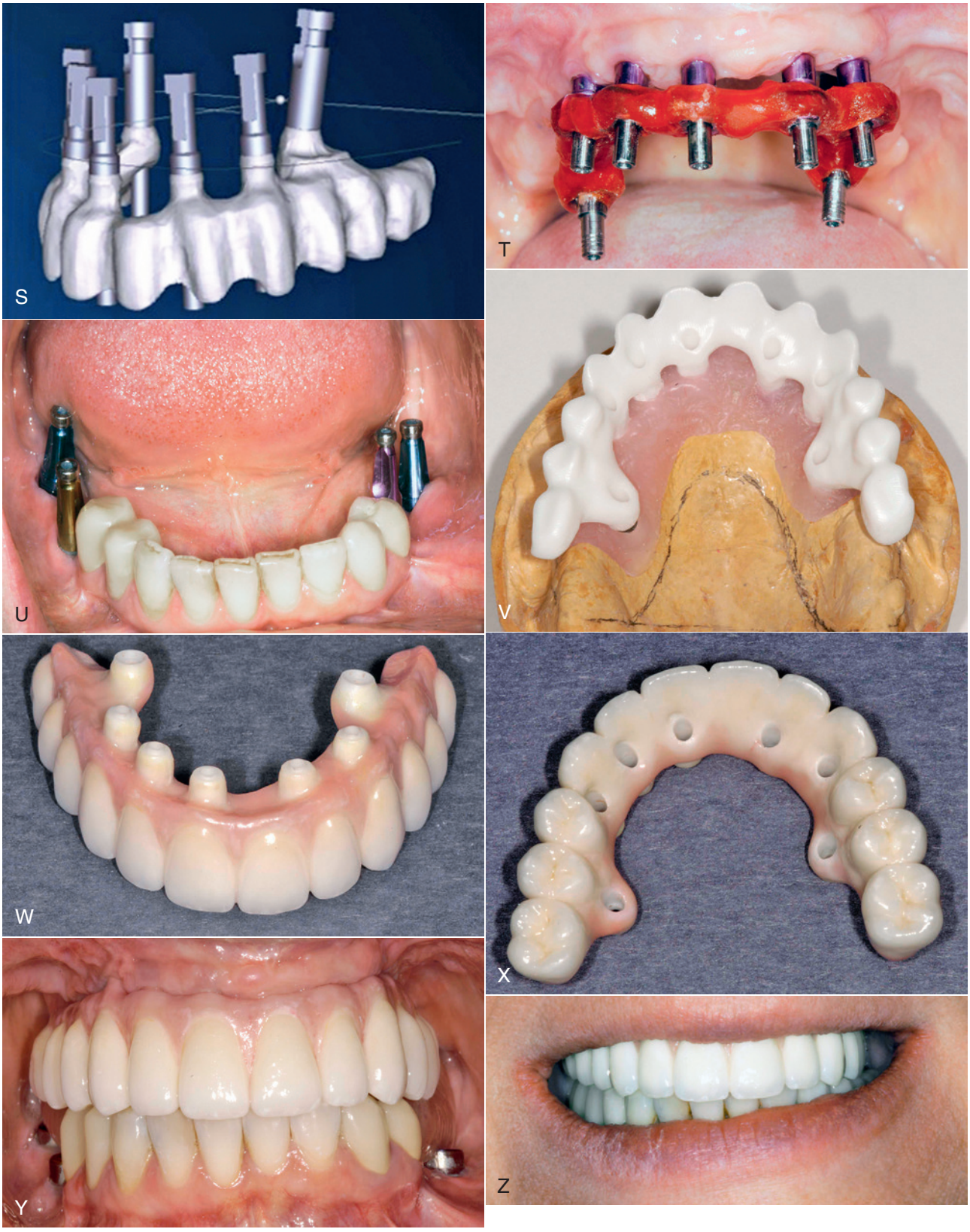








• **Fig. 15.20, cont'd** (M) Placement of zygomaticus implant. (N) Immediately after surgery, after placement of all implants. (O) and (P) Radiographs of implants placed. (Q) Occlusal view of maxilla after 6 months of healing. (R) Laboratory cast of maxilla.



• **Fig. 15.20, cont'd** (S) Computer design of planned zirconia framework for hybrid prosthesis. (T) Preparation for an open-tray transfer impression. (U) Impression transfers in place for impression of mandible. (V) Computer-aided design and computer-aided manufacturing zirconia framework. (W) and (X) Completed porcelain to zirconia hybrid prosthesis. (Y) Completed prosthetics. (Z) Patient's smile at completion of treatment. (L, Courtesy Nobel Biocare USA, Yorba Linda, CA.)

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PART IV

Infections

Odontogenic infections are generally caused by a mix of bacteria that have a propensity to cause abscess formation. In addition, the roots of the teeth provide a pathway for infecting bacteria to enter the deep tissues of the periodontium and periapical regions. Therefore odontogenic infections cause deep-seated abscesses, and they almost always require some form of surgical therapy. Treatments range from endodontic therapy and gingival curettage to extraction, incision, and drainage of the deep fascial spaces of the head and neck. Antibiotic therapy is usually only an adjunctive treatment to the required surgery. Prophylactic antibiotic therapy may prevent distant infections caused by bacteremias arising from oral-maxillofacial surgical procedures; such therapy may also prevent some postoperative wound infections. This section presents the principles of management and prevention of infections in dental patients.

Chapter 16 describes the basic management techniques, including surgery and antibiotic administration, in the treatment of odontogenic infections. This chapter also discusses the principles of antibiotic prophylaxis for the prevention of wound infection and distant metastatic infection such as infectious endocarditis.

Chapter 17 presents an overview of complex odontogenic infections that involve the deep fascial spaces, which may necessitate hospitalization of the patient. Osteomyelitis and other unusual infections are also discussed.

Chapter 18 presents the indications, rationale, and technical aspects of surgical endodontics. Although periapical surgery is occasionally necessary for successful endodontic management, it is necessary for the clinician to choose this treatment modality wisely. Therefore the discussion of the indications and contraindications for endodontic surgery is extensive, and the technical aspects of surgical endodontics are well illustrated.

Chapter 19 presents information about patients at risk for infection and other problems that are caused by compromise of the patient's host defense as a result of radiotherapy or cancer chemotherapy. These patients are susceptible to a variety of problems, and the prevention and management of these problems are discussed.

Chapter 20 describes maxillary sinus problems that arise from odontogenic infections and other problems. General practitioners need to be able to recognize these problems because symptoms of sinus disease often mimic or even accompany odontogenic infections. Dentists may have to provide diagnoses in order to properly refer these patients to the appropriate health care professional for definitive care.

Finally, Chapter 21 discusses salivary gland diseases, primarily the obstructive and infectious types. The major diagnostic and therapeutic modalities used in managing these problems are presented.

16

Principles of Management and Prevention of Odontogenic Infections

MICHAEL D. HAN, MICHAEL R. MARKIEWICZ, AND MICHAEL MILORO

CHAPTER OUTLINE

Odontogenic infections are commonly encountered clinical problems that may have serious consequences if not managed promptly and properly. Although a wide range of clinical practitioners, including emergency medicine and primary care physicians and nurse practitioners, encounter odontogenic infections, the role of the dentist is crucial and indispensable. It is imperative to thoroughly understand the pathogenesis and natural progression of infections in the head and neck region and be able to recognize risk factors, as well as signs and symptoms of each stage of progression, to render proper diagnosis and management, *regardless of one's level of training or expertise.* It is equally crucial to understand that *management of odontogenic infections is primarily surgical in nature.*

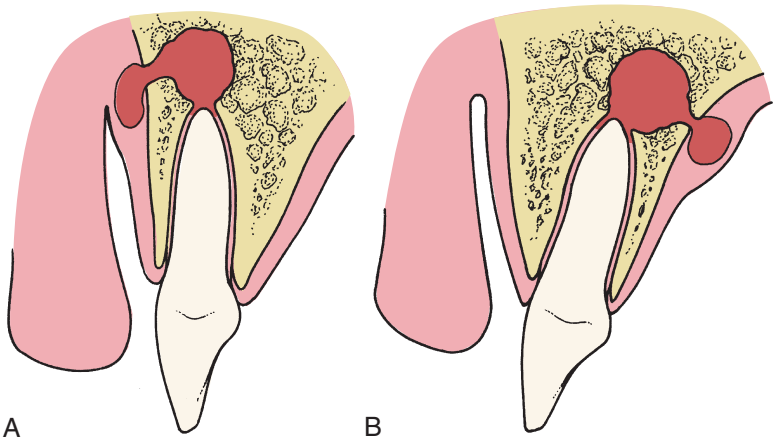
This chapter focuses on two broad sections. The first discusses the microbiology and pathophysiology of odontogenic infections, along with basic principles of nonsurgical and surgical management. Special emphasis is placed on the general dentist's role in the management of odontogenic infections. The second section focuses on recognition and prevention of odontogenic infections, specifically on prophylactic antibiotic therapy that may be indicated in various clinical scenarios.

Microbiology of Odontogenic Infections

Odontogenic infections are primarily caused by normal oral bacterial flora, which include aerobic and anaerobic gram-positive cocci and anaerobic gram-negative rods. Odontogenic infections are almost invariably polymicrobial, involving multiple bacteria, and the identification of a single primary organism is usually not possible via routine culture and sensitivity testing. Approximately 50% to 60% of all odontogenic infections involve a combination of both aerobic and anaerobic bacteria.

The most commonly isolated aerobic bacteria from odontogenic infections are the *viridans*-type *Streptococci*. These bacteria are facultative organisms that possess the ability to survive with or without oxygen. These bacteria are believed to initiate the progression of a superficial infection into the deeper tissues. The most commonly isolated anaerobic bacteria from odontogenic infections include *Bacteroides* spp., followed by *Prevotella* and *Peptostreptococcus* spp. (Table 16.1).

Once bacteria infiltrate the deeper soft tissues, they penetrate throughout the fascial spaces, or potential spaces, and spread by producing *hyaluronidase,* an enzyme that cleaves hyaluronic acid and allows the spread of the infection through the subcutaneous

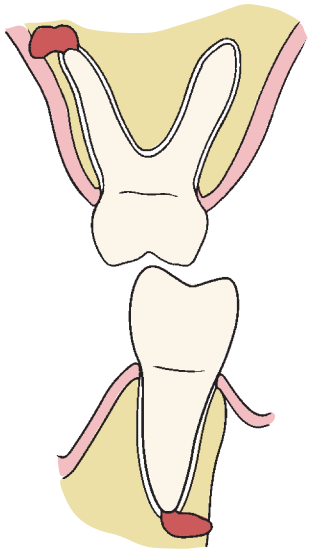


• **Fig. 16.1** (A) Periradicular infection in a maxillary incisor with the root apex close to the facial bone results in erosion of the facial cortex and vestibular abscess. (B) Maxillary incisor with the root apex closer to the palatal cortex, increasing the likelihood of palatal cortical erosion and palatal abscess.

TABLE 16.1 Major Organisms Isolated in Odontogenic Infections

Organism	Occurrence
Aerobic	
Staphylococcus aureus	20%
Coagulase-negative staphylococci	10%
Streptococcus viridans	45%
Corynebacterium spp.	5%
Pseudomonas aeruginosa	5%
Anaerobic	
Prevotella	30%
Bacteroides	30%
Peptostreptococcus	20%
Porphyromonas	5%

Data from Bahl R, Sandhu S, Gupta M. Odontogenic infections: microbiology and management. *Contemp Clin Dent.* 2014;5(3):307–311.



• **Fig. 16.2** Periapical infections arising from mandibular molars generally erode through the lingual cortex (left), whereas infections from maxillary molars generally erode through the thin buccal cortex (right).

tissues. As the infection spreads into the deeper tissues, byproducts of bacterial metabolism create an acidic environment, facilitating the growth of anaerobes. As anaerobes predominate, there is further tissue breakdown and liquefaction necrosis as well as the breakdown of white blood cells (WBCs). This results in microabscesses, which may coalesce and clinically manifest as an *abscess*. In addition, the pressure from the expanding abscess increases the hydrostatic pressure on the surrounding blood vessels, preventing compromising blood flow leading to ischemia, and thereby further increasing the zone of necrosis within the abscess cavity.

Pathophysiology of Odontogenic Infections

Odontogenic infections, as the term implies, arise from tooth-related endodontic or periodontal sources. These etiologies may include a necrotic pulp from a carious or fractured tooth, pericoronitis from a partially impacted tooth, or deep periodontal pockets. Regardless of the source, when inadequately managed, an infection will progress and spread through *the path of least resistance*. For an odontogenic infection of endodontic origin, the infection in the periradicular region will gradually erode through the facial or lingual cortex of the bone of the maxilla or mandible. The location of this erosion through bone largely depends upon the faciolingual location of the source of the infection, as well as the thickness of the cortical bone (Fig. 16.1). For example, an odontogenic infection arising from a necrotic pulp of a mandibular molar will generally erode through the lingual cortex, because the apices of these teeth tend to be on the lingual aspect of the mandible and the cortex tends to be thinner on the lingual than on the buccal surface (Fig. 16.2). Infection from a necrotic pulp of a maxillary molar will tend to erode through the facial cortex because the facial bone is thin, which offers little resistance to erosion, and represents the path of least resistance.

Once the infection erodes through bone, it continues to spread through the path of least resistance via potential spaces. These spaces, as the term implies, are not actual "spaces" that exist in

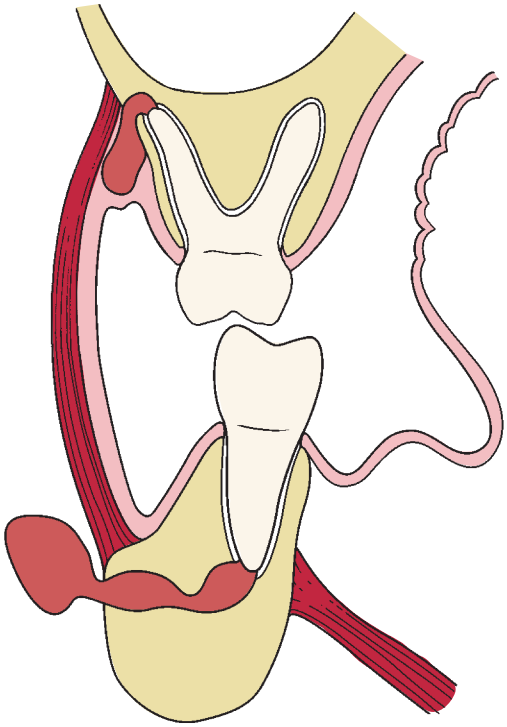
healthy tissues; they are only created when infiltrated by an infection or surgical manipulation. The location of the involved potential space depends primarily on the location of the bony erosion relative to adjacent muscle attachments on the bone. When the erosion is superior (or cranial, or coronal) to the buccinator muscle attachment, infection will involve the vestibular space in the mandible; it will involve the buccal space in the maxilla if the cortical perforation occurs facially (Fig. 16.3). When the facial erosion is inferior (or caudal, or apical) to the buccinator attachment, infection will involve the buccal space in the mandible, and the vestibular space in the maxilla. When the erosion is lingual, involvement of the palatal space (maxilla) or sublingual space (mandible) will occur. For the mandible, a lingual perforation superior to the mylohyoid muscle will lead to the sublingual space, and to the submandibular space if inferior to the mylohyoid muscle (Fig. 16.4). Such infections will invariably progress to deeper spaces unless managed promptly and properly. Infections of periodontal origin will seldom involve severe bony erosion, and will typically spread directly through these potential spaces.

When infections reach the soft tissues, it generally manifests in four stages: inoculation (edema), cellulitis, abscess, and resolution (Table 16.2). The *inoculation (edema) stage* refers to the stage in which the invading bacteria begin to colonize and typically occurs in the first 3 days of onset of symptoms. This stage is characterized by diffuse, soft, doughy red swelling that is mildly tender. The *cellulitis stage* occurs between days 3 and 5 and represents the intense inflammatory response elicited by the infecting mixed microbial flora. This stage is characterized by poorly defined diffuse firm red swelling that is exquisitely painful to palpation. As the infection evolves and anaerobes begin to predominate, liquefaction of tissues occurs with the formation of purulence, which is the hallmark of the *abscess stage*. As purulence is formed, the swelling and redness become better defined and localized, and the consistency changes from firm to fluctuant. When an infection is drained, either spontaneously or via surgery, the host defense mechanism destroys the involved bacteria and healing begins to occur; this is the hallmark of the *resolution stage*.

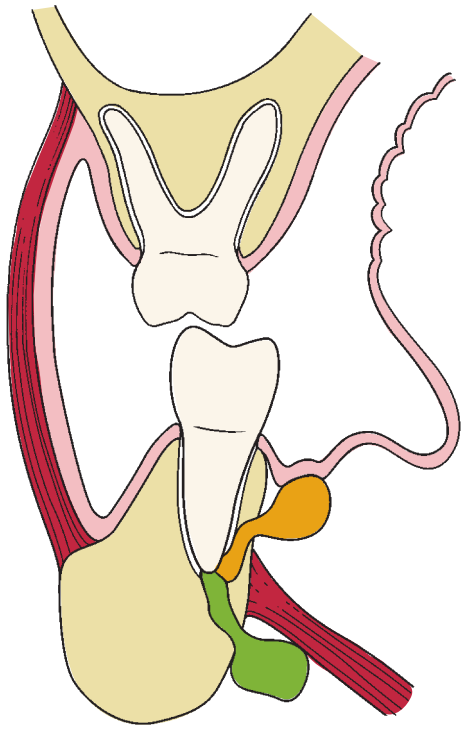
In clinical practice, the most commonly encountered odontogenic infection is a vestibular space abscess of endodontic origin (Fig. 16.5). These infections may occasionally rupture and drain spontaneously, which results in temporary resolution, preventing spread to deeper potential spaces. Spontaneously draining infections may

TABLE 16.2 Characteristics of Inoculation, Cellulitis, and Abscess

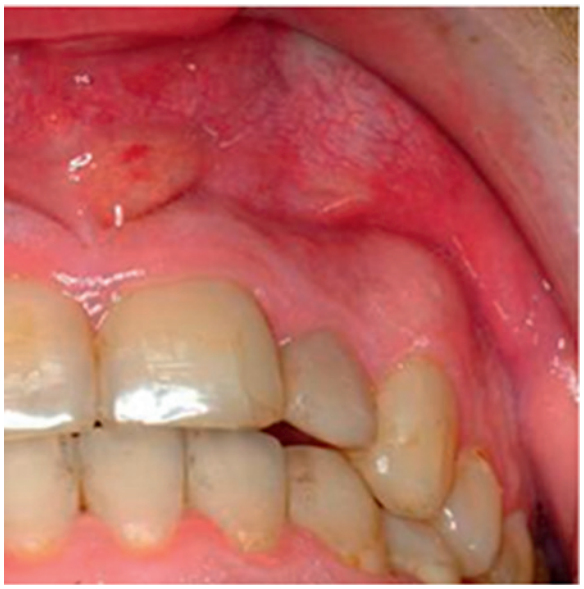
Characteristic	Inoculation	Cellulitis	Abscess
Duration	0–3 days	1–5 days	4–10 days
Pain, borders	Mild, diffuse	Diffuse	Localized
Size	Variable	Large	Smaller
Color	Normal	Red	Shiny center
Consistency	Jelly or dough-like	Board-like	Soft center
Progression	Increasing	Increasing	Decreasing
Purulence	Absent	Absent	Present
Bacteria	Aerobic	Mixed	Anaerobic
Seriousness	Low	Greater	Less



• **Fig. 16.3** A cortical perforation inferior to the buccinator attachment from a maxillary molar will lead to involvement of the vestibular space. When the cortical perforation is inferior to the buccinator attachment in the mandible, the buccal space will be involved.



• **Fig. 16.4** Lingual perforation superior to the mylohyoid attachment will result in involvement of the sublingual space (shown in orange). When the cortical perforation is inferior to the mylohyoid attachment, the submandibular space will be involved (shown in green).



• **Fig. 16.5** Fluctuant edema and erythema of the maxillary left anterior vestibule associated with necrotic pulp of the maxillary left lateral incisor.

continue to drain and form a *fistula* to the oral cavity or a *sinus tract* to skin, or reclose and result in the reforming of an abscess.

Principles of Management

Management of odontogenic infections involves three factors: (1) controlling the source of the infection, (2) establishing drainage, and (3) mobilizing the host defense system. The practitioner's predominant role is to maximize control of the first two factors to allow the host defense system to take over and combat the infection. This involves elimination of the source of the infection and providing drainage of any accumulated infection. As long as the source of the infection (i.e., endodontically or periodontally involved tooth) is present, permanent resolution will never occur. Likewise, if a significant bacterial load (>10^5 colony-forming units/mL) is present in the form of a collection of purulence or cellulitis, the host defense system may not be able to overcome the infection. It is therefore of paramount importance to understand that management of odontogenic infections is primarily surgical in nature. In other words, odontogenic infections are managed primarily with removal of the etiology and surgical incision and drainage, and antibiotics should not be regarded as the primary or sole form of treatment for infections.

With this in mind, the following universal principles should be used in the management of odontogenic infections, regardless of the severity of the infection.

Principle 1: Determine Severity of Infection

Odontogenic infections can range from routine and localized to severe and life-threatening. The practitioner's first goal is to determine the severity and intervene accordingly. This allows control of the infection and prevention from progressing to the deeper potential tissue spaces. Determination of severity begins with a complete history, followed by physical examination, and any necessary ancillary testing (e.g., radiographic imaging studies, laboratory studies).

TABLE 16.3 Components of History-Taking and Their Significance

Component	Significance
Chief complaint (e.g., symptoms)	• Origin, etiology of infection • Involved anatomic space(s) • Severity of infection
History of present illness (e.g., onset, chronicity and duration, evolution of symptoms, treatment history)	• Origin, etiology of infection • Involved anatomic space(s) • Aggressiveness of infection
Medical history and medications	• Other comorbidities that may affect management
Social history	• Social factors that may affect management (e.g., substance abuse, access to dental and medical care)
Review of systems	• Involved anatomic space(s) • Severity • Other comorbidities that may affect management (other than those elicited on medical history)

Complete History

The goal of history-taking is to gather as much pertinent information as possible and to guide the clinician in as accurate and efficient a manner as possible. Components of history-taking and their significance are summarized in Table 16.3.

The first step in history-taking is to thoroughly elicit the patient's chief complaint. Although it is important to document the chief complaint in the patient's own words, vague complaints such as "my tooth hurts," "my jaw hurts," and "my face is swollen" must be probed further to include details such as the location, severity, duration, and quality of the pain and/or swelling. Certain symptoms are associated with severe infections with involvement of deeper spaces; this should raise immediate concerns and lower the threshold for prompt, if not immediate, expert consultation or activation of the emergency medical system. These include fever and malaise, difficulty breathing (dyspnea), difficulty or pain on swallowing (dysphagia or odynophagia), change in voice (dysphonia), and limited mouth opening (trismus).

The next step is to obtain a thorough history of the chief complaint (history of present illness). This provides the clinician with valuable clues that could help determine the origin and etiology of the infection, any involved anatomic spaces, and the aggressiveness of the infection.

Common questions include:

- "Did you have any pain or other symptoms before this occurred?"
- "Did you have any dental treatment or injuries before these symptoms appeared?"
- "For how long have you had these symptoms?"
- "Did the pain change in character, intensity, or location?"
- "Have you sought any care for this problem? If so, what treatment?"

Knowledge of the initial symptoms gives the clinician clues as to the origin of the infection. For example, if the patient had a history of chronic dental pain in the area of the chief complaint, necrosis or severe periodontal disease of this tooth could be the

suspected cause. This will allow the clinician to focus on this area during the comprehensive physical examination. Changes in the character and location of pain could indicate progression of the infection. For example, if pain from a mandibular molar changed to pain in the jaw and the neck, the clinician should have a high suspicion of spread to a deeper space(s). Duration of the symptoms could help the clinician determine the aggressiveness of the infection. In general, symptoms that have been steady and persistent for an extended period of time (>30 days) indicate a chronic infection that is being contained by the host defense system. On the other hand, acute-onset symptoms with rapid exacerbation generally indicate a more aggressive infection, compromise of the host defense system, or both. Previous treatment history also provides the clinician with important clues regarding the aggressiveness of the infection. If a patient presents with an infection despite having had the cause of the infection removed and/or drainage of the infection, this could indicate an aggressive infection requiring the need for more aggressive management.

After meticulously obtaining information about the symptoms and history, a thorough past medical history and social history are elicited in the usual fashion. When using a questionnaire-based form for a health history, it is essential for the practitioner not only to review the patient's responses, but to further discuss the responses with the patient and/or caregiver to avoid missing important items or miscommunication. If the patient is a poor historian, it is often necessary to contact the patient's primary care provider or specialist to obtain a complete medical history via medical consultation.

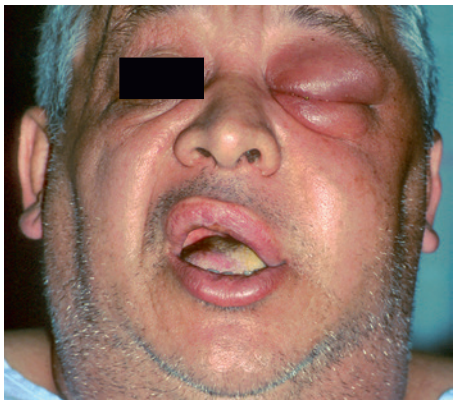
The next step is a thorough review of systems. This is the step in the history-taking when further symptoms are elicited, including not only those of the oral cavity and head and neck, but those of the entire body (such as constitutional symptoms, chest pain, shortness of breath, polyuria, polydipsia, and polyphagia). This step is crucial in identifying pertinent positive and negative symptoms that could help either rule in or rule out severe infections. It is also crucial in finding potential medical problems (comorbidities) that could impact the healing and resolution of the infection, not elicited in the medical history (such as undiagnosed diabetes mellitus or a human immunodeficiency virus [HIV] infection or other immunocompromised state).

Physical Examination

Physical examination must be performed in a comprehensive and organized fashion, and the clinician should avoid examining the oral cavity first, which makes it easy to miss obvious yet extremely important findings that have a direct impact upon management. It is recommended that the clinician begin from "big to small," or "outside then inside." This begins with obtaining vital signs (temperature, blood pressure, heart rate, and respiratory rate). Patients with odontogenic infections often have an elevated heart rate of more than 100 beats/min *(tachycardia),* a respiratory rate of more than 20 breaths/min (tachypnea), and increased blood pressure (hypertension). Although pain and anxiety can elevate these vital signs, such findings should raise concerns for the practitioner. An elevated temperature to 101°F (38.3°C) or higher strongly indicates bacteremia and systemic involvement and invariably requires immediate intervention, typically by an oral and maxillofacial surgeon. In addition to vital signs, oxygen saturation (SpO_2) should be determined with pulse oximetry to ensure adequate tissue oxygenation. Decreased oxygen saturations below 95% in an otherwise healthy patient should raise concerns for the possibility of airway compromise or obstruction.

After obtaining vital signs, the patient should be examined for general appearance. This could occur as early as the moment the patient enters the examination room. If the patient does not appear distressed and is ambulating and speaking without difficulty, the likelihood of a severe infection is not very likely. On the other hand, if the patient appears fatigued and lethargic (Fig. 16.6), has an increased work of breathing, has a change in their voice pattern, and is unable to handle secretions (drooling), it is highly likely that a severe infection is present. The clinician should also listen for any signs of high-pitched breath sounds (stridor), which could indicate obstruction of some part of the airway.

Next, a focused head and neck examination should be performed, beginning with inspection. The clinician should carefully look for any swelling or asymmetry, as well as erythema (redness) of the head and neck region. If any of these findings is present, it could indicate involvement of the surrounding space(s), especially if it corresponds to the area of the patient's symptoms. Common areas of head and neck swelling include the temporal, orbital, nasolabial, cheek, and mandibular angle regions and along the inferior border of the mandible (Table 16.4). Any areas of swelling must be examined with gentle palpation and characterized accordingly. The consistency may be soft and normal, doughy, firm and hard



• **Fig. 16.6** Patient with left canine space infection with periorbital space extension, with malaise and characteristic "toxic appearance" indicating compromised host defenses. (From Flynn TR. Surgical management of orofacial infections. *Atlas Oral Maxillofac Surg Clin North Am*. 2000;8:79.)

TABLE 16.4 Common Areas of Extraoral Swelling in Odontogenic Infections

Region	Commonly Involved Space(s)
Temple	Superficial temporal space, deep temporal space
Orbit	Periorbital space
Nasolabial	Canine space
Cheek	Buccal space
Angle of mandible	Masseteric space, lateral pharyngeal space
Inferior border of mandible and neck (lateral)	Submandibular space
Inferior border of mandible and neck (midline)	Submental space

(indurated), or fluctuant. A doughy consistency is commonly seen in the inoculation (edema) stage of the infection. At this stage, tenderness is generally mild and diffuse. Induration is usually a hallmark of cellulitis and is diffuse and exquisitely tender to palpation. Fluctuance indicates a fluid (e.g., purulence) collection, which is characteristic of the abscess stage. At this stage, the infection is better localized than the cellulitis stage and less tender due to less tissue pressure. It must be noted that an odontogenic infection is an ongoing spectrum of stages; therefore all of these various consistencies could overlap and be present at the same time.

Mandibular mouth opening should be assessed; this is of particular importance for three main reasons. The first is that limited mouth opening (trismus) may indicate involvement of deep spaces, in particular the masticator spaces (spaces involving the muscles of mastication), which require prompt aggressive treatment by an oral and maxillofacial surgeon to prevent progression to deeper spaces and airway compromise. The degree of trismus generally corresponds to the severity of the infection. It must also be noted that swelling is not a prominent finding in such infections (in fact, it may not be present at all), which further highlights the significance of trismus. The second reason that mouth opening is important is for intraoral access. Limited mandibular opening precludes a thorough intraoral examination or intraoral surgical intervention. Therefore patients with severe trismus secondary to an odontogenic infection often require surgical drainage and elimination of the infection source under general anesthesia in a hospital setting. The third reason trismus is important is that when a patient with limited mouth opening undergoes general anesthesia, special considerations and measures must be made to protect the airway with an endotracheal tube, usually via endoscopically guided fiberoptic nasal intubation techniques. It must be noted that although trismus may be due to guarding (self-protection) secondary to pain or anxiety, the clinician should nevertheless have a heightened sense of awareness when encountering trismus. Using a maximum interincisal opening of 40 mm as the norm, the clinician can measure the distance between the maxillary and mandibular incisors without assistance (active) and with gentle assistance (passive). Ideally a ruler should be used to measure the interincisal distance; however, the use of fingerbreadths (three fingerbreadths generally corresponds to 40 mm) is a common and acceptable method. A limited mouth opening may indicate involvement of the masticator spaces, and trismus of less than 15 mm usually indicates the presence of a severe infection.

After examining the head and neck, attention is directed to the oral cavity. This examination should also be performed in a systematic fashion, progressing from general to specific areas. The clinician should avoid the temptation of examining the swelling or dentition first. Areas such as the pharyngeal walls, uvula, and the floor of mouth must be examined. Infections extending to such areas could compromise the airway, and abnormalities must be recorded and further investigated. Then, the hard and soft palate, the facial vestibule, and the gingiva should be carefully inspected, palpated, and characterized. Next, the dentition should be examined for caries, periodontal disease, large restorations, any defects around existing restorations, tooth fractures, mobility, percussion sensitivity, and vitality (for involved teeth only). When a severely carious or periodontally involved tooth is in the immediate vicinity of an intraoral swelling, it can oftentimes be deemed the source of the infection. However, when multiple problematic teeth are present or the physical examination is equivocal, ancillary testing such as vitality testing and radiographic examination is warranted.

Imaging Studies

In a general dental or oral and maxillofacial surgery office, common imaging studies used for odontogenic infections include periapical radiographs, panoramic radiographs, and cone-beam computed tomography. Bitewing radiographs, which are frequently obtained for routine caries surveillance and restorative purposes, have no significant role in the assessment of odontogenic infections because they do not capture the periapical region, which is the most common and important area from which odontogenic infections originate. Panoramic radiographs allow a general overall view of the jaws, nasal cavity, maxillary sinuses, and dentition, and have the benefit of simple acquisition with minimal discomfort for the patient (especially if trismus is present). Periapical views allow a more detailed assessment of the teeth and their periapical regions and have the benefit of less radiation dosage. A cone-beam computed tomography scan allows a three-dimensional view of the maxillofacial skeleton and teeth and is useful if the source of the infection is unclear based upon the history and clinical examination (e.g., multiple adjacent carious teeth, suspected jaw fracture, or osteomyelitis). The clinician must weigh the risks and benefits of each imaging modality and provide the most comprehensive assessment with the least morbidity to the patient (ALARA rule: as low as reasonably achievable). Adjunctive techniques could be used such as insertion of a radiopaque material (such as gutta percha) through an existing parulis, fistula, sinus tract, or periodontal pocket to localize the precise source of the infection. This technique is useful when multiple defective teeth are adjacent to an area of infection. Deep fascial space infections that either pose a risk for airway compromise (such as the lateral pharyngeal space or retropharyngeal space) or are not easily identified on physical examination (such as the infratemporal space) may benefit from obtaining medical-grade computed tomography imaging in a hospital setting. It must be emphasized that radiographic examination can never substitute for a thorough history and physical examination.

Laboratory Studies

Laboratory testing may be used to assist in the patient evaluation. However, for odontogenic infections, these are invariably limited to use in a hospital setting. The main purpose of this ancillary testing is to assess the host's systemic response to the infection, via bacteremia, as well as to monitor recovery following any treatment provided. Since localized infections (e.g., vestibular abscesses) generally do not result in significant constitutional symptoms, laboratory tests are rarely, if ever, required. However, deeper space infections, such as infratemporal lateral pharyngeal and retropharyngeal space abscesses are difficult to examine clinically and are typically associated with significant constitutional symptoms such as fever and malaise. In such infections, laboratory studies also serve as adjuncts to the physical examination when assessing response to treatment.

The most commonly used laboratory study is the complete blood count, with focus on the white blood cell (WBC) count, and more specifically, the WBC differential count. The rationale for this test is that an elevated WBC represents a strong immune response to the infection in the form of increased WBC production and mobilization into the bloodstream. It is important to understand that in an acute setting, the WBC count may be affected by noninfectious factors such as medications (e.g., corticosteroids) and stress and should always be correlated within the overall clinical context. A differential WBC count can help mitigate the effects of such factors by focusing on the immature granulocytes

(polymorphonuclear leukocytes and neutrophil band cells, or a "left shift" in the differential WBC count), which serve as better indicators of an infectious process; an increase in these immature cells indicates that the bone marrow is increasing production of these cells in order to combat a systemic infection. Following resolution of the bacteremia and infection, the WBC count will gradually return to baseline; this can be a useful study to monitor progression of the infection.

Similar to any other ancillary testing, laboratory studies are intended to complement the history and physical examination and, more importantly, affect management of the patient. Indiscriminate radiologic or laboratory testing cannot be justified if it is not expected to impact upon the overall management of the patient.

Overall Assessment

Once a thorough patient history is obtained and a comprehensive physical examination is performed followed by any indicated ancillary testing, the clinician should be able to determine the location and stage of the infection as well as the etiology and severity of the infection. As discussed previously, the majority of the assessment could be determined based upon a thorough history and physical examination, and any necessary ancillary tests such as imaging and laboratory studies may help the clinician formulate an accurate diagnosis. The location of the infection may be confirmed based on an accurate physical examination as well as imaging studies, when necessary. The specific stage of the infection (inoculation, cellulitis, abscess, resolution stages) is based largely on the history as well as clinical presentation. In general, cellulitis, which appears in the initial stages of infection, indicates greater severity with uncertain progression, whereas an abscess indicates that the host defense system has effectively localized the infection via containment. The etiology of the infection is determined by integrating the history, physical examination, and imaging studies. It is important to note that the clinician should always consider nonodontogenic etiologies (e.g., tumor) in the differential diagnosis and not assume that all swellings or pain around the head, neck, and oral region are odontogenic in nature.

Principle 2: Evaluate State of Patient's Host Defense Mechanisms

A crucial part of healing following an odontogenic infection is the presence of an intact host defense system, because it is ultimately the patient's host defenses that combat an infection following surgical management, when indicated. Therefore the importance of accurately assessing the patient's host defenses, and optimizing them, cannot be overemphasized. This underscores the importance of obtaining a thorough history on patient presentation. When the host defense mechanism is compromised, it must be compensated for by aggressively managing the infection with surgical treatment and, in most cases, adjunctive antibiotic therapy.

Medical Comorbidities

Two main categories of medical comorbidities that adversely affect the host defense system are inadequately controlled metabolic diseases and conditions that directly affect the immune system.

Poorly controlled diabetes mellitus is strongly associated with impaired healing. Hyperglycemia causes decreased leukocyte chemotaxis and phagocytosis and severely impairs one's ability to resist and combat infections. Patients with severe infections, especially in a hospital setting, require careful control of blood glucose levels in order to optimize the host defense system after appropriate surgical management. Severe alcoholism, which is frequently accompanied by malnutrition, also severely impairs the body's ability to defend against infections.

Hematologic cancers such as leukemia and lymphoma adversely affect the function of leukocytes and therefore the ability to defend against infections. In addition, in severe HIV infections, both the B and T lymphocytes are affected, making the patient particularly susceptible to infections and a poor response to treatment. However, HIV seropositivity alone does not indicate a lack of ability to defend against odontogenic infections, because odontogenic infections are caused mostly by extracellular pathogens, not intracellular pathogens, against which T lymphocytes are primarily responsible to combat.

Certain medications depress the immune system and increase the risk of odontogenic infections and poor treatment response despite appropriate management. Chemotherapeutic agents for malignant conditions commonly cause bone marrow depression, thereby weakening the immune system. In some chemotherapeutic agents, these effects can last for up to 1 year or more. Immunosuppressants and corticosteroids used for various indications (such as autoimmune diseases and organ transplantation) impair the function of lymphocytes and decrease immunoglobulin production.

Principle 3: Determine Whether Patient Should Be Treated by General Dentist or Oral and Maxillofacial Surgeon

When detected early, the vast majority of odontogenic infections may be safely managed by the general dentist; however, several factors must be considered in determining whether an infection should be managed by a specialist. The decision should be based upon location, severity, surgical access, and status of host defenses (Box 16.1). It must be stressed that accurate assessment is a prerequisite to management of any infection, regardless of one's level of training. Two examples of case selection are illustrated in Box 16.2 and Figs. 16.7 and 16.8.

Location and Severity

As a general rule, odontogenic infections that are severe and involve deeper spaces require prompt management by an oral and maxillofacial surgeon, typically in a hospital setting. These infections usually present with concerning signs and symptoms such as fever, difficulty breathing and/or swallowing, trismus, and drooling.

• BOX 16.1 Criteria for Referral to an Oral and Maxillofacial Surgeon

- Difficulty breathing
- Difficulty swallowing
- Dehydration
- Moderate to severe trismus (interincisal opening <25 mm)
- Swelling extending beyond the alveolar process
- Elevated temperature >101°F (38.3°C)
- Malaise and toxic appearance
- Compromised host defenses
- Need for general anesthesia
- Failed prior treatment

• BOX 16.2 Examples of Mild and Moderate Odontogenic Infections

Case 1: Right Vestibular Space Abscess

Key Findings (Clinical Significance)

- Well-appearing and in no acute distress (intact host defense system)
- Subtle to mild extraoral swelling (early stages)
- Mild intraoral swelling (early stage)

Management and Rationale

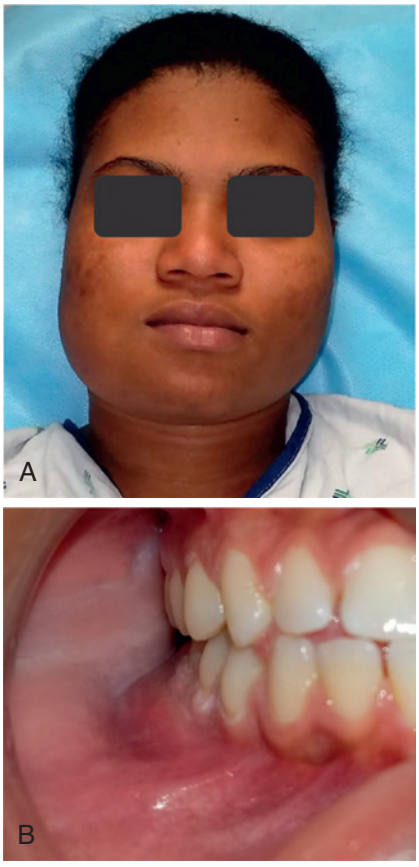
- Incision and drainage with elimination of source (tooth #30) in office setting.
- Reevaluation of patient in 2–3 days.
- Superficial location with mild symptoms indicate early stages, with no evidence of host defense compromise. Sufficient access allows immediate surgical treatment with source control (pulp extirpation with subsequent root canal treatment or extraction of tooth) and incision and drainage.

Case 2: Left Buccal Space Abscess

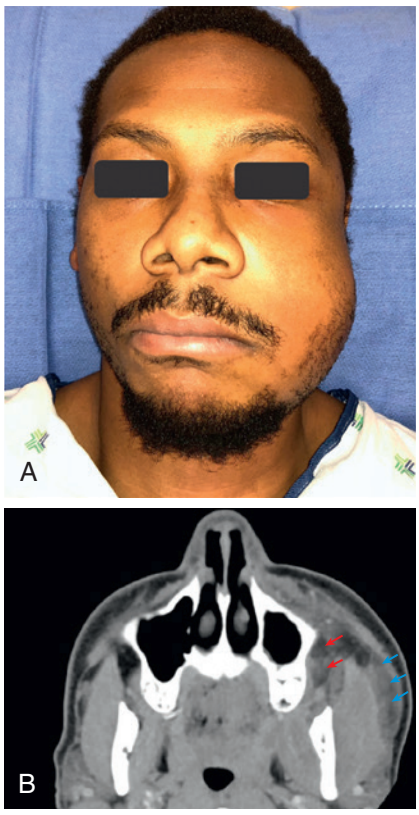
- In mild distress (mild compromise in host defense system)
- Moderate extraoral swelling (advanced stage)
- Induration and severe tenderness of left cheek (cellulitis changes)
- Involvement of infratemporal space on imaging (advanced stage, difficult region to examine clinically)

Management and Rationale

- Immediate referral to oral and maxillofacial surgeon or to local hospital with oral and maxillofacial surgery coverage.
- Further imaging studies required (CT with contrast [see Fig. 16.8B]).
- Incision and drainage under general anesthesia due to deep space involvement.
- Inpatient monitoring with clinical examination and laboratory studies. The inability to sufficiently examine the infratemporal space requires heavier reliance on ancillary studies such as laboratory and imaging studies.
- Intravenous antibiotics required initially to supplement surgical drainage of deep fascial space abscess (deep temporal space).



• **Fig. 16.7** Right vestibular space abscess (see Case 1 in Box 16.2).



• **Fig. 16.8** (A) Left buccal space abscess (see Case 2 in Box 16.2). (B) Computed tomographic scan. Blue arrows indicate the buccal space; red arrows indicate the infratemporal space.

Difficulty breathing, difficulty swallowing, and difficulty with handling of oral secretions are indicators of airway compromise, and patients demonstrating such signs and symptoms should be transported to a local hospital emergency room immediately (ideally with a consultation by an oral and maxillofacial surgeon).

Localized infections such as those involving the alveolar process and the vestibule are amenable to minor surgical procedures in a general dental office setting. These infections often allow for simultaneous elimination of the source of the infection (e.g. extraction, root canal treatment). Infections in close proximity to important vital structures such as the mental and infraorbital neurovascular bundles should generally be managed by an oral and maxillofacial surgeon.

Surgical Access

Surgical access must be adequate to allow for appropriate drainage and control of the etiology of the infection. Patients with odontogenic infections often present with trismus, which limits intraoral access (and often represents severe infections). These patients usually require surgical care under general anesthesia, with subsequent monitoring and medical management in a hospital setting. Such patients should be promptly referred to an oral and maxillofacial surgeon for appropriate surgical and medical care without delay.

Status of Host Defenses

Patients with underlying medical comorbidities that affect host defenses require expeditious and aggressive management by an oral and maxillofacial surgeon. Many patients with or without underlying conditions are often dehydrated and have elevated blood glucose, which could further compromise the host defense system. Typically patients with compromised host defenses may need medical consultation during their inpatient hospital stay in order to eliminate this as a potential confounding factor in resolution of an infection.

Principle 4: Treat Infections Surgically

One of the most common misconceptions about odontogenic infections is the role of antibiotics as the main treatment modality. It cannot be stressed enough that ***odontogenic infections are a surgically managed disease process*** and that antibiotics only serve an adjunctive role, *if they are indicated at all*. Robust evidence clearly shows that surgical management is significantly superior to antibiotic-only therapy in improving various clinical parameters, including body temperature, laboratory values, and hospital stay. When considering the three factors involved in the management of odontogenic infections—eliminating the source of the infection, establishing surgical drainage, and mobilizing the host defense system—it is easy to understand the central role of surgical management because the first two factors can only be achieved surgically. In this context, surgery includes not only incision and drainage and extraction of the offending tooth or teeth, but all forms of elimination of the source of infection such as pulp extirpation (with subsequent definitive root canal therapy) and periodontal therapy.

Once the diagnosis of an odontogenic infection is established (with proper identification of the source), the first component of surgical management involves elimination of the cause, also referred to as *source control*. The method of source control depends on the specific etiology (endodontic or periodontal), as well as the severity. If an infection is determined to be endodontic in nature, such as in a necrotic pulp from caries or tooth fracture, source control involves pulp extirpation with subsequent root canal treatment. If the source is deemed to be periodontal in origin, then scaling and root planing with debridement is the typical treatment method. In either case, if the tooth or teeth are deemed nonsalvageable, the patient is unwilling to undergo definitive restorative treatment, or if the infection is determined to be aggressive, extraction provides the most definitive source control. Whenever possible, source control should be performed immediately. However, certain situations preclude adequate source control. An example is significant trismus that does not allow the clinician to properly access the offending tooth or teeth due to limited access to the oral cavity. In such instances, depending on the severity and location of the infection, the clinician may begin empirical antibiotic therapy or perform incision and drainage first to improve mandibular opening prior to eliminating the infection source. When an infection is deemed serious and aggressive, the patient must be treated under general anesthesia in a controlled operating room setting for immediate surgical management.

Following source control, surgical drainage of the infection is the second component of surgical treatment. Incision and drainage facilitates healing by two main mechanisms. The first and most important mechanism is decreasing the bacterial load. Lowering the bacterial load with elimination of the source and drainage of the infection allows the host defense system (third component of management) to remove any residual infection. The second mechanism of surgical drainage is decreasing the pressure of the infected tissues. When the hydrostatic pressure of the infected tissues is decompressed with surgical drainage, the local blood supply is improved, and this allows the host defense system, and adjunctive antibiotics, to better reach the infected area. For odontogenic infections, surgical drainage can be in the form of endodontic access through the tooth or incision and drainage through a mucosal or cutaneous incision access. When an infection of pulpal origin is localized to the alveolar process and the patient is immunocompetent, drainage of the infection via a standard endodontic access and through the apical foramen will generally provide sufficient drainage of the infection. This will require that the tooth be salvageable (otherwise, extraction will provide the "drainage," in addition to definitive removal of the source of the infection). However, when an endodontic access does not provide adequate drainage, when an infection has extended past the alveolar process and into the vestibular space or other soft tissue spaces, or when a patient is deemed immunocompromised, surgical incision and drainage is indicated. Incision and drainage is not solely reserved for abscesses, but can facilitate healing of cellulitis via the same mechanism—decreasing bacterial load and decreasing local tissue pressure. One must understand that the purpose of surgical drainage is not simply to "remove purulence," but also to decompress the soft tissues and provide an egress (tract) to prevent potential reaccumulation of infection in the same location. Also, surgical drainage must be differentiated from simple evacuation of purulence. Procedures such as needle aspiration have little to no role in the definitive management of odontogenic infections. Clinical situations that do not necessitate an incision and drainage procedure include the absence of swelling, or the early inoculation stage, where swelling is soft, diffuse, and only mildly tender. But, as mentioned previously, surgical drainage may be considered for cellulitis to improve vascularity for healing and systemic antibiotic penetration. However, most other situations with an odontogenic infection necessitate surgical drainage. The following description of incision and drainage technique is for a vestibular abscess, which is by far the most commonly encountered odontogenic infection.

Surgical Technique

The first step in surgical management of odontogenic infections is to determine the most appropriate route for surgical access for incision and drainage. The clinician must be certain that the patient has adequate mandibular range of motion to allow for sufficient access to incise, explore, and drain the infected area. When the access is deemed insufficient, analgesia and anxiolysis may be used, because limited mandibular mouth opening with a vestibular space infection is almost invariably due to guarding from pain. If these measures do not improve intraoral access, the patient must be promptly referred to an oral and maxillofacial surgeon.

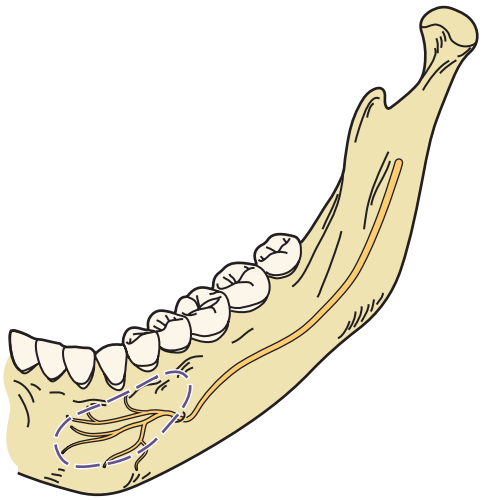
The next step in surgical treatment is to determine the need for microbiologic analysis and culture and sensitivity testing. Although not necessary on a routine basis, some situations warrant serious consideration for laboratory evaluation (Box 16.3). If culture tests are to be obtained, the clinician should have access to aerobic and anaerobic sterile culture tubes. These specimens require evaluation by a laboratory facility, so the clinician should have a mechanism in place for processing the specimens promptly in order to obtain results that may guide appropriate antibiotic therapy.

Regarding the specific intraoral incision and drainage procedure, after antisepsis of the surgical site is achieved with a mouth rinse with 0.12% chlorhexidine solution, the next step is to choose the method of analgesia and pain control. For odontogenic vestibular infections, adequate analgesia can be achieved with standard local anesthesia techniques. Regional nerve block anesthesia is always preferred over infiltration techniques for two reasons: (1) penetration of the local anesthetic is difficult when the agent is injected directly into an infected area because the acidic (low pH) local environment with the localized collection of purulence, tissue fluid, and debris make it difficult for the anesthetic agent to diffuse into the tissues and affect blockade of the sodium channels of the nerve and (2) infiltration anesthesia carries the risk of seeding infection to neighboring uninfected sites or tissue spaces, if the needle is advanced through the area of infection into adjacent tissues. Alternatively, infiltration anesthesia techniques can be performed; however, special care is necessary to avoid reuse of a needle from an uninfected site and to inject in a submucosal plane to allow for infiltration of the agent into the tissues. Once the area is sufficiently anesthetized, a culture specimen is obtained at this time that is usually performed by using a small (usually 3 mL) sterile syringe attached to a large-caliber needle (usually 18 gauge). The needle is inserted into the swelling, and purulence or tissue fluid is aspirated. The aspirated fluid is transferred to the aerobic and anaerobic (and occasionally fungal) sterile culture tubes and sent to the laboratory for microbiologic analysis, which may include Gram staining and culture and sensitivity testing. It is crucial for the practitioner to provide clinical details including the patient history, anatomical location of the fluid, and character of the infection when completing the laboratory request form.

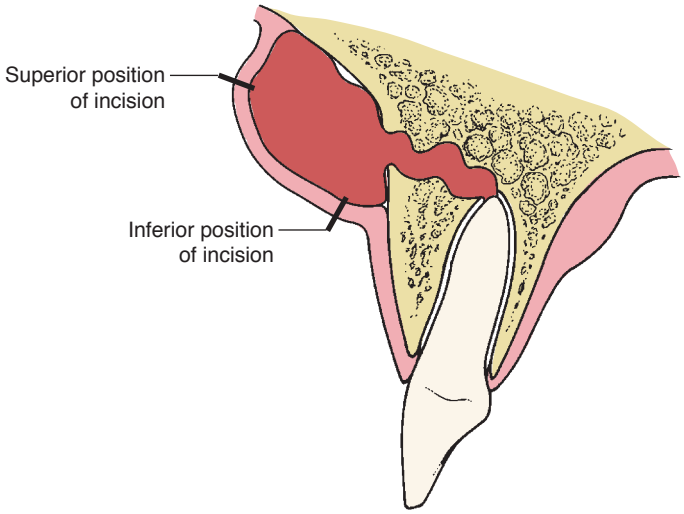
• BOX 16.3 Indications for Culture and Antibiotic Sensitivity Testing

- Rapidly progressive infection
- Previous, multiple antibiotic therapy
- Nonresponsive infection (after >48 h)
- Recurrent infection
- Compromised host defenses

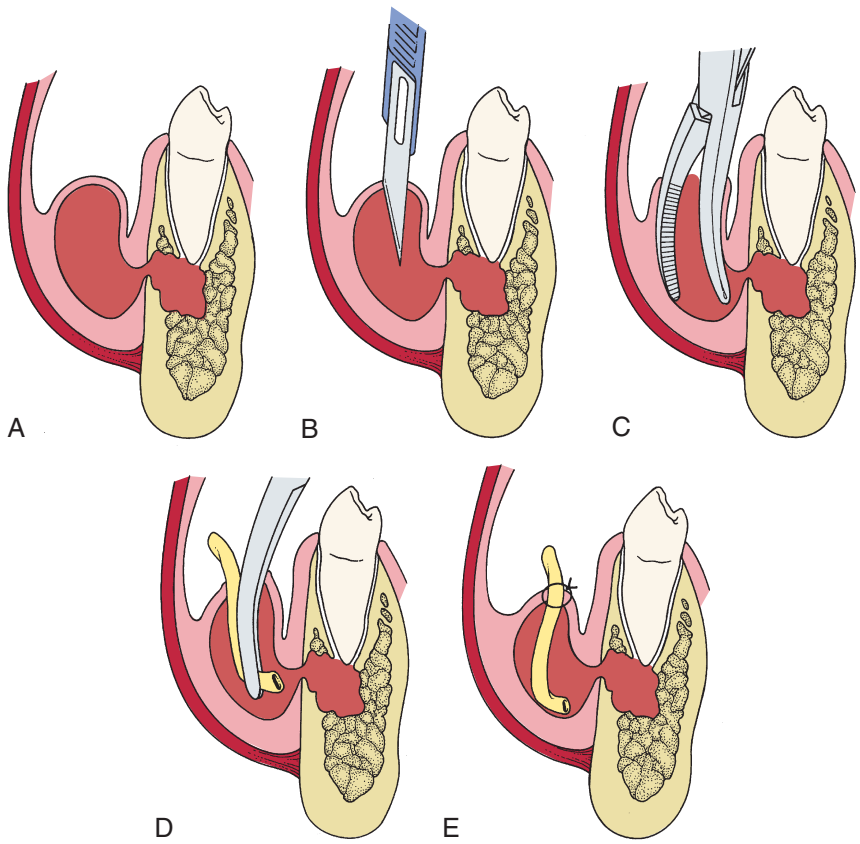
The next step in surgical management is the incision. In general, the incision is placed directly over the area of maximum swelling to allow for dependent drainage. However, it is important to avoid incising across the path of vital structures, such as the mental neurovascular bundle in the mandibular premolar region (Fig. 16.9). Also, consideration should be given toward placement of the incision at the inferior aspect of an upper vestibular infection to allow for maximum gravity-dependent drainage (Fig. 16.10). For extraoral incision and drainage procedures for complex odontogenic infections, there are other factors that must be considered, including facial scar and potential vascular and facial nerve injury. The length of the incision must be sufficient—at least 10 to 15 mm—and the depth must be at a depth of at least through the mucosal and submucosal tissue layers. A common error is to create the incision too superficial, too short, or both. A superficial incision will not allow proper drainage of the underlying purulence or tissue fluid and will prevent effective decompression of the infected tissues. A short incision will not allow thorough



• Fig. 16.9 Location of the mental neurovascular bundle must be considered when placing an incision for a vestibular infection in the mandibular premolar region.



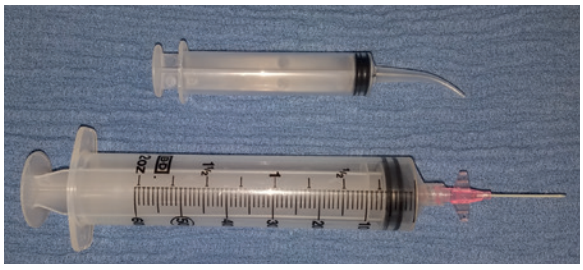
• Fig. 16.10 For a maxillary vestibular abscess, placing the incision in a dependent position inferiorly may prevent incomplete drainage from pooling of the purulence on the inferior aspect of the abscess cavity.



• **Fig. 16.11** Incision and drainage technique for vestibular abscess. (A) Periapical infection of a mandibular premolar (note buccal cortical erosion above the buccinators muscle attachment). (B) Incision made into fluctuant swelling to the depth of the abscess cavity. (C) Curved hemostat used in opening motion in various directions to break loculations of purulence within the abscess cavity. (D) Insertion of a drain into the depth of the abscess cavity. (E) Suturing of the drain with a single suture.

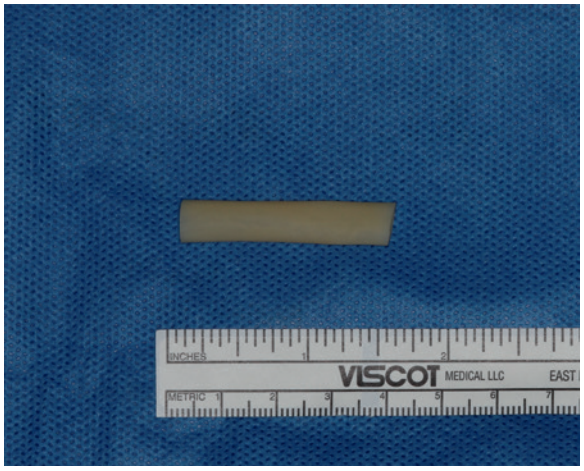
exploration of the spaces involved to perform disruption of the loculations (small clusters of purulence within an abscess cavity) and may cause tearing of the already fragile tissues during manipulation, which would not allow proper healing. Tearing of tissues not only leads to increased scarring, but it also carries the risk of damage to adjacent structures such as the mental neurovascular bundle. To avoid these problems, the clinician may elect to create a longer incision (up to 15 mm rather than 10 mm), and at full-depth through all tissues layers, including the periosteum, to the level of the bone. A periosteal elevator can be used in a sweeping motion in the subperiosteal plane to ascertain whether appropriate depth has been obtained. Then, curved hemostats may be used to disrupt the loculations within the abscess cavity. This is achieved by inserting the hemostats well into the abscess cavity and opening the instrument in several directions (Fig. 16.11). Care must be taken to avoid blindly closing the hemostats, because this maneuver could damage important structures (nerves, vessels) by crushing them.

After thoroughly draining and decompressing the infection, the clinician may elect to irrigate the abscess cavity with sterile normal saline using a syringe with a thin tip (Fig. 16.12). A drain may also be placed if concerns exist for reaccumulation of purulence. Although sterile Penrose drains are some of the most frequently used forms of drains (Fig. 16.13), equally effective alternatives include a piece of a sterile glove or sterilized rubber dam. The



• **Fig. 16.12** A thin-tipped syringe (Monoject) or a syringe with an angiocatheter attached can be used to thoroughly irrigate the abscess cavity with sterile saline solution after incision and drainage.

drain is sutured to the tissues adjacent to the incision (or near the edge of the incision) with a nonresorbable suture material (see Fig. 3.5). As a general rule, the drain should be placed to the depth of the abscess cavity and sutured to reasonably healthy-appearing tissues to avoid tearing through the tissues when passing the needle. The drain should remain in place until epithelialization of the tract has occurred or when the patient improves clinically and continued drainage ceases. This occurs typically within 2 to 5 days after the incision and drainage procedure. Once the drain is removed, the wound is left to heal by secondary intention.



• **Fig. 16.13** A ¼-inch Penrose drain is commonly used to allow continued drainage and decompression of odontogenic infections.

Principle 5: Support Patient Medically

Systemic support is an indispensable component of management of odontogenic infections, because, as mentioned previously, it is ultimately the patient's host defenses that eventually combat the infection. Once the source of the infection is eliminated and the infection drained, the bacterial load is decreased. The clinician's role is to optimize the patient's ability to eliminate residual infection by supportive means. These supportive measures include hydration, improved nutrition, pain control, adjunctive antibiotic therapy, and blood glucose control. Most patients presenting with odontogenic infections are dehydrated and poorly nourished due to poor oral intake from pain and discomfort. Thorough surgical care (i.e., source control and incision and drainage) should always be supplemented with adequate pain control and encouragement of oral (or intravenous) hydration and improved nutritional intake. For the vast majority of patients, these measures provide the necessary support of the host defense system for an uneventful recovery. For the acutely dehydrated patient, the clinician may elect to administer fluids intravenously to replenish lost intravascular volume. The presence of fever increases the caloric and fluid requirements, and this must be taken into consideration. Elevated blood sugar levels are often observed in patients with odontogenic infections. This is especially the case in patients who have an underlying diagnosis of diabetes mellitus. Hyperglycemia is associated with compromised systemic resistance to infections and poor wound healing. In diabetic (and even some nondiabetic) patients with severe infections, it is often necessary to control blood sugar in an inpatient setting as part of the systemic support process.

The patient may present with other systemic illnesses that require special attention such as hypertension, dysrhythmias, congestive heart failure, and autoimmune diseases with immunosuppressive therapy. Especially when multiple such comorbidities exist, expert consultation is frequently necessary from different specialists such as internal medicine and infectious diseases.

Principle 6: Choose and Prescribe Appropriate Antibiotic

Although odontogenic infections must be managed with surgery, certain situations benefit from adjunctive antibiotic therapy. The clinician should never assume antibiotics are required for appropriately managing odontogenic infections. Inappropriate reliance on antibiotics not only poses the risk of increased antibiotic resistance and increased risk of antibiotic adverse effects (including opportunistic infections and more serious risks such as anaphylaxis), but it also may lead to inadequate surgical management. It must be clearly understood that antibiotics should always be regarded as an adjunct to, not a substitution for, surgical management. This fact is also supported by systematic reviews that indicate that the choice of antibiotic does not significantly affect treatment outcomes when used in conjunction with surgical treatment (source control and incision and drainage).

• BOX 16.4 Use of Adjunctive Antibiotic Therapy

Appropriate Uses

- Swelling extending beyond the alveolar process
- Presence of cellulitis (with or without concomitant abscess)
- Trismus
- Lymphadenopathy
- Fever (>101°F [38.3°C])
- Severe pericoronitis
- Osteomyelitis
- Immunocompromised patient (with appropriate surgical management of infection)

Inappropriate Uses

- Patient demand
- Severe pain (not attributable to infection)
- Toothache
- Periapical periodontitis or abscess
- Alveolar osteitis (dry socket)
- Postoperative administration in an immunocompetent patient after multiple dental extractions
- Mild pericoronitis
- Drained abscess limited to the alveolar process

Determine the Need for Antibiotic Administration

Whenever antibiotic therapy is considered, the clinician must carefully weigh the risks and benefits. Examples of appropriate and inappropriate antibiotic use are listed in Box 16.4. Three main factors should be considered when determining the appropriateness of adjunctive antibiotic use: (1) severity of the infection, (2) ability to render surgical treatment, and (3) patient host defense system. Severe infections, especially those involving the deeper fascial spaces and those with cellulitis, benefit from antibiotic therapy after thorough source control and aggressive incision and drainage. Since some deep spaces (e.g., infratemporal space, lateral pharyngeal space, retropharyngeal space) cannot be examined sufficiently without computed tomography imaging, there is a greater risk of "incomplete" drainage even after a thorough incision and drainage, compared with a superficial oral vestibular infection, which is readily accessible for examination and surgery. Therefore the role of adjunctive antibiotic therapy is more significant in severe infections involving deeper spaces. If an acute infection does not allow for an otherwise straightforward source control and incision and drainage, empiric antibiotic therapy may occasionally precede surgical management. An example is a patient with severe pericoronitis and limited mandibular opening secondary to pain. Control of the acute pericoronitis with empiric antibiotics frequently improves the mandibular range of motion, allowing the clinician to provide the necessary surgical treatment to manage the infection. Lastly, if a patient is immunocompromised, adjunctive antibiotics

may be considered to compensate for the deficient host defense system. As mentioned previously, when possible, antibiotics should always be preceded by aggressive surgical treatment, including source control and incision and drainage. There is no evidence that supports the routine use of antibiotics for managing odontogenic infections in the immunocompromised patient, and decisions must be made on an individual basis using sound clinical judgment.

Common inappropriate antibiotic uses include dental pain from acute pulpitis, spontaneously draining periapical abscesses, and alveolar osteitis (dry socket). Acute pulpitis is limited to the pulpal system, does not respond to antibiotic therapy, and should be managed with restorative care or endodontic treatment. A draining periapical abscess is a chronic localized condition and is the equivalent of a surgically drained abscess cavity. In such cases, elimination of the source of the infection (root canal therapy or tooth extraction) is all that is required. Alveolar osteitis is an inflammatory process, and not an infection, that requires local palliative care (pain control and intrasocket irrigation and medicaments) and for which antibiotics have little to no effect on resolution.

Use Empirical Antibiotic Therapy Routinely

Odontogenic infections are almost invariably caused by normal oral flora (predominantly facultative oral streptococci, anaerobic streptococci, and *Prevotella* and *Fusobacterium* species) and typically have a predictable bacterial composition. This predictability makes the routine use of culture and sensitivity testing unnecessary and impractical because the causative organisms are already known. As mentioned previously, microbiologic testing should be reserved for special circumstances such as rapidly progressive infections, osteomyelitis, nonresponsive or recurrent infections, and compromised host defenses. The predictable nature of the causative organisms in odontogenic infections also favors the use of a limited number of antibiotics, when indicated. These include penicillin, amoxicillin, clindamycin, and azithromycin, which are effective against aerobic and facultative streptococci and oral anaerobes. Metronidazole, a nitroimidazole antibiotic that targets obligate anaerobes, is seldom used in routine infections and is occasionally used only in conjunction with standard antibiotics in severe infections with a positive culture for a significant level of anaerobic bacteria. Dosing regimens should also be considered, because this is directly related to compliance and efficacy of antibiotic therapy. The frequency of administration of a drug is inversely related to compliance. For example, clindamycin is dosed orally four times daily, whereas amoxicillin-clavulanate (Augmentin) is dosed orally twice daily, with a higher compliance rate and therefore a more effective form of antibiotic treatment. Despite the significance of convenience, the clinician should focus on educating the patient on the importance of compliance and aim to prescribe antibiotics primarily based on their clinical necessity.

Use an Antibiotic With the Narrowest Spectrum

Broad-spectrum antibiotics can dramatically alter the normal bacterial flora of various organ systems such as the skin and the gastrointestinal (GI) tract, which could lead to untoward effects, such as the development of superinfections or opportunistic infections (e.g., fungal) that are usually controlled by the existing bacteria. Broad-spectrum antibiotics can also lead to the development of bacterial antibiotic resistance. Therefore the clinician must always consider using a narrow-spectrum antibiotic to target streptococci and oral anaerobic bacteria without disrupting the normal flora of the oral cavity, skin, and the GI tract. Guidelines established by the American Dental Association Council on Scientific Affairs support judicious use of narrow-spectrum antibiotics when managing odontogenic infections. Box 16.5 shows examples of commonly used broad- and narrow-spectrum antibiotics for odontogenic infections.

• BOX 16.5 Narrow-Spectrum and Broad-Spectrum Antibiotics

Narrow-Spectrum Antibiotics Useful for Treating Simple Odontogenic Infections

- Penicillin
- Amoxicillin
- Clindamycin
- Metronidazole

Broad-Spectrum Antibiotics Useful for Treating Complex Odontogenic Infections

- Amoxicillin with clavulanic acid (for sinus infections)
- Azithromycin
- Moxifloxacin

Use the Antibiotic With the Lowest Incidence of Toxicity and Side Effects

As with any drug, antibiotics have adverse effects, which may vary from mild to severe. It is the clinician's responsibility to be thoroughly aware of the adverse effects of commonly used antibiotics in order to weigh the risks and benefits of antibiotic usage. Older generation antibiotics, such as penicillin and azithromycin, tend to have lower incidences of adverse effects. The most common side effects of penicillin are allergies, with common manifestations including hives, rash, and GI upset (diarrhea). Severe adverse reactions such as anaphylaxis are rare. Despite this fact and despite the introduction of newer antibiotics, penicillin (beta-lactam antibiotics) remains the mainstay of therapy for odontogenic infections. Similarly, adverse reactions are relatively rare for azithromycin; in fact, azithromycin is considered to have the best effectiveness-to-toxicity ratio among macrolide antibiotics for odontogenic infections. The long-term use of clindamycin is commonly thought to be associated with pseudomembranous colitis, which is caused by alteration of the GI flora and subsequent overgrowth of *Clostridium difficile*; however, this condition can occur with the use of almost any antibiotic and usually occurs in severely debilitated patients. Moxifloxacin is a fluoroquinolone antibiotic with a broad spectrum and is much more effective against oral bacteria than its older counterparts. However, this drug has significant adverse effects such as spontaneous tendon rupture, hepatitis, dysrhythmia, peripheral neuropathy, and psychiatric effects.

Use a Bactericidal Antibiotic Whenever Possible

Bactericidal antibiotics are preferred over *bacteriostatic* antibiotics because they lyse and kill bacteria and lessen the burden on the host defense system. On the other hand, bacteriostatic antibiotics such as azithromycin and clindamycin (at low doses; at high doses clindamycin is bactericidal) slow down bacterial reproduction and allow the host defense to eliminate the bacteria. Although both types of antibiotics are effective in the immunocompetent patient with an intact host defense system, bacteriostatic antibiotics may be less effective in patients with a compromised immune system. When considering the fact that antibiotics play a greater role in

managing odontogenic infections in immunocompromised patients, it is especially important to choose a bactericidal antibiotic or antibiotic dose whenever possible.

Be Aware of the Cost of Antibiotics

Another important, yet often overlooked, consideration is the cost of antibiotics. Unnecessarily expensive drugs place a financial burden not only on the patient, but also on the health care system, and they should be used only when the clinical circumstances warrant it. For example, moxifloxacin, while noted for its efficacy and convenience, is expensive, making routine use difficult to justify, especially for odontogenic infections. Also, the choice of generic medications over brand-name versions helps decrease overall costs.

Principle 7: Administer Antibiotic Properly

The proper dose, timing, and duration of administration of antibiotics are as important as proper antibiotic selection. The goal is to achieve a high-enough plasma level to kill or halt the bacteria that are sensitive to the antibiotic while minimizing adverse side effects. The target peak plasma level is usually at least four to five times the minimal inhibitory concentration of the targeted bacteria. The clinician should refer to the manufacturer's dosage recommendations based upon the indications. Duration of administration can vary depending on the patient's response to surgical treatment and antibiotic therapy, but the typical regimen consists of a 4- to 5-day course. As mentioned previously, odontogenic infections are treated primarily by surgical means, and antibiotics only serve as adjuncts. Thus the need for a prolonged course of antibiotics is rare and, in fact, could indicate inadequate source control, drainage, or both. On the other hand, a prescribed course of antibiotics must be completed, regardless of symptoms, to minimize the risk of increasing antibiotic resistance. If a patient for any reason has any unused antibiotics, they must be discarded to avoid improper future use, which could jeopardize the patient and his or her community.

Principle 8: Evaluate Patient Frequently

Once appropriate surgical management (source control and drainage), with or without antibiotic therapy, has been provided, the patient must be carefully monitored for appropriate clinical response. In most cases of uncomplicated odontogenic infections in immunocompetent patients, uneventful healing occurs within 1 week. The typical follow-up period is 2 to 3 days after surgical treatment. At this time, an appropriately responding patient will have significant improvement of pain, intraoral swelling, and overall wellness. If swelling and induration have decreased and there is no persistent drainage, any surgically placed drains should be removed, and the wound should be allowed to heal by secondary intention. If the patient has persistent swelling, pain, drainage, and even constitutional symptoms, the clinician should carefully assess the cause of the inadequate clinical response.

As a general rule, *inadequate surgical treatment* (source control, drainage, or both) should be presumed the primary reason until proven otherwise. It is especially important to ascertain complete removal of the source of the infection. If a tooth, or teeth, had been extracted, the extraction sites need to be carefully examined to ensure there are no residual tooth fragments, bony sequestra, or foreign bodies (e.g., broken burr or file). Imaging such as periapical radiographs may be used to identify such residual causes. A tooth that previously had pulp extirpation or root planing as source control may need to be considered for extraction. Also, teeth in the area of the infection may need to be reevaluated to determine whether they are contributing to the persistent infection. Inadequately drained infections may require repeat drainage, often with extension of the original incision to allow for exploration of the entire space(s).

Another reason for inadequate response is compromised host defenses. If a compromise is identified, it must be controlled (e.g., hydration, nutrition, glycemic control) and surgical measures aggressively performed. Adjunctive antibiotics are usually indicated when host defense is compromised, often for longer periods.

Another reason for failure is problems with antibiotic administration. This could be due to poor compliance or inappropriate choice of antibiotic. When a patient is unable to take antibiotics as directed, it is important to determine the reason. Many times the reason may be financial or convenience-related, and, in such cases, generic drugs with longer dosing intervals may be preferred. Rarely, an empirically prescribed antibiotic may not sufficiently cover the targeted bacteria. If a culture and sensitivity test was ordered at the initial surgery, the results must be checked to ensure appropriate selection of the antibiotic. If a microbiologic test was not performed during the initial surgery, obtaining a culture during the reevaluation visit may elicit microorganisms not sensitive to the prescribed antibiotic.

General Dentist's Role in the Management of Odontogenic Infections

The general dentist plays perhaps the most important role in the management of odontogenic infections. There are several reasons that reinforce this position. First, most patients with odontogenic infections initially present to a dental office because the symptoms frequently involve dental pain. The second reason is that the general dentist has the training to properly diagnose an odontogenic infection and identify the source. This allows the dentist to assess the severity and complexity of the infection and properly treat or refer the patient in a timely fashion. Much like the role of the restorative dentist in a complex dental rehabilitation case, the role of the general dentist is often central to the overall management of odontogenic infections. The third and often overlooked reason is the preventive role of the general dentist. Odontogenic infections are best treated by prevention. Although various factors such as resource allocation and public dental insurance coverage affect one's ability to receive routine dental care, general dentists can make a profound impact on prevention through education and timely provision of preventive and therapeutic care. When risk factors for odontogenic infections (such as fractured or carious teeth, significant periodontal disease) are identified and addressed promptly, odontogenic infections may be effectively prevented.

The central role of the general dentist should not be confused with the expectation that general dentists should be able to treat all odontogenic infections. The most important role is for the dentist to recognize, assess, and triage the infection. When an infection is deemed complex or beyond the comfort level of the dentist, the patient should be promptly referred to an oral and maxillofacial surgeon (or to a local hospital emergency department with a staff oral and maxillofacial surgeon if deemed potentially life threatening). When an immunocompetent patient has an odontogenic infection that is deemed well-localized (within the alveolus and vestibular space) and amenable to a routine incision and drainage with source control, the dentist may treat the patient with subsequent follow-up visits. The general dentist should not resort to antibiotic therapy without surgical management, which

might delay appropriate treatment or referral. This is not only ineffective, but could also allow spread of the infection to a deeper space(s), which would require more invasive and costly treatment, such as extraoral incision and drainage in a hospital setting by an oral and maxillofacial surgeon.

Principles of Prevention of Infection

Infections may occur even in the absence of a diseased state. Examples include surgical site infections and infections of distant organs via hematogenous spread (metastatic infection).

However, although antibiotics are effective adjuncts for established infections, their use in preventing infections (i.e., prophylactic administration) is controversial and less evidence-based. This section will discuss preoperative or prophylactic antibiotic administration for two clinical scenarios: prevention of wound infection after surgery and prevention of metastatic infection.

Principles of Prophylaxis of Wound Infection

Postoperative infections occur in approximately 6% to 9% of clean-contaminated (e.g., oral cavity) surgeries and as many as 40% in procedures involving dirty wounds. Perioperative antibiotics can lower the infection rate to approximately 3.3% and, specifically for oral and maxillofacial surgery, by 70%. However, the clinician must interpret the data with caution.

First, the incidence of infection after oral surgical procedures is very low; in fact, the rates are comparable to the frequency of allergic reactions due to antibiotic usage. Second, surgical site infections after routine oral surgery are minor and respond readily to antibiotics or minor procedures such as intraoral incision and drainage in an office setting. Systematic reviews of clinical trials regarding oral surgical procedures have failed to identify any postoperative deep space infections of the head and neck region. The benefits of routine prescribing of antibiotics before every oral surgery procedure (decrease in already low incidence of mild surgical site infections) cannot justify the increased risk of adverse reactions to antibiotics, the increased risk of promoting antibiotic-resistant bacteria, and the financial burden on the patient and the healthcare system. Therefore preoperative antibiotics are only recommended for select circumstances, including long surgical procedures and patients with compromised host defenses.

Longer operative times have been shown to increase the risk of surgical site infections, and this has been demonstrated in multiple studies and systematic reviews with meta-analyses, which have confirmed a consistent association between increased operative times and the occurrence of surgical site infections. Although most oral surgical procedures are short, preoperative antibiotics may be considered for long and complicated procedures (e.g., extensive alveoloplasty with placement of multiple dental implants and bone grafts).

Patients with a compromised ability to combat infections may be prone to surgical site infections. Examples include patients with poorly controlled metabolic disease such as diabetes mellitus, patients receiving chemotherapy or immunosuppressive medications, and those with end-stage renal disease. Preoperative (and in some instances postoperative) antibiotics are strongly recommended for such patients, even for minor oral surgical procedures.

Dental implants, although previously thought to require preoperative antibiotics for infection prevention, have been shown not to benefit from this approach in systematic reviews with meta-analyses. In these studies, no differences in infection rates were seen when antibiotics were used when compared with placebo or no antibiotics. Although studies show higher implant success rates with antibiotics, multiple confounding variables such as systemic comorbidities, smoking, and parafunction may lead the clinician to misinterpret the results and inappropriately prescribe antibiotics routinely.

Once a patient is deemed an appropriate candidate for preoperative antibiotics, the appropriate medication must be chosen. The ideal antibiotic should be effective against the normal oral flora, have a narrow spectrum, and have the least adverse effects. Therefore the selection criteria are identical to that for established infections. In addition, the antibiotic must be administered so that the plasma concentration is at its peak during the surgical insult, with the peak being higher than when antibiotics are administered for therapeutic purposes. This usually equates to roughly twice the usual therapeutic dose—at least 2 hours (ideally 1 hour) prior to the surgery for oral antibiotics. Commonly used preoperative antibiotic regimens are listed in Table 16.5.

Despite the availability of antibiotics as an aid in preventing infections, the clinician must always adhere to strict surgical protocols, including careful tissue handling, asepsis, and avoidance of cross-contamination. Antibiotics should never be used in an attempt to overcome poor surgical technique or a lack of a proper asepsis protocol. Of note, sterile gloves have been shown to have no benefit when compared with nonsterile gloves in outpatient oral surgical procedures.

Principles of Prophylaxis Against Metastatic Infection

Metastatic infections refer to infections that occur in distant sites, not directly connected to the site of origin of the infection. Metastatic infections most commonly occur via a hematogenous route. As such, prophylactic administration of antibiotics has been used in various scenarios prior to dental treatment to minimize bacteremia and therefore the incidence of metastatic infections. Sites that are considered most susceptible to the metastatic spread of infection include the heart valves and prosthetic joint replacements. Infection of the heart valves results in infective endocarditis, whereas infection of prosthetic joints leads to prosthetic failure.

Prophylaxis Against Infective Endocarditis

Substantial evidence exists that questions the effectiveness of prophylactic antibiotics for infective (subacute) bacterial endocarditis (SBE) when a patient undergoes invasive dental treatment, including oral surgery. However, SBE prophylaxis is still recommended for select clinical situations. The current rationale for prophylactic antibiotic administration for infective endocarditis is based on the fact that infective endocarditis has significant morbidity and mortality. As with any intervention, the benefits and risks must be carefully weighed. In the case of prophylaxis against infective endocarditis, the benefits of preventing severe morbidity and mortality in the select group of at-risk patients are deemed to outweigh the risks of adverse reactions to antibiotics, discussed previously. This is in contrast to routine antibiotic prophylaxis for wound infection, where the benefits of preventing infrequent minor, easily-treated infections in a very large population are thought to not justify the risks of adverse antibiotic reactions and high cost.

In this light, indications for infective endocarditis prophylaxis have consistently narrowed regarding the formal recommendations

TABLE 16.5 Antibiotic Regimens for Prophylaxis of Surgical Site and Metastatic Infections

Situation	Agent	REGIMEN 30–60 MIN BEFORE PROCEDURE	
		Adults	Children[a]
Oral	Amoxicillin	2 g	50 mg/kg
Parenteral	Ampicillin	2 g IM or IV	50 mg/kg IM or IV
	Cefazolin/ceftriaxone[b]	1 g IM or IV	50 mg/kg IM or IV
Penicillin allergy (oral)	Cephalexin	2 g	50 mg/kg
	Clindamycin	600 mg	20 mg/kg
	Azithromycin/clarithromycin	500 mg	15 mg/kg
Penicillin allergy (parenteral)	Cefazolin/ceftriaxone[b]	1 g IM or IV	50 mg/kg IM or IV
	Clindamycin	600 mg IM or IV	20 mg/kg IM or IV

[a]Total pediatric dose should not exceed adult dose.
[b]Cephalosporins should not be used in patients with immediate-type hypersensitivity reaction to penicillins. Other first-generation or second-generation oral cephalosporins may be substituted in equivalent adult or pediatric doses.
IM, Intramuscularly; *IV,* intravenously.

• BOX 16.6 Infective Endocarditis Prophylaxis Recommendations (2017 Update)

Prophylaxis against infective endocarditis is reasonable before dental procedures that involve manipulation of gingival tissue, manipulation of the periapical region of teeth, or perforation of the oral mucosa in patients with the following:

1. Prosthetic cardiac valves, including transcatheter-implanted prostheses and homografts.
2. Prosthetic material used for cardiac valve repair, such as annuloplasty rings and cords.
3. Previous infective endocarditis.
4. Unrepaired cyanotic congenital heart disease or repaired congenital heart disease, with residual shunts or valvular regurgitation at the site of or adjacent to the site of a prosthetic patch or prosthetic device.
5. Cardiac transplant with valve regurgitation due to a structurally abnormal valve.

Data from Nishimura RA, Otto CM, Bonow RO, et al. AHA/ACC Focused Update of the 2014 AHA/ACC Guideline for the Management of Patients with Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines; 2017.

by the American Heart Association. The latest recommendations appeared in 2017, jointly established with the American College of Cardiology (Box 16.6). It is mandatory that every dentist stay up-to-date on the current recommendations, as well as future evidence-based updates, as they become available.

It must also be stressed that nonantibiotic prophylactic measures should be rigorously implemented in the at-risk patient groups. Maintaining optimal oral hygiene should be the main goal in preventing infective endocarditis, as bacteremia not only occurs during invasive dental procedures, but also during repeated everyday activities such as chewing, toothbrushing, and flossing. Also, prior to and during invasive dental procedures, surgical asepsis (such as chlorhexidine gluconate rinses prior to procedure) and careful surgical technique should be employed.

Some special situations warrant consideration of intra- or postoperative antibiotics for infective endocarditis prevention. Examples include an at-risk patient whose specific condition was not disclosed until after initiating the dental procedure or an at-risk patient with unexpected bleeding during an otherwise minimally invasive dental procedure. In such cases, antibiotics should be administered as soon as possible (no later than 4 hours after observed bleeding), using the same dosages as for standard SBE prophylaxis.

Lastly, the clinician must understand that infective endocarditis may still occur despite appropriate practice and strict adherence to the American Heart Association recommendations, and it is important to fully inform at-risk patients of this possibility.

Prophylaxis Against Prosthetic Joint Infection

Prosthetic joint replacements are also potentially susceptible to infection from transient bacteremia. When infected, prosthetic joints have a poor prognosis, and frequently require removal with subsequent replacement. As such, similar to prophylaxis against infective endocarditis, early versions of recommendations set forth by the American Academy of Orthopaedic Surgeons involved a broad set of indications for antibiotic prophylaxis—in fact, recommendations from 2009 suggested use of antibiotics for all patients with prosthetic joints. However, subsequent revisions greatly narrowed the indications. In 2016, the American Academy of Orthopaedic Surgeons and American Dental Association published appropriate use criteria for prophylactic antibiotics for orthopedic implants. It recommends limiting use to recently placed prostheses in patients with evidence of immunocompromise or poor glycemic control. This is due to the lack of causal evidence of dental or oral surgical procedures directly leading to prosthesis infections, mainly due to the very transient nature of bacteremia during the intra- and immediate postoperative period. Instead, other chronic infections such as those in urogenital, GI, pulmonary, and cutaneous sites could contribute to metastatic infections to prosthetic joints. Similar to the previously published recommendations, the 2016 *Appropriate Use Criteria* stress the continued need for sound independent judgment by the clinician. This includes close communication with the orthopedic surgeon as well as the patient. It is ultimately the dentist's decision (and therefore responsibility) to render what he or she deems is the best care for the patient.

The presence of an established odontogenic infection may present a different scenario compared with elective oral surgery in noninfected tissues. With established infections, the patient is exposed

to a prolonged period of bacteremia. Therefore it is crucial to aggressively manage the infection with immediate source control, incision, and drainage and also adjunctive antibiotic treatment. Culture and sensitivity testing have a greater importance compared with infections in patients without prosthetic joints, because if the prosthesis does get infected, antibiotics could be selected more accurately (rather than simply empirically).

Prophylaxis in Patients With Other Cardiovascular Conditions

Patients who receive chronic renal dialysis warrant consideration for antibiotic prophylaxis prior to invasive dental procedures. Renal dialysis often requires a surgically created arteriovenous shunt in the forearm, and these shunts could be susceptible to metastatic infection due to turbulent flow. The same is true for ventriculoatrial shunts in patients with hydrocephaly. These shunts, created for intracranial decompression, could also be susceptible to metastatic infection. When encountering such patients, the dentist should communicate with the patient's physicians (nephrologist for the dialysis patient or neurosurgeon for the hydrocephaly patient) to determine a plan appropriate for the specific patient.

Several conditions commonly thought to be susceptible to metastatic infections are not indications for antibiotic prophylaxis. These include transvenous pacemakers, coronary artery angioplasty procedures, alloplastic vascular grafts, and other nonvalvular cardiovascular devices (including cardiac stents and vena caval filters). However, strong consideration for antibiotic prophylaxis should be given when there is an already established infection.

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Complex Odontogenic Infections

MICHAEL R. MARKIEWICZ, MICHAEL D. HAN, AND MICHAEL MILORO

CHAPTER OUTLINE

Introduction

Orofacial infections are the most common reason that patients present to the dentist or dental specialist; the infections are primarily due to dental caries, with inflammatory periapical pathology manifesting clinically as pain and swelling. However, periapical lesions involving the root apex may extend to, and beyond, the bone of the maxilla or mandible, then spreading to the adjacent and distant soft tissues. In general, odontogenic infections are managed adequately with caries control, endodontic therapy, scaling and root planning, and/or tooth extraction. If the infection extends outside of the alveolus and basal bone of the jaws into the surrounding soft tissues, the most prudent management is prompt surgical incision and drainage to prevent significant patient morbidity and airway compromise. Moreover, if the infection extends outside of, or distal to, the vestibule, it is usually best managed by an oral and maxillofacial surgeon who has extensive training in the management of the airway and the surgical management of head and neck infections. Infections that extend to the deep fascial spaces of the neck can result in significant edema, dysphonia, dysphagia, inability to handle secretions, systemic symptoms, and in the most severe cases, airway compromise. These urgent or emergent clinical scenarios require immediate attention and management. The objectives of this chapter are to review the relevant anatomy of the head and neck, etiology of complex orofacial infections, the clinical presentation signs and symptoms, diagnostic methods, and surgical and nonsurgical management of odontogenic infections, and discuss other infections of the head and neck region.

Anatomy

Management of infections of the head and neck requires the clinician to have a sound fundamental knowledge of head and neck anatomy—in particular, an understanding of the potential deep spaces created by the fascial planes of the head and neck through which infections can progress. In general, the regional anatomy of the head and neck can be regionalized on classifications based upon (1) the "triangles" of the neck, (2) those developed related to anatomy affected by penetrating neck trauma, and (3) infections of the head and neck.

The cervical fascial layers of the head and neck determine the boundaries of deep space neck infections. A thorough knowledge of the anatomy of these spaces will assist the practitioner in assessing the clinical and radiographic findings in the diagnosis of oral and maxillofacial infections. In addition, knowledge of the fascial spaces of the head and neck, and the vital structures that are contained within these spaces, will assist the clinician in providing adequate surgical access and drainage while avoiding iatrogenic injury and further potential patient morbidity. Furthermore, a clear knowledge of the muscular and fibrous soft tissue attachments to the maxillomandibular complex is critical to understanding the path of spread of an orofacial infection. An example of this is the significance of the position of the mylohyoid muscle attachment in relation to an infected mandibular tooth apex regarding whether the infection will extend into the sublingual space or the submandibular space. It is important to note that, prior to spreading to the deep fascial spaces of the neck, most oral infections will penetrate the facial cortical bone of the maxilla or mandible leading initially to a vestibular space abscess prior to further dissemination of the infection.

The deep spaces of the head and neck are fascia-lined spaces containing loose areolar connective tissue. Their purpose is to cushion and protect the nerves, muscles, vessels, and other important

structures that run through them. These are "potential" spaces, only existing when invaded by bacteria or other material that leads to edema opening the space followed by a cellulitis phase and then an abscess stage (Table 17.1).

The cervical fascia of the head and neck is divided into superficial and deep layers. The superficial fascia lies immediately deep to the skin surface, envelopes the platysma muscle as well as the muscles of facial expression, and consists mainly of subcutaneous tissue and connective tissues. It contains predominately superficial nerves and veins (Fig. 17.1). The deep layer of cervical fascia can be divided into the superficial, middle, and deep layers. Furthermore, the middle layer of the deep cervical fascia can be divided further into the muscular and visceral layers, whereas the deep layer can be divided into the posterior prevertebral and anterior alar layers (Figs. 17.2 and 17.3). The superficial layer of the deep cervical fascia (SLDF) originates posteriorly at the nuchal ridge and extends laterally and anteriorly, dividing to envelop the trapezius muscle and sternocleidomastoid muscle and attaching to the hyoid bone anteriorly. It envelops both the parotid and submandibular glands, then fusing with the fascia surrounding the anterior bellies of the digastric and mylohyoid muscles to form the inferior margin of the submandibular space. At the level of the mandible, the fascia splits and the internal layer covers the medial surface of the pterygoid muscles extending superiorly to the base of the skull. The external layer extends superiorly to envelope the masseter muscle and inserts into the zygomatic arch. Inferiorly, the SLDF inserts into the clavicles, sternum, and acromion process of the scapula. This forms the outer (superficial) layer of most deep fascial space neck infections. The muscular layer of the deep cervical fascia surrounds the buccinator, pharyngeal constrictor, sternothyroid, sternohyoid, and thyrohyoid muscles. It inserts on the hyoid bone and thyroid cartilages and then fuses with alar division of deep cervical fascia, forming an anterior wall of retropharyngeal space. The visceral aspect of the middle cervical fascia envelopes the trachea, thyroid, and esophagus and then extends inferiorly to join the pericardium. The deep layer of the cervical fascia is divided into the anterior alar fascia and the posterior prevertebral division, which is adherent to anterior aspect of vertebral bodies from the base of the skull to the vertebrae. It surrounds the muscles of the deep neck in the posterior triangle, enveloping the brachial plexus and subclavian vessels; this helps prevent posterior extension of infections into the mediastinum. The "danger space" is a potential space that lies between the alar and prevertebral fascia.

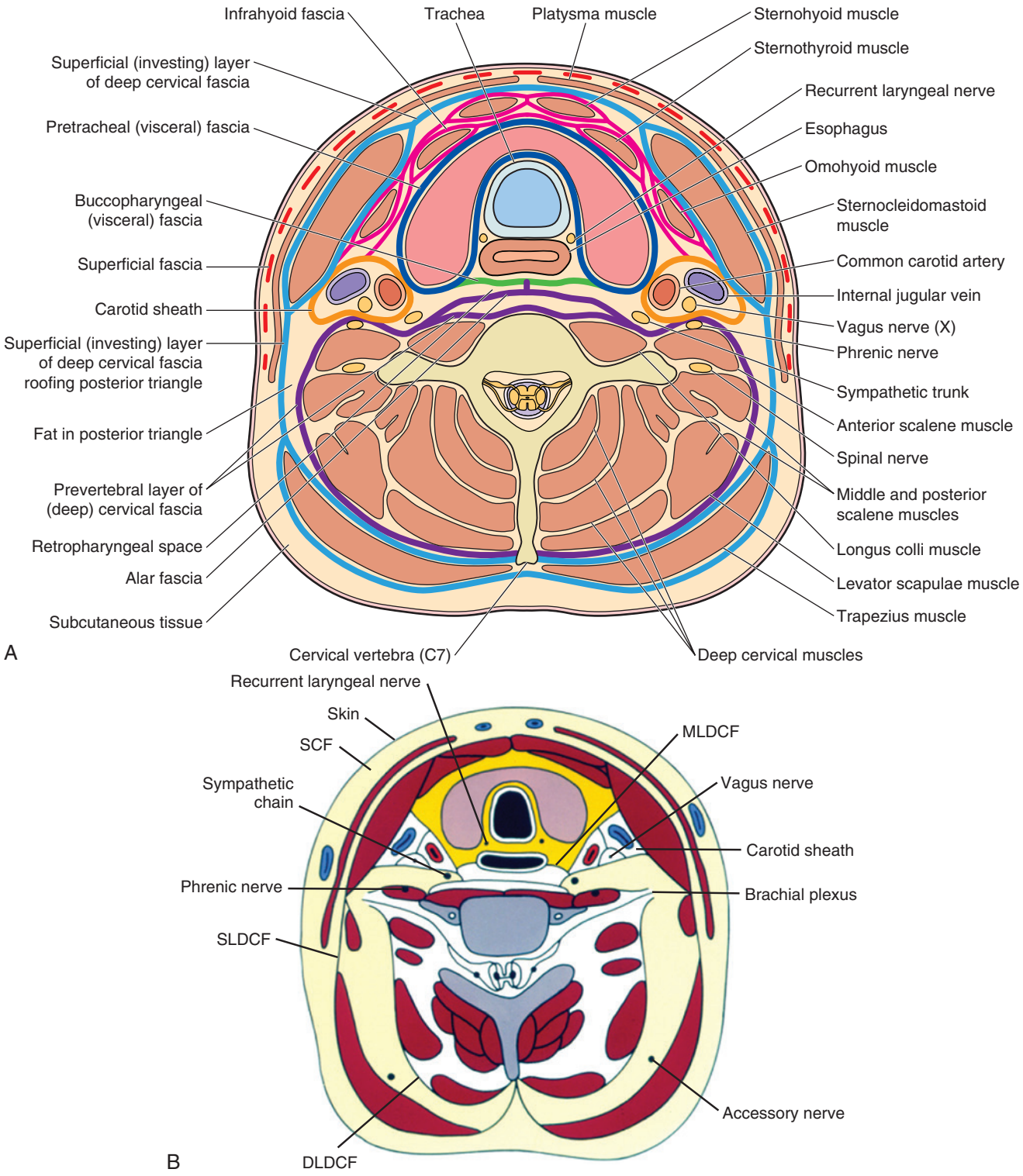
It is important to note that the deep fascial spaces of the head and neck are only potential spaces, and they are established only when invaded by space-occupying masses such as tumors, inflammation, or infection. The lubricating loose areolar protective tissue border is susceptible to invasion by the host inflammatory mediators such as macrophages, lymphocytes, and polymorphonuclear leukocytes, thereby becoming edematous within their interstitial space. Further progression of this cellulitis can lead to liquefactive necrosis within the fascial planes with fluid formation consisting of white blood cells and products of tissue necrosis and limitation of vascularity to the region due to increased hemostatic pressure, resulting in abscess formation.

As mentioned previously, the relationship between the anatomic boundaries where an odontogenic infection penetrates the outer cortex of the alveolar bone and spreads into the surrounding muscle and fascial attachments is critical to the path of spread of the infection via the path of least resistance. Usually the root apices are cephalad to the muscle attachment; therefore, when they penetrate the alveolar bone, they present as a vestibular space

TABLE 17.1 Stages of Infection

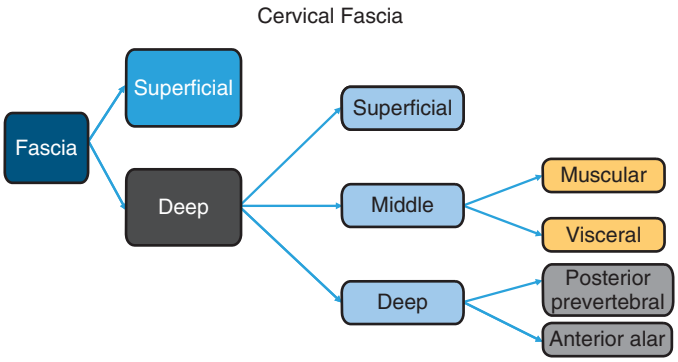
Finding	Edema (Inoculation)	Cellulitis	Abscess
Definition	Interstitial fluid buildup from neighboring inflammation or infection	Spread of bacteria into a space along with interstitial fluid accumulation	Breakdown of liquefactive necrosis to form purulence within the soft tissues
Duration	0–3 days	3–7 days	>5 days
Pain	Mild-moderate	Severe and generalized	Severe, focal area of involvement
Size	Small	Large	Small to large
Localization	Diffuse	Diffuse	Well-circumscribed
Palpation	Soft and diffusely indurated	More tender to palpation	Usually fluctuant
Appearance	Comparable to adjacent skin, mild erythema	Erythematous	Erythematous with centralized fluctuance
Skin quality	Normal to firm	Firm	Firm to hard
Surface temperature	Elevated compared with surrounding tissues	Elevated compared with surrounding tissues	Elevated with central area less elevated
Loss of function	None to minimal	Moderate to severe	Moderate to severe
Tissue fluid	Edema	Serosanguineous or purulence	Localized collection of purulence
Levels of malaise	Mild	Moderate to severe	Severe
Severity	Mild	Moderate to severe	Severe
Bacteria profile	Aerobic	Mixed aerobic/anaerobic	Anaerobic

Modified from Flynn TR. Anatomy of oral and maxillofacial infections. In: Topazian RG, Goldberg MH, Hupp JR, eds. *Oral and Maxillofacial Infections.* 4th ed. Philadelphia: WB Saunders; 2002.



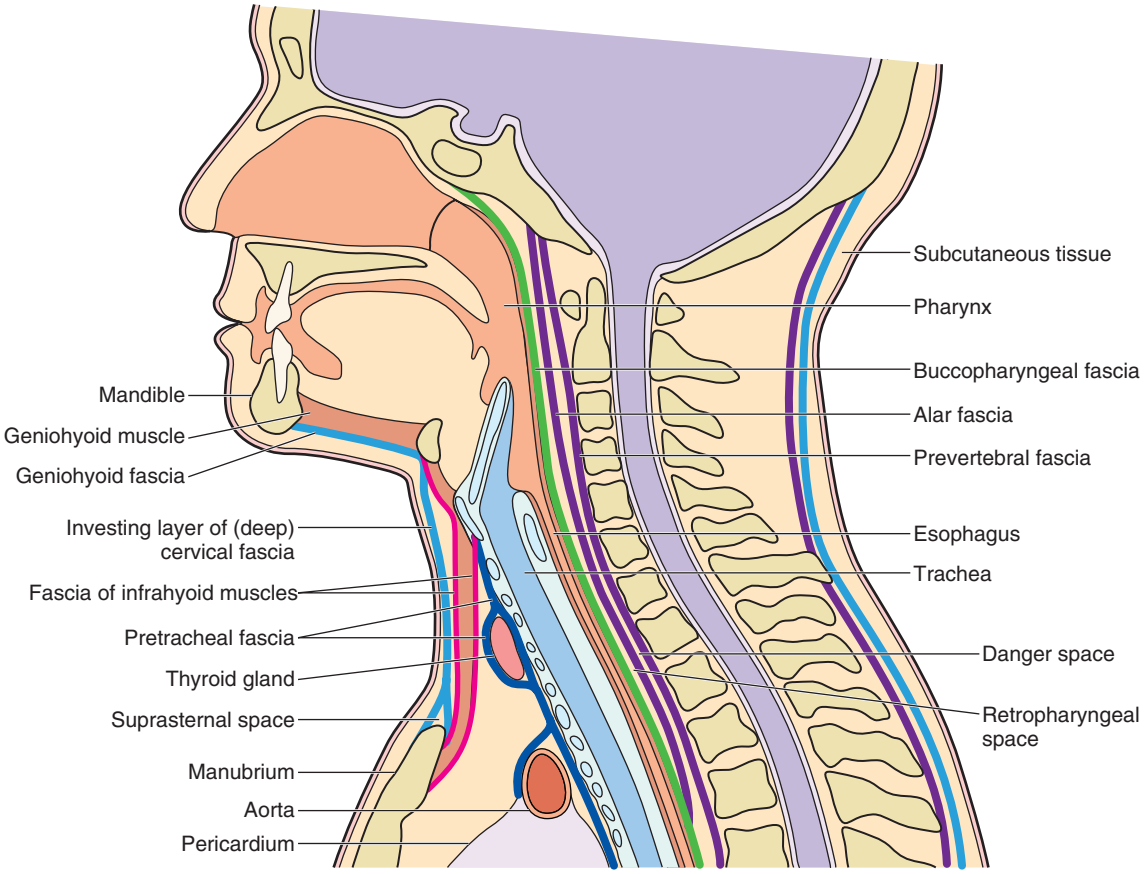
• **Fig. 17.1** The superficial fascia of the neck lies immediately deep to the skin *(red dashed line)* and envelops the platysma as well as the muscles of facial expression. It consists mainly of subcutaneous and connective tissue and contains superficial nerves and veins. DLDCF, Deep layer, deep cervical fascia; MLDCF, middle layer, deep cervical fascia; SCF, superficial cervical fascia; SLDCF, superficial layer, deep cervical fascia. (A, From Norton NS. *Netter's Head and Neck Anatomy for Dentistry*. Philadelphia: Elsevier; 2012:437–450. B, From Som PM, Curtin HD. *Head and Neck Imaging*. Philadelphia: Elsevier; 2011: 2203–2234.)

abscess, and, in some instances, a buccal space infection (Fig. 17.4). Initially these represent an infection of the space of the body of the mandible (which is confined by the periosteum of the mandible). These infections can also travel to the subcutaneous tissues and subsequently the skin, leading to an orocutaneous fistula (or, more appropriately termed, sinus tract). This may happen commonly via the buccal space with borders determined by the maxilla, masseter muscle, mandible, buccinator muscle, and the muscles of facial expression and associated fascia. Whether the infection travels to the buccal space as opposed to remaining adherent to the maxilla or mandible depends on the level of cortical perforation with relation to the attachment of the buccinator muscle. If cephalad to the buccinator muscle attachment in the maxilla and caudal to the muscle attachment in the mandible, the infection may travel to the buccal space. However, if the root apex and location of cortical penetration is superior and inferior to the buccinator muscle attachment in the maxilla and mandible, respectively, the infection will likely present as a vestibular space infection. In this subperiosteal plane, vestibular space infections may then travel to the canine space, followed by infraorbital space in the maxilla, and from the space of the body of the mandible to a submandibular space infection in the mandible that then has the potential to rapidly propagate to deeper fascial spaces (Table 17.2).

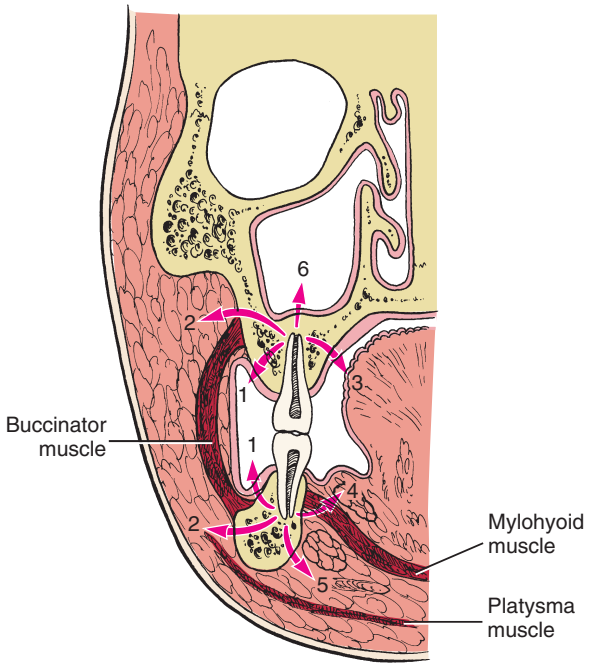


• **Fig. 17.2** Classification and hierarchy of fascial layers of the face and neck.

It is paramount to correctly diagnose the specific spaces involved in orofacial infections, because this is critical in determining the need for urgent surgical management. For example, buccal space infections may be drained intraorally or transcutaneously, especially if the infection is located in a superficial position below the skin surface (Fig. 17.5). In an extraoral drainage procedure the incision and drainage site should be placed in a position inferior to the area of spontaneous drainage, rather than directly in the area of maximum edema with tissue necrosis, to allow for dependent drainage of the infection, as well as to allow for optimal cosmesis of the scar following resolution of the infection. However, for a vestibular space, canine space, or space of the body of the mandible



• **Fig. 17.3** Anatomy of the deep fascial layers of the neck. The red highlighted layer represents the superficial layer of deep cervical fascia. (From Norton NS. *Netter's Head and Neck Anatomy for Dentistry*. Philadelphia: Elsevier; 2012:437–450.)



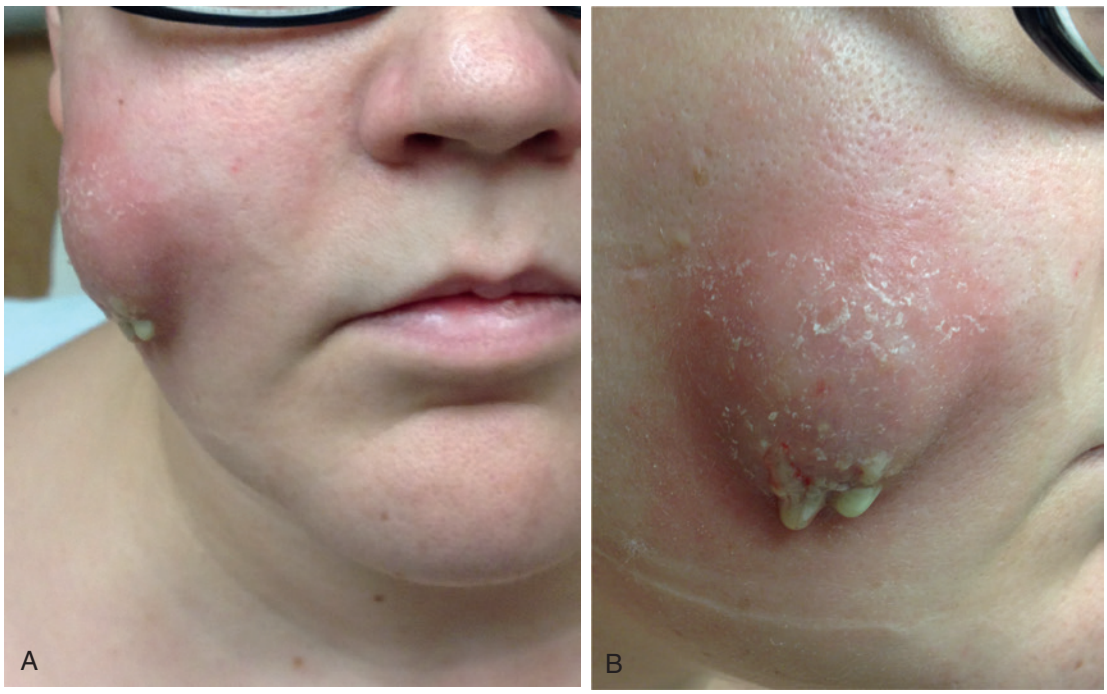
• **Fig. 17.4** Once eroded through bone, infection can express itself in a variety of places depending on thickness of overlying bone and relationship of muscle attachments to site of perforation. Six possible locations are the vestibular abscess *(1),* buccal space *(2),* palatal abscess *(3),* sublingual space *(4),* submandibular space *(5),* and maxillary sinus *(6)*. Buccal space abscess with spontaneous transcutaneous path of drainage (often path of least resistance). (Modified from Flint PW, Haughey BH, Lund VJ, et al, eds. *Cummings Otolaryngology: Head and Neck Surgery*. 5th ed. Philadelphia: Elsevier; 2010.)

infection, surgical drainage is best performed via an intraoral approach if dependent drainage can be achieved and because these spaces follow the paths of least resistance by which the infection would most likely spread (Fig. 17.6). Infection may then progress from these so-called primary spaces to the secondary spaces, or deep fascial spaces of the neck, such as the pterygomandibular space, parapharyngeal spaces (lateral and retropharyngeal), carotid space, and pretracheal spaces (space of Burns).

Microbiology and Antibiotic Management

Most oral and maxillofacial and deep space neck infections are polymicrobial in nature; only 5% of bacterial organisms can be identified as aerobic, whereas 25% are identified as anaerobic in nature. Anaerobic-related bacterial infections are fastidious and often difficult to culture effectively because the specimens obtained are generally exposed to oxygen when collected. The most common aerobic bacterial species identified in head and neck infections are *Streptococcus* and *Staphylococcus* species. The most common anaerobic species found in head and neck infections are *Bacteroides*, *Fusobacterium*, *Peptostreptococcus, Pigmented Prevotella, and Porphyromonas* species. Despite advances in antimicrobial therapy, the primary antibiotic indicated in the treatment of oral and maxillofacial infections is penicillin (beta-lactam antibiotic) or clindamycin (if an allergy to penicillin exists). Alternatively, cephalosporin antibiotics (e.g., cefoxitin), a carbapenem antibiotic (e.g., imipenem, meropenem), or a macrolide antibiotic (e.g., azithromycin) may be used.

As an example of orofacial infections and antibiotic management, because the etiology of maxillary sinusitis is often odontogenic in nature from maxillary teeth, optimal antibiotic management should be initiated promptly. The treatment of maxillary sinusitis,



• **Fig. 17.5** Buccal space abscess spontaneously draining through the skin of the cheek (path of least resistance).

TABLE 17.2 Spaces of the Head and Neck

	Borders	Potential Source of Infection	Contents	Adjacent Spaces	Surgical Approach for Incision and Drainage
Primary Maxillary					
Buccal	Modiolus Masseter muscle Maxilla Mandible/skin Buccinator muscle Deep cervical fascia, muscles of facial expression	Upper/lower premolars Upper molars	Parotid duct Facial vein Buccal fat pad	Infraorbital Pterygomandibular Infratemporal	Intraoral (for mild infections) Extraoral (for moderate to severe infections)
Palatal space	Palate, periosteum, palatal cortex	Lateral incisor, posterior teeth (palatal roots)	Greater palatine neurovascular bundle, minor salivary glands	Peritonsillar, buccal, vestibular	Intraoral
Vestibular space	Oral vestibular mucosa, muscles of facial expression (buccinators muscle)	Any tooth in dentition	Submucosa, connective tissue, mental nerves	Buccal, subcutaneous	Intraoral
Secondary Maxillary Spaces					
Infraorbital/canine space	Nasal cartilages Buccal space Quadratus labii superioris muscle Oral mucosa (canine space) Levator anguli oris muscle, maxilla	Upper canine/ upper premolar	Angular artery Infraorbital nerve	Buccal Canine Orbit	Intraoral
Orbital space	Bony walls of the orbit, orbital septum, optic foreman	Maxillary sinusitis, maxillary teeth	Globe, extraocular muscles, cranial nerves II, III, IV, V, VI	Maxillary sinus, ethmoid sinus, infratemporal fossa	Extraoral
Primary Mandibular					
Body of the mandible	Superior attachment of periosteum, periosteum, body of the mandible, inferior border of the mandible	Mandibular posterior teeth	Body of the mandible; inferior alveolar nerve, artery, vein; alveolus	Masticator, sublingual and submandibular	Intraoral/extraoral
Secondary Spaces					
Masticator Space					
Masseteric space	Buccal space, parotid gland, zygomatic arch, inferior border of mandible, ascending ramus of mandible, masseter muscle	Mandibular third molars	Masseteric vessels	Buccal	Extraoral/intraoral
Pterygomandibular space	Buccal space, parotid gland, pterygoid muscle, inferior border of mandible, medial pterygoid muscle, ascending ramus of mandible	Mandibular third molars	Third division of trigeminal nerve	Buccal	Extraoral/intraoral
Superficial temporal		Maxillary and mandibular molars	Temporal fat pad, frontal branch of facial nerve	Buccal/deep temporal	Intraoral/extraoral

TABLE 17.2 Spaces of the Head and Neck—cont'd

	Borders	Potential Source of Infection	Contents	Adjacent Spaces	Surgical Approach for Incision and Drainage
Deep temporal		Maxillary molars	Pterygoid plexus, maxillary artery and vein, third division of trigeminal nerve	Buccal, superficial temporal, inferior petrosal sinus	Intraoral/extraoral
Submandibular	Anterior belly of digastricmuscle, posterior belly of digastric muscle, inferior and medial surfaces of mandible, digastric tendon, platysma muscle, mylohyoid muscle	Mandibular molars	Submandibular gland, facial artery and vein, lymph nodes	Sublingual, submental, lateral pharyngeal, buccal	Extraoral
Sublingual	Lingual surface of mandible, submandibular space, oral mucosa, mylohyoid muscle, muscles of the tongue, lingual surface of mandible	Mandibular premolars and molars	Sublingual glands, Wharton ducts	Submandibular, lateral pharyngeal	Intraoral/extraoral
Submental	Inferior border of mandible, hyoid bone, mylohyoid muscle, investing fascia, anterior bellies of digastric muscle	Lower anterior teeth	Anterior jugular vein, lymph nodes	Submandibular	Extraoral
Parotid space	Superficial layer deep cervical fascia (splits), stylomandibular ligament (submandibular gland), subcutaneous tissues	Parotitis	Parotid gland, intraparotid lymph nodes, the facial nerve, the retromandibular vein, and the external carotid artery	Masticator, lateral pharyngeal, carotid	Extraoral
Peritonsillar space	Oropharyngeal mucosa, superior pharyngeal constrictor muscle (visceral [buccopharyngeal] fascia)	Tonsillitis	Palatine tonsil	Lateral pharyngeal	Intraoral/extraoral (if lateral pharyngeal space involvement)
Advanced Spaces					
Lateral pharyngeal	Superior and middle pharyngeal constrictors, carotid sheath and floor of the neck, skull base, hyoid bone, retropharyngeal space, medial pterygoid muscle	Lower third molars, tonsillitis	Carotid artery, internal jugular vein, vagus nerve, cervical sympathetic chain	Pterygomandibular, submandibular, sublingual, peritonsillar, retropharyngeal	Extraoral

Continued

TABLE 17.2 Spaces of the Head and Neck—cont'd

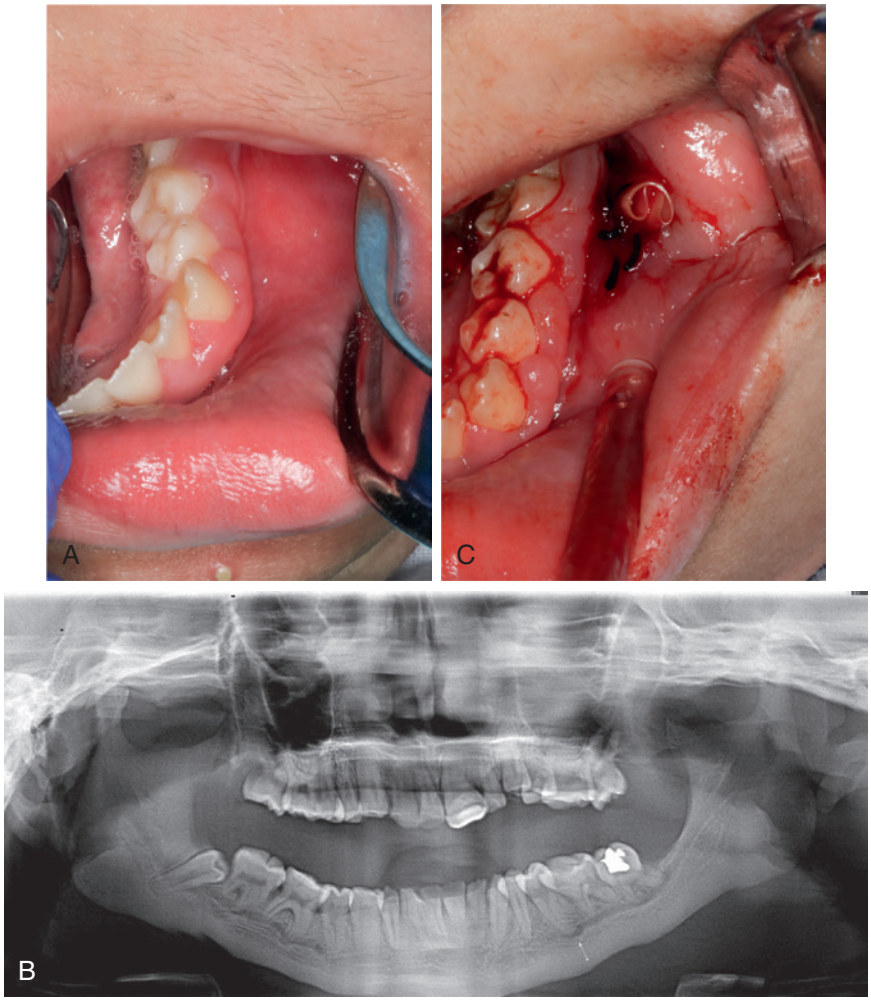
	Borders	Potential Source of Infection	Contents	Adjacent Spaces	Surgical Approach for Incision and Drainage
Retropharyngeal	Superior and middle pharyngeal constrictors, alar fascia, skull base, fusion of alar and prevertebral fascia, carotid sheath and lateral pharyngeal space	No direct route from odontogenic source (usually lateral pharyngeal)	Lymph nodes	Lateral pharyngeal, carotid sheath	Extraoral
Carotid space	Superior mediastinum, jugular foreman	Parapharyngeal spaces	Carotid artery, internal jugular vein, vagus nerve	Parapharyngeal	Extraoral
Pretracheal space	Fusion of middle layer of deep cervical fascia, travels to superior mediastinum, sternothyroid-thyrohyoid muscles	Extension from retropharyngeal space	Sternohyoid and sternothyroid muscles	Retropharyngeal, mediastinum	Extraoral
Visceral space	Visceral division of middle layer of deep cervical fascia, thyroid cartilage, enters mediastinum	Peritonsillar space, palatal space	Pharynx, larynx, trachea, esophagus, thyroid glands	Peritonsillar, palatal	Extraoral
Danger space	Base of skull, diaphragm, fusion of alar and prevertebral fascia	Pharyngeal spaces, visceral space	Areolar connective tissue	Posterior mediastinum	Extraoral
Mediastinum	First rib and manubrium of sternum, imaginary line drawn from bottom of fourth thoracic vertebrae	Danger space	Great vessels and major branches, thoracic duct, trachea, esophagus, thymic remnant, phrenic nerve, lymph nodes	Danger	Extraoral

Modified from Flynn TR. Anatomy of oral and maxillofacial infections. In: Topazian RG, Goldberg MH, Hupp JR, eds. *Oral and Maxillofacial Infections.* 4th ed. Philadelphia: WB Saunders; 2002.

which may progress beyond the boundaries of the sinus, usually includes a beta-lactam antibiotic with a beta-lactamase inhibitor (e.g., ampicillin/sulbactam), with or without metronidazole, that has a spectrum that includes the normal sinus flora (e.g., *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis*). Seventy percent of odontogenic-related maxillary sinusitis bacterial isolates are susceptible to amoxicillin clavulanate, and 80% of *Staphylococcus* species cultured are capable of producing beta-lactamase, an enzyme that renders beta-lactam antibiotics (penicillin) ineffective, and increases the likelihood of spread of the infection to adjacent spaces. However, 50% of all maxillary sinusitis pathogens have been found to be resistant to clindamycin, making this specific antibiotic not ideal for antimicrobial therapy (see Chapter 16). Whereas odontogenic infections are bacterial in nature and often benefit greatly from antibiotic therapy, it is important to remember that the mainstay of treatment of odontogenic infections is surgical management and that antibiotics should only be used as adjuvant therapy.

Medical Comorbidities

The role of systemic disease cannot be understated with regard to an increased susceptibility to the development of head and neck infections of any microbial origin. Patients with one or more medical comorbidities, or those who are immunocompromised, are more likely to be affected by bacterial and fungal sources of orofacial infection. Patients who have impaired neutrophil function, such as those who have human immunodeficiency virus disease, diabetes mellitus, elderly, or those on chronic hemodialysis have inherent decreased phagocytosis and host bactericidal mechanisms. Furthermore, patients undergoing systemic chemotherapy may be neutropenic, and therefore unable to mount a "normal" host immune response to an odontogenic infection. These patients will often not present with an abscess due to their impaired neutrophil function or decreased number of circulating neutrophils (neutropenia). Diabetic patients are especially susceptible to infection due to an increased level of glycosylated hemoglobin (HbA1c), decreased



• **Fig. 17.6** (A–B) Vestibular body of the mandible space infection is drained transorally via a vestibular incision and drainage approach (C).

vascularity and peripheral vascular disease, and decreased ability to resolve uncomplicated infections. Chronic hyperglycemia also affects other aspects of the host immune system, including white blood cell dysfunction. Patients with diabetes mellitus may be more prone to the development of an infection; when this occurs, these patients may have an increased severity of the infection, a higher rate of associated complications, increased morbidity, prolonged intensive care and hospital length of stay, and require more aggressive medical and surgical therapies. It is critical for the treating provider to manage and optimize the patient medically (e.g., obtain optimal blood glucose control as reflected in the HbA1c levels), as well as surgically, to promptly and aggressively resolve infections in this group of patients. In addition, diabetics are more susceptible to rare or unusual bacterial and fungal infections, which may present a diagnostic challenge when choosing the most appropriate antibiotic and antifungal medications.

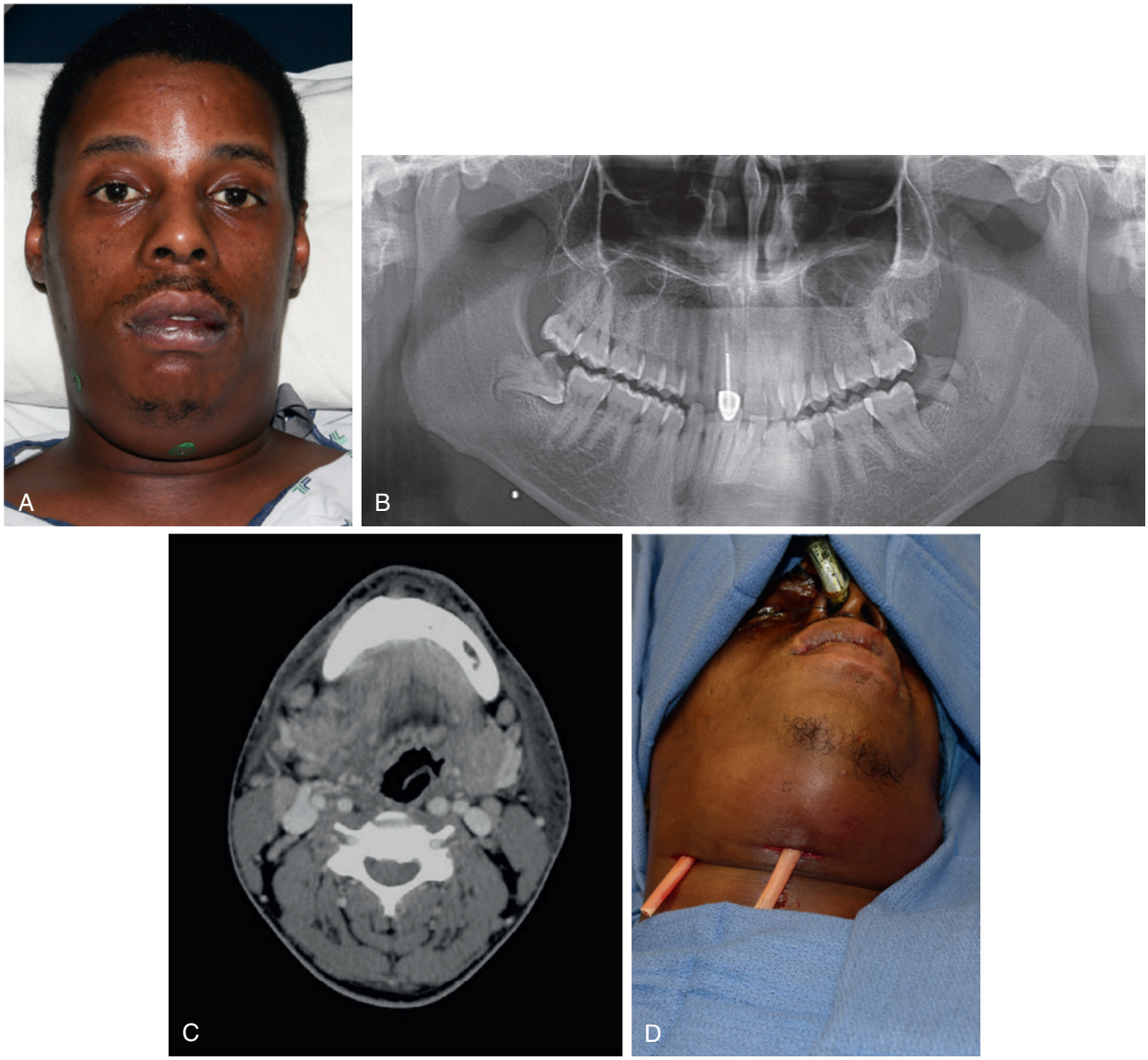
Deep Fascial Space Infections

Infections Arising From Any Tooth

The spaces most commonly affected by odontogenic infections, and therefore the most common space involvement seen on clinical examination by the dentist or dental specialist, are the vestibular, buccal, and subcutaneous spaces. Infections of the maxillary and mandibular teeth almost always begin as a vestibular space abscess based upon the spread via the path of least resistance through the buccal or lingual plates of bone. Secondarily, these vestibular infections commonly spread to the canine/infraorbital space in the maxilla and the space of the body of the mandible in the mandible. The buccal space, which may be commonly involved in infections originating from the maxillary and mandibular teeth, is contiguous with the subcutaneous space. Therefore buccal space infections most commonly drain spontaneously via the skin at the inferior border of the mandible as an orocutaneous fistula, or sinus tract. If left untreated, these relatively simple-to-treat infections can spread to the deep fascial spaces of the neck, which are associated with significant patient morbidity (Fig. 17.7).

Infections Arising From Maxillary Teeth

The maxilla is different from the mandible in that, unlike the mandible that is U-shaped, the bony palate forces infections arising from palatal cusps of maxillary teeth into the palatal space. This space, formed by the bone of the palate and the overlying periosteum, is often a drainage point for infections arising from the apices of the palatal roots of maxillary teeth. The lingual apices of the mandibular teeth, however, will usually drain to the sublingual

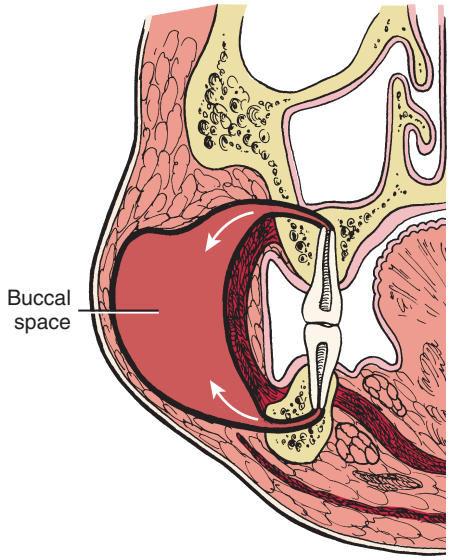


• **Fig. 17.7** (A–C) Submandibular space infection of odontogenic origin (untreated right mandibular carious tooth). The infection originally presented as vestibular space abscess. (D) The patient required incision and drainage via a transcervical approach.

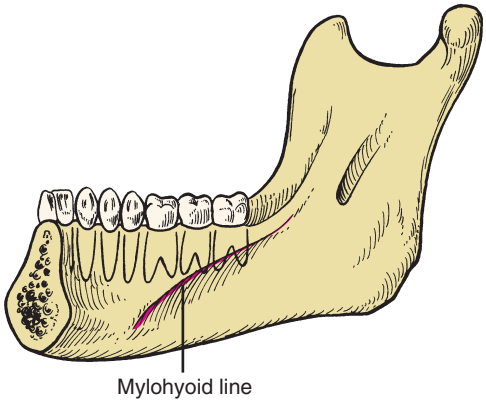
space or submandibular space, depending upon whether they are cephalad or caudal to the mylohyoid muscle, respectively.

For those infections originating from the buccal roots of teeth, or from teeth with root apices positioned more buccally, the usual path of spread is to the vestibular space, and then to the canine and infraorbital space in the maxilla. The canine or infraorbital space is bounded by the quadratus labii superioris and levator anguli oris muscles, the nasal cartilages, and the oral mucosa. This space is affected most by infections arising from the particularly long root of the maxillary canine tooth. When infections originating from the apex of the maxillary canine root perforate the alveolar bone superior to the attachment of the levator anguli oris muscle and inferior to the origin of the levator labii superioris muscle, the canine space will become involved. Alternatively, this space may become infected by extension from an adjacent buccal space infection. Similarly, infraorbital space infections may spread directly into the buccal space. The space inferior to the canine space (caudal to the levator anguli oris muscle) is the vestibular space that often drains spontaneously into the oral cavity. Conversely, an abscess of the infraorbital space will often drain at points near the medial and lateral canthi of the eye because these areas lie medial and lateral to the attachment of the levator labii superioris muscle to the inferior orbital rim and represent the paths of least resistance in this region. On clinical examination of a canine space infection, the nasolabial fold with be obliterated or flattened by the tissue edema below this specific facial landmark.

The *buccal space* is bounded superficially by the overlying skin and subcutaneous tissues and deeply by the buccinator muscle. Maxillary molars are most commonly associated with buccal space infections because infections arising from their buccal root apices perforate the alveolar bone immediately superior to the attachment of the buccinator muscle on the alveolar process (Fig. 17.8). Clinically there may be skin irregularities over the zygomatic arch, because the fascial layers superficial to the arch are tightly bound



• **Fig. 17.8** The buccal space lies between buccinator muscle and overlying skin and superficial fascia. This potential space may become involved via infection of maxillary or mandibular molars *(arrows)*. (Modified from Flint PW, Haughey BH, Lund VJ, et al, eds. *Cummings Otolaryngology: Head and Neck Surgery*. 5th ed. Philadelphia: Elsevier; 2010.)



• **Fig. 17.9** The mylohyoid line is area of attachment of mylohyoid muscle. Lingual cortical plate perforation by infection from premolars and first molar causes sublingual space infection, whereas infection from the third molar involves the submandibular space. (Modified from Flint PW, Haughey BH, Lund VJ, et al, eds. *Cummings Otolaryngology: Head and Neck Surgery*. 5th ed. Philadelphia: Elsevier; 2010.)

to the bone of the arch and become edematous superficially. Therefore, if there is no extension into adjacent spaces, the zygomatic arch and inferior border of the mandible usually remain palpable clinically in the setting of buccal space abscesses.

The *infratemporal space* is a potential fascial space that may be involved in the spread of maxillary odontogenic infections. It is a space that lies posterior to the maxilla and is continuous laterally and superiorly with the deep temporal space; therefore infections involving one of these spaces usually involve the other space. The infratemporal space is bordered medially by the lateral pterygoid plate of the sphenoid bone and superiorly by the base of the skull. Vital structures within this space include, but are not limited to, branches of the internal maxillary artery and pterygoid venous plexus. The pterygoid plexus is unique in that it provides emissary veins that travel through foramina in the base of skull and connect with intracranial dural sinuses. Infections reaching the pterygoid plexus may travel directly to the cavernous sinus because the veins of the head and neck lack valves to prevent retrograde propagation of bacteria. Infections of maxillary third molars most commonly contribute to bacterial spread to the infratemporal space. Due to the deep location, infections in the infratemporal space are difficult to examine adequately in the clinical setting, although temporal fullness may be visible.

The spread of periapical infections from maxillary teeth may erode superiorly and penetrate the floor of the maxillary sinus, causing maxillary sinusitis, and perhaps also spread to neighboring sinuses. Of note, odontogenic infections are implicated in 10% to 40% of cases of maxillary sinusitis and up to 75% of unilateral cases of maxillary sinusitis. However, maxillary teeth, as a source of sinusitis, are often overlooked clinically; in fact, patients will often be treated with medical and surgical management for chronic rhinosinusitis without assessing the dental disease as a potential contributory factor. Causes of maxillary sinusitis include iatrogenic, implant-related, traumatic, periapical osteitis, endodontic foreign bodies, restorative materials, bone grafting materials, and retained tooth or bone fragments. Any violation of the Schneiderian membrane may precipitate maxillary sinusitis, either from the spread of a periapical infection or penetration by a dental implant or an iatrogenic injury from sinus membrane elevation for placement of a bone graft. The most common clinical findings in maxillary sinusitis include facial pain, postnasal discharge, and congestion. The most common anaerobic gram-negative bacteria found associated with odontogenic-related maxillary sinusitis include *Streptococcus*, *Peptostreptococcus*, and *Fusobacterium* species. Aerobes include *Streptococcus* and *Staphylococcus* species, with these organisms present in 75% of cases of odontogenic sinusitis and acute infection. Less common but more difficult to treat etiologies include *Aspergillus* species. Acute sinusitis from odontogenic origin can propagate through the ethmoid sinus and spread to the periorbital space. Preseptal cellulitis—that is, an infection of the eyelid structures anterior to the orbital septum—will occasionally lead to an orbital cellulitis. Infections may travel freely (because there are no valves in the veins of the head and neck) either from the infraorbital vein into the infraorbital space, or the inferior ophthalmic vein, or via the sinuses to join with the common ophthalmic vein through the superior orbital fissure, which can then travel to the cavernous sinus (cavernous sinus thrombosis) and can be fatal even with optimal medical and surgical management. Surgical management of the sinus in odontogenic-related maxillary sinusitis includes open or functional endoscopic-assisted sinus surgery.

Infections Arising From Mandibular Teeth

The most common initial route of spread for infections originating from mandibular teeth is the vestibular space. However, infections may also initially or secondarily enter the sublingual space or submandibular space (depending upon the level of the root apex in relation to the attachment of the mylohyoid on the lingual aspect of the mandible; Fig. 17.9), the masticator space, or the buccal space. From here infections may travel to the secondary or deep neck fascial spaces. The space of the body of the mandible is a potential space between the cortical bone of the mandible and overlying periosteum and becomes involved when an infection erodes through the periosteum, leading to the creation of an infection between the bone and periosteum of the mandible. Similar to the palatal space in the maxilla, a space that is also formed

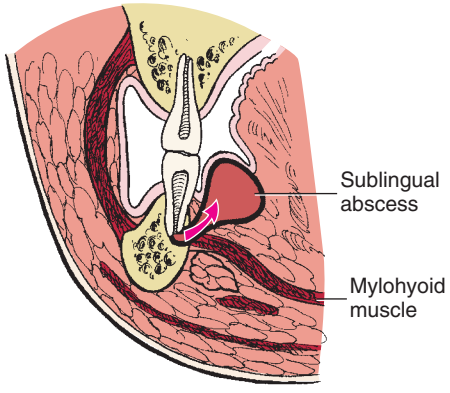
between the bone and overlying periosteum, infections of this space can become very diffuse due to the shape of the mandible and extend to adjacent spaces (sublingual, submandibular spaces). For example, an infection arising from a mandibular tooth root apex that is located caudal to the attachment of the buccinator muscle will initially involve the space of the body of the mandible and then secondarily affect the buccal space.

Perimandibular spaces, as described by Grodinsky and Holyoke, include the submandibular, sublingual, and submental spaces. The submandibular and sublingual spaces would be considered the same space if not for one key boundary—the attachment of the mylohyoid muscle to the medial surface of the mandible (mylohyoid line; see Fig. 17.9). These perimandibular spaces become involved when infections originating from the premolars and molars perforate the lingual cortex of the mandible. If the infection perforates the mandible cephalad to the attachment of the mylohyoid muscle, the infection will enter the sublingual space. If the infection perforates the lingual cortex inferior to the attachment of the mylohyoid muscle to the mandible, then it will enter the submandibular space.

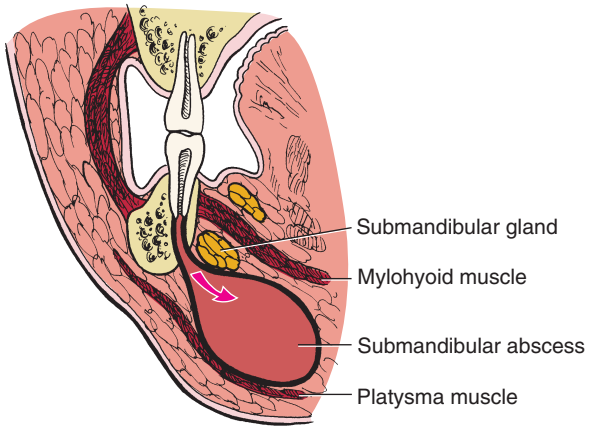
The *sublingual space* is a perimandibular space that is commonly the first deep fascial space involved in mandibular odontogenic infections (Fig. 17.10). The boundaries include the floor of the mouth submucosa and the mylohyoid muscle. It is unusual to observe an isolated sublingual space infection without a synchronous submandibular space infection. This is due to the fact that the sublingual space has no posterior boundary and freely communicates with the submandibular space. However, unlike a submandibular space abscess, in an isolated sublingual space abscess, by definition there should be no noticeable extraoral swelling because the infection is limited to a location that is cephalad to the mylohyoid muscle. Clinical findings of isolated sublingual space involvement include tongue and floor of mouth elevation, with difficulty with speech or swallowing, especially in later stage infections or in bilateral sublingual space infections.

The *submandibular space*, as opposed to the sublingual space, almost always manifests with the clinical finding of visible extraoral swelling (Fig. 17.11, see also Fig. 17.7). This edema results because, by definition, a submandibular space infection occurs caudal to the mylohyoid muscle, and therefore the SLDF and platysma muscle are the only barriers between the abscess cavity and the skin. Clinically it is the SLDF that is surgically entered during an incision and drainage procedure and produces the release of purulence when present. As with the sublingual space, there is no posterior boundary of the submandibular space, and it communicates freely with the deeper fascial spaces of the neck (e.g., pterygomandibular and lateral pharyngeal spaces) that may result in significant morbidity when involved. The submandibular space is triangular in configuration, formed by the inferior border of the mandible and the anterior and posterior bellies of the digastric muscles.

The *submental space* is affected often by infections originating from the mandibular incisor teeth. However, commonly the submental space becomes involved as an extension of submandibular space infections. This is due to the fact that the only anterior barrier of the submandibular space is the anterior belly of the digastric muscle, which is not a true barrier between the submandibular and submental spaces. Furthermore, infections from one submandibular space may pass through the submental space to then involve the contralateral submandibular space. Involvement of sublingual, submandibular, and submental spaces is known as Ludwig angina. This is a term often used inappropriately by clinicians for any perimandibular space infection; but when it does exist, it has clinical significance because the airway may be compromised. When a cellulitis or abscess involves all three of these spaces (actually, five spaces: two submandibular spaces, two sublingual spaces, and one submental space), the airway should be the primary consideration and be secured promptly (e.g., tracheal intubation of tracheostomy). The clinical findings in Ludwig angina include firm induration of the skin in the submental and submandibular regions extraorally and elevation of the floor of the mouth and tongue intraorally (sublingual space) and possibly fluctuant swellings (abscess cavities) bilaterally from the inferior border of the mandible to the hyoid bone. The inferior border of the mandible is often not palpable due to significant firm swelling. Other clinical findings include dysphagia, dysphonia, trismus, floor of mouth, tongue elevation (causing inability to visualize and evaluate the posterior oropharynx), cervical immobility, globus sensation (feeling of a lump in throat) in the late stages, inability to handle oral secretions, head held in a forward "sniffing" position, a "hot potato" voice, and increased work of breathing due to upper airway obstruction. In the early and mid-1900s, Ludwig angina was associated



• **Fig. 17.10** The sublingual space lies between the oral mucosa and the mylohyoid muscle. The space is primarily involved by infection from mandibular premolars and first molar. (Modified from Flint PW, Haughey BH, Lund VJ, et al, eds. *Cummings Otolaryngology: Head and Neck Surgery*. 5th ed. Philadelphia: Elsevier; 2010.)



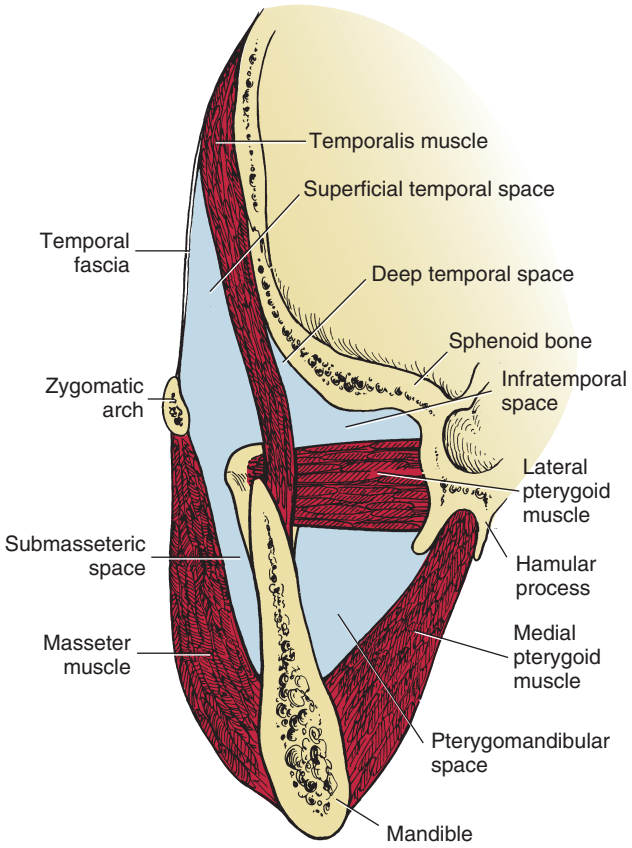
• **Fig. 17.11** The submandibular space lies between the mylohyoid muscle and anterior layer of the deep cervical fascia, just deep to the platysma muscle, and includes the lingual and inferior surfaces of the mandible below the mylohyoid muscle attachment. (Modified from Flint PW, Haughey BH, Lund VJ, et al, eds. *Cummings Otolaryngology: Head and Neck Surgery*. 5th ed. Philadelphia: Elsevier; 2010.)

with high morbidity and mortality, and it was determined that securing the airway as early as possible, with early surgical intervention in the form of incision and drainage, significantly reduced patient morbidity.

As an example of the manner in which deep space neck infections spread freely in the head and neck, the sublingual and submandibular spaces coalesce at the posterior aspect of the mylohyoid muscle to form the buccopharyngeal gap. It is at the junction of this gap that the styloglossus and stylohyoid muscles pass between the superior and middle pharyngeal constrictor muscles in their path from the styloid process to the tongue and hyoid bone, respectively. Once infections pass from the submandibular space through the buccopharyngeal gap to enter the *pterygomandibular space*, they may then progress to the *lateral pharyngeal space*, and rapidly, if left untreated, to the *retropharyngeal space*. A second pathway of spread from the submandibular space to the lateral pharyngeal space is directly posterior around the posterior belly of the digastric muscle. These deep fascial space neck infections can cause even greater morbidity not only due to their proximity to the airway, but also to their potential communication to the mediastinum.

The submandibular and masticator spaces are the most common space involved in deep space neck infections requiring hospital admission. The *masticator space* includes four spaces: *masseteric* (or *submasseteric*) *space*, *pterygomandibular space*, *superficial temporal space*, and *deep temporal space* (Fig. 17.12). Importantly, the pterygomandibular space of the masticator space is involved in 78% of cases. The most common offending tooth in masticator space infections is the mandibular third molar due to pericoronitis. The most common direct route of spread of infection from the mandibular third molars is to the pterygomandibular space. The boundaries of the pterygomandibular space include the buccal space, parotid gland, pterygoid muscle, inferior border of mandible, medial pterygoid muscle, and ascending ramus of mandible (see Table 17.1). However, these infections can spread rapidly to the other components of the masticator space, as well as to the lateral pharyngeal space.

The *masticator space*(s) are affected commonly from odontogenic infections and formed by the splitting of the anterior layer of the deep cervical fascia. This superficial, or investing, layer of the deep cervical fascia surrounds all of the muscles of mastication. This fascia, which divides at the inferior border of the mandible to pass laterally over the masseter muscle and medially over the medial pterygoid muscle, terminates at the junction of the pterygoid plates and sphenoid bone. Lateral to this location is the parotideomasseteric fascia. It travels over the masseter muscle fusing to the periosteum of the zygomatic arch. This fascia continues superior to the zygomatic arch as deep temporal fascia covering the temporalis muscle and terminating at the insertion of the temporalis muscle at the temporal crest. There are four separate compartments that comprise the masticator space, including *masseteric* or *submasseteric space*, *pterygomandibular space*, *deep temporal space*, and *superficial temporal space* (see Fig. 17.12). The *submasseteric space* is bounded by the masseter muscle and ascending ramus of the mandible. The pterygomandibular space is formed by the medial pterygoid muscle and ascending ramus. The superficial temporal space is formed by the temporalis fascia and temporalis muscle. The deep temporal space is formed by temporalis muscle and calvarium. These four spaces function as "subspaces" of the masticator space, but they can all become involved rapidly once one compartment is affected. The submasseteric and superficial temporal spaces are separated by the zygomatic arch. The pterygomandibular and deep temporal spaces are separated by the lateral pterygoid muscle. The



• **Fig. 17.12** The masticator space is bounded by the fascia overlying the masseter muscle, medial pterygoid muscle, temporalis muscle, and the skull. The superficial and deep temporal spaces are separated from each other by the temporalis muscle. The lateral pterygoid muscle divides the pterygomandibular space from the infratemporal portion of the deep temporal space, and the zygomatic arch divides the submasseteric space from the superficial temporal space. (Modified from Flint PW, Haughey BH, Lund VJ, et al, eds. *Cummings Otolaryngology: Head and Neck Surgery*. 5th ed. Philadelphia: Elsevier; 2010.)

infratemporal space is the inferior aspect of the deep temporal space and lies between the lateral pterygoid muscle and infratemporal crest of the sphenoid bone. Traditionally it is the pterygomandibular and submasseteric spaces that are involved first when a posterior mandibular molar (e.g., periapical infection or pericoronitis) is the offending source. Another common cause of submasseteric space infections is an infected mandibular angle fracture. Radiographic (e.g., computed tomography [CT], magnetic resonance imaging [MRI]) signs of a submasseteric space infection may include diffuse enlargement of the masseter muscle due to swelling. The primary clinical finding in masticator space involvement is trismus due to inflammation of the muscle(s) of mastication.

Similar to the submasseteric space, infections of the pterygomandibular space often originate from an infected mandibular third molar or adjacent soft tissue inflammation. When an isolated pterygomandibular space is present, minimal extraoral facial swelling will be present. However, a critical clinical feature is trismus due to the involvement of the medial pterygoid muscle. Radiographically (e.g., CT, MRI), the medial pterygoid muscle may be enlarged due to inflammation and edematous engorgement. In the case of abscess formation, a fluid collection may be seen between the medial pterygoid muscle and the medial surface of the ramus of

the mandible. A CT scan with intravenous contrast will help visualize the abscess cavity because the contrast will be isolated to the blood vessels at the periphery of the abscess cavity and will be seen as "ring enhancement." Intraoral examination is typically very difficult to perform due to marked trismus, but it may reveal erythema and edema of the anterior tonsillar pillar region and, occasionally, deviation of the uvula to the unaffected side, especially when the infection begins to extend into the lateral pharyngeal space. The airway may be compromised, which contributes further to the severity and urgency of the clinical scenario.

Because infections usually spread in a caudal gravity-dependent manner, only the most severe infections will reach the temporal spaces (superficial and deep). Clinically there will be pain and edema, with fluctuance in advanced temporal space infections overlying the temporal bone superior to the zygomatic arch. Swelling is not usually seen caudal to the zygomatic arch due to the dense attachment of the anterior layer of the deep cervical fascia to the zygomatic arch. In fact, involvement of both the submasseteric and temporal spaces produces an hourglass-appearing edematous swelling due to the lack of the swelling just inferior to the zygomatic arch.

Deep Cervical Fascial Space Infections

Propagation of these primary fascial spaces to the secondary or deep fascial spaces of the neck is associated with significant morbidity, and, in some cases, mortality due to the significant potential for impending airway compromise. In addition to impingement on the airway, which is the most common life-threatening complication seen with deep space neck infections, these infections may also involve the vital structures of the neck such as the great vessels (e.g., carotid artery, jugular vein). Any extension posteriorly from the pterygomandibular, submandibular, or sublingual spaces will lead to involvement of the lateral pharyngeal space (Fig. 17.13, see also Fig. 17.1). This space, with an inverted triangle shape, extends from the base of the skull (sphenoid bone) superiorly to the level of the hyoid bone inferiorly. This space is bordered laterally by the medial pterygoid muscle and medially by the superior pharyngeal constrictor muscle. Anteriorly the space is bounded by the pterygomandibular raphe and posteriorly by the retropharyngeal space. There are two compartments to the lateral pharyngeal space, both of which are important to delineate to assess the severity of the infection. The *anterior compartment* of the lateral pharyngeal space contains primarily loose areolar connective tissue, with the styloid process and its associated muscles forming the posterior border. The *posterior compartment*, bordered anteriorly by the styloid process, contains the carotid sheath (contents: common carotid [and internal carotid] artery [medial], internal jugular vein [lateral], and vagus nerve [posterior], and deep cervical lymph nodes), glossopharyngeal nerve, and hypoglossal nerve. Clinically extension of infections to the lateral pharyngeal space will result in trismus due to involvement of the medial pterygoid muscle, as well as cellulitis or fluctuant swelling of the lateral neck. This swelling is localized between the inferior border of the mandible and sternocleidomastoid muscle, and therefore a significant finding in lateral pharyngeal space involvement is the inability to visualize and palpate the angle of the mandible. Intraorally, pressure due to edema on the superior constrictor muscle will result in bulging of the lateral wall of the oropharynx toward the midline (pharyngeal draping). In addition, these patients may have dysphagia, dysphonia, an inability to handle salivary secretions, and a high-grade fever. There is often significant malaise, with impending airway compromise due to direct impingement on the oropharynx and hypopharynx.

Lateral pharyngeal space infections are extremely dangerous because of their potential to spread quickly more caudally to other deep fascial spaces of the neck, including the retropharyngeal space (Fig. 17.14). These infections can progress at a rapid rate, which is concerning due to not only the effect on the airway, but also the potential involvement of the contents of these spaces, including thrombosis of the internal jugular vein, erosion of the wall of the carotid artery, and possible impingement on cranial nerves IX, X, and XII.

The *retropharyngeal space* is located behind the posterior pharyngeal wall (Fig. 17.15). The anterior boundary of this space is formed by the superior, middle, and inferior pharyngeal constrictor muscles and retropharyngeal fascia, and the posterior boundary is the alar fascia. The superior boundary is formed by the base of the skull, whereas the most caudal boundary is a point usually located between the sixth cervical and fourth thoracic vertebrae. This caudal boundary is where the alar fascia fuses anteriorly with the buccopharyngeal fascia. The retropharyngeal space contains loose areolar connective tissue and lymph nodes and may easily become involved by infection due to extension from the lateral pharyngeal space. When this occurs, the infection can spread caudally and posteriorly to the danger space (Fig. 17.16). The borders of the danger space are the alar fascia anteriorly and the prevertebral fascia posteriorly. The superior border of the danger space is the skull base, and the inferior boundary is the diaphragm. The prevertebral space is rarely involved with odontogenic infections due to the tight adherence of the prevertebral fascia with the vertebrae (see Fig. 17.16). A rare instance of a prevertebral space infection may occur with osteomyelitis of the vertebrae bone.

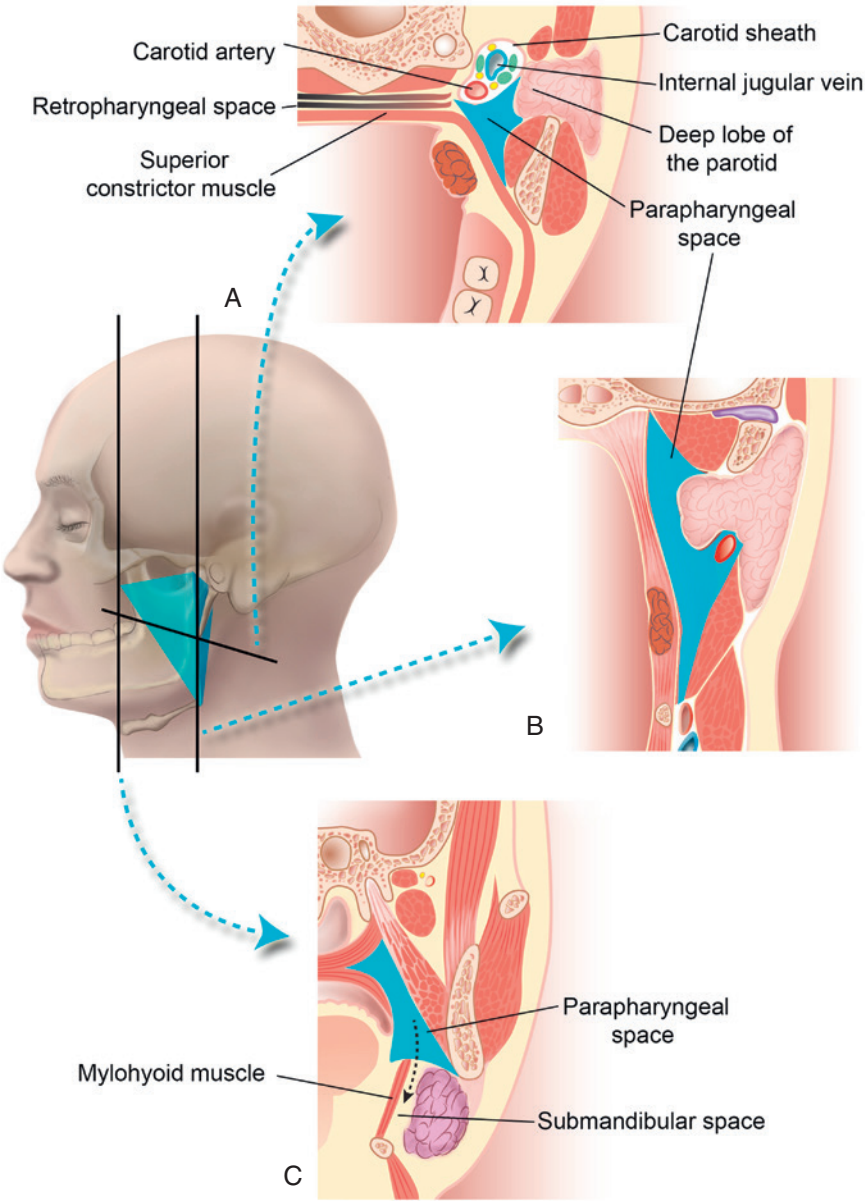
The mediastinum is a large cavity located between the lungs and containing the heart, phrenic nerve, vagus nerve, trachea, main stem bronchi, esophagus, and the great vessels (aorta and superior and inferior vena cavae; Fig. 17.17). Infections may progress to involve the mediastinum (mediastinitis), and clinically this will present with a critically ill appearance due to compression of the heart and lungs. Due to possible neural compression, the neurologic innervation (e.g., vagus nerve) of the cardiovascular and respiratory systems may be interrupted, and the esophagus, lungs, and lower airway may rupture, causing immediate life-threatening events. Despite prompt cardiothoracic surgical intervention, the mortality of mediastinitis remains high.

Management of Fascial Space Infections

The management of odontogenic infections of the head and neck has several primary goals: (1) medical optimization, (2) airway protection (general endotracheal intubation or surgical airway), (3) removal of the source of infection, (4) surgical incision and drainage, (5) adjunctive antibiotic therapy, and (6) frequent assessment of response to therapy. Utilization of these principles may not result in complete resolution of an infection but may identify the need for additional treatment measures. Medical comorbidities have already been discussed, as well as the role of adjunctive antibiotic therapy. Importantly, it is critical to reevaluate the patient response periodically after any form(s) of intervention in order to adjust the treatment as indicated.

Airway Management

Serious infections in the proximity of the upper airway may cause airway obstruction, leading to respiratory insufficiency or respiratory

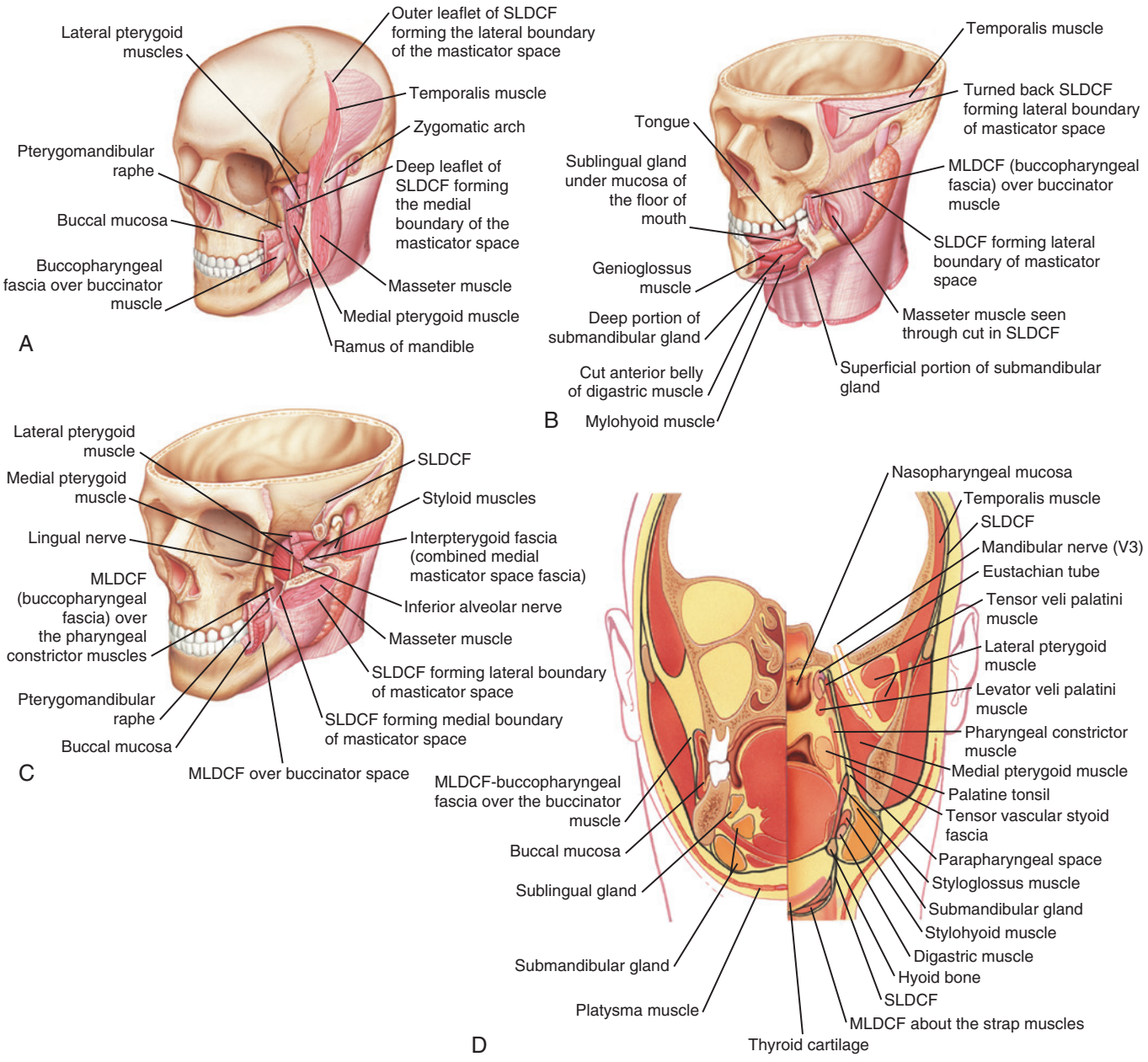


• **Fig. 17.13** (A) Axial section through the oral pharynx demonstrating the contents of the parapharyngeal space. The prestyloid space contains the deep lobe of the parotid, fat, and lymph nodes. The poststyloid compartment contains the internal jugular vein; internal carotid artery; cranial nerves IX, X, XI, and XII; sympathetic trunk and superior sympathetic ganglion; ascending pharyngeal artery; and lymph nodes. Note its proximity and continuity with the peritonsillar and retropharyngeal spaces. (B) Coronal section through the oropharynx showing the vertical extent of the parapharyngeal space. (C) Coronal section sliced more anterior demonstrating the continuity of the parapharyngeal and submandibular spaces. (From Blumberg JM, Judson BL. *Oper Tech Otolaryngol Head Neck Surg*. 2014;25[3]:304–309.)

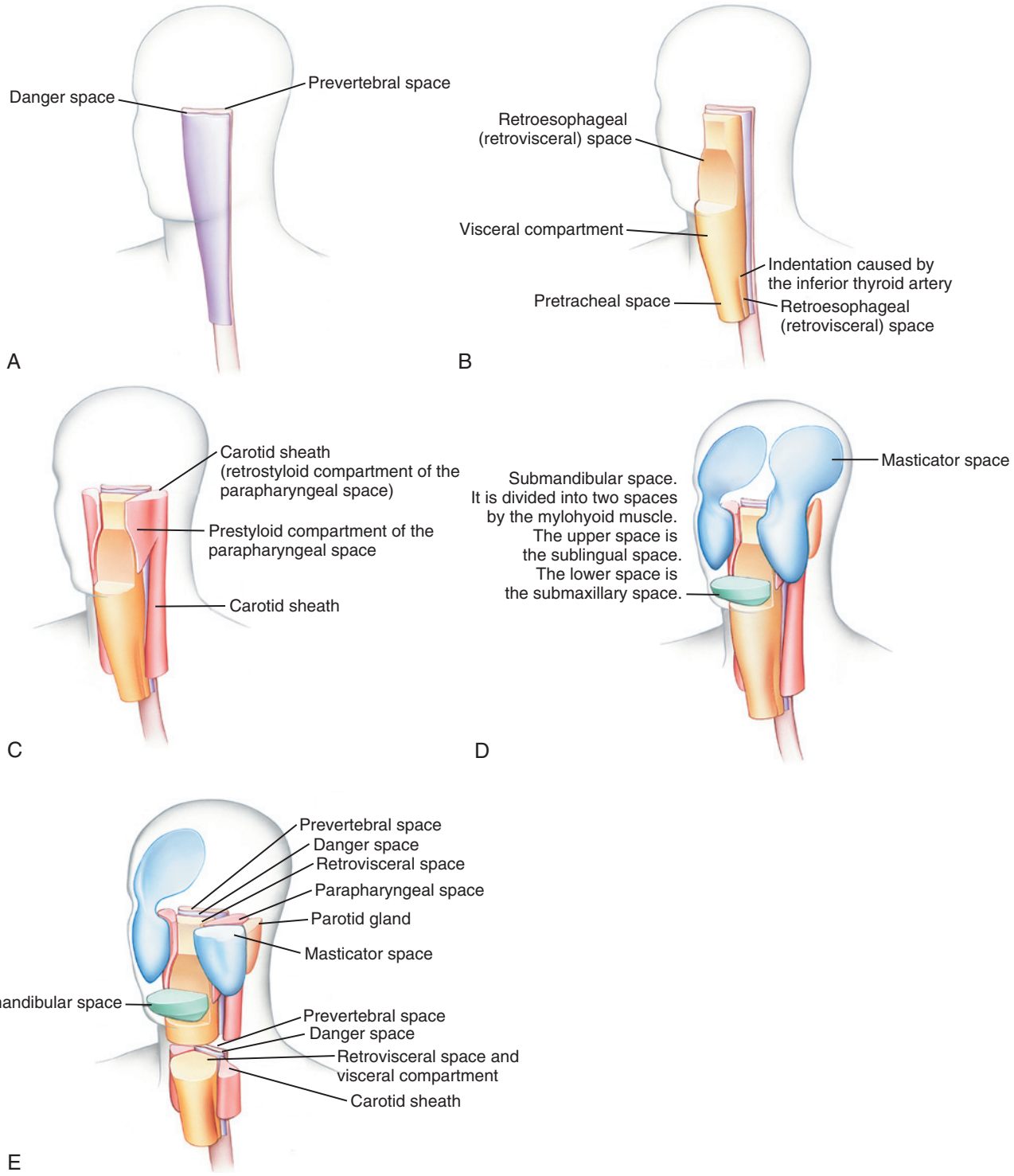
failure. When patency of the upper airway cannot be maintained with routine maneuvers (e.g., head tilt, jaw thrust), immediate airway access and patency must be established surgically. Typically this is accomplished with a cricothyrotomy or tracheotomy. One of the many indications for tracheotomy is to bypass an upper airway obstruction, which is often necessary in the setting of deep space neck infections. In this scenario, tracheotomy may be urgent or emergent; therefore it is imperative for the clinician to be capable of creating a surgical airway. The need for a surgical airway may be noted during the preoperative period, and a controlled awake tracheotomy may be performed under light sedation and local anesthesia. However, in the case where attempts to establish an airway are unsuccessful, including the use of fiberoptic endoscopic tracheal intubation or video-assisted intubation, the tracheostomy may become emergent. Therefore preparation is critical; all instrumentation should be present for performing a tracheotomy, and the anesthesiology team should be involved in the proposed plan.

Surgical Management

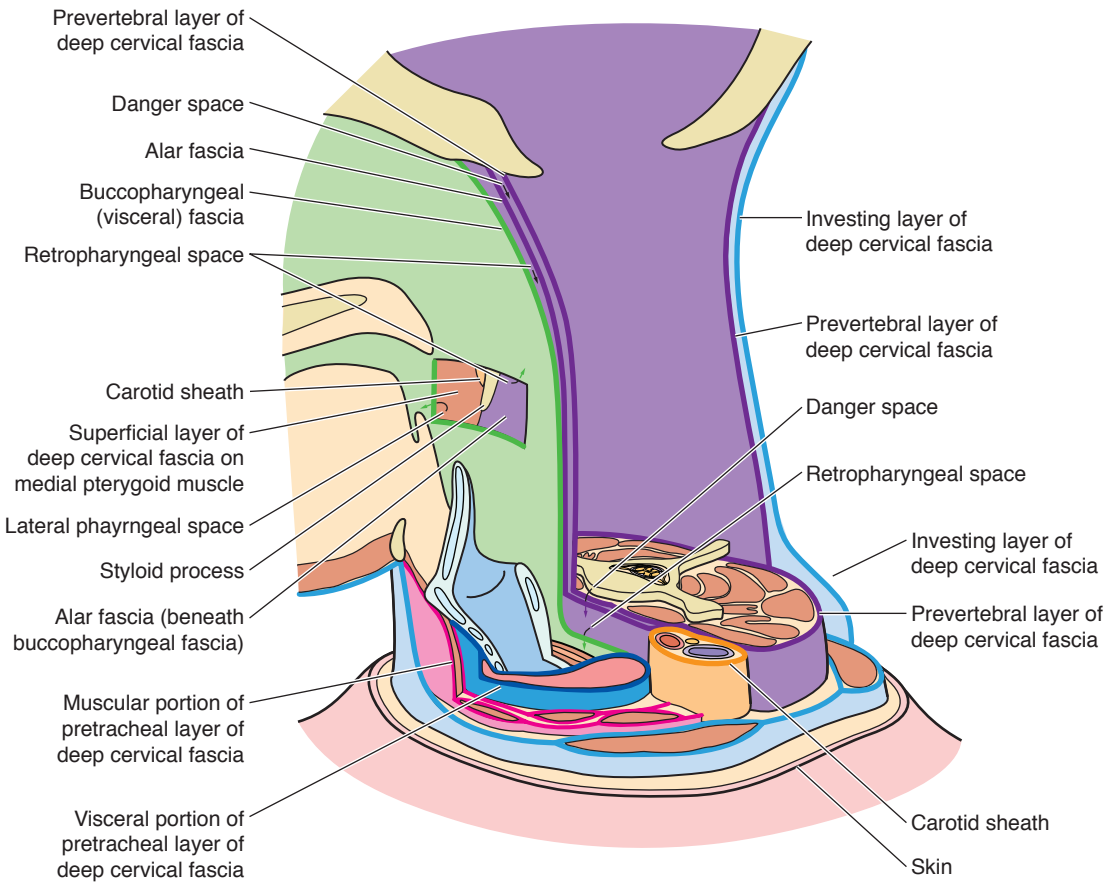
Once the airway has been assessed and secured, the surgical management of the source of infection is of crucial importance.



• **Fig. 17.14** Left oblique view of facial region and neck. (A) A coronal cut has been made through the ramus of the mandible. The deep and superficial fascial leaflets of the masticator space are shown, as is the relationship of the masticator space to the buccopharyngeal fascia. (B) An axial cut has been made through the temporalis muscle, and a portion of the mandible has been removed to expose the floor of mouth structures. (C) An axial cut has been made through the mid-mandibular ramus. The left zygoma and most of the arch have been removed to expose the deep structures of the region. (D) A coronal drawing of the facial region and upper neck. On the right side of the drawing, the coronal cut is through the region of the foramen ovale and palatine tonsil. On the left side of the drawing, the cut is through the region of mid floor of mouth. *MLDCF,* Middle layer, deep cervical fascia; *SLDCF,* superficial layer, deep cervical fascia. (From Som PM, Curtin HD. *Head and Neck Imaging*. Philadelphia: Elsevier; 2011:2203–2234.)



• **Fig. 17.15** Head and neck in lateral oblique view. The prevertebral and danger spaces are shown (A), as well as the visceral space (B). Note the separate pretracheal space and retrovisceral space below the level of the insertion of the inferior thyroid artery. The left parapharyngeal space is shown (C), as is the carotid sheath. (D) Masticator and submandibular spaces. (E) Axial cuts through the levels of the upper pharynx and mid-neck illustrating their special relationships. (From Som PM, Curtin HD. *Head and Neck Imaging*. Philadelphia: Elsevier; 2011:2203–2234.)



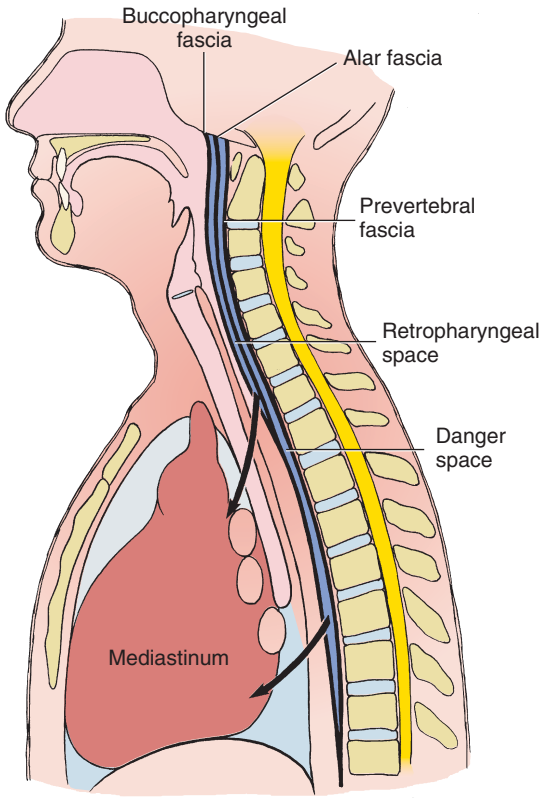
• **Fig. 17.16** Lateral pharyngeal space infections can progress to the retropharyngeal space. Further progression could be to the danger space just before reaching the mediastinum. (From Norton, NS. *Netter's Head and Neck Anatomy for Dentistry*. Philadelphia: Elsevier; 2012:437–450.)

Whether it be a vestibular abscess, an odontogenic-related maxillary sinusitis, or a deep fascial neck space infection, the primary goal of therapy is elimination of the source of infection. Management of the airway, removal of the offending source of infection, and decompression of the fluid collection (incision and drainage) are performed most appropriately in the operating room setting with general anesthesia, especially for complex odontogenic infections. Removal of the offending source reduces the severity of the infection, shortens hospital stay, and together with surgical treatment of the abscess, results in prompt return to activities of daily living. Basic surgical principles in the management of deep fascial space infections of the neck include the creation of an incision that is adequate to perform exploration of all of the involved spaces, drainage of the infection, and drain placement to allow for continued spontaneous drainage of the infection (dependent drainage). The goal of surgical access to the infection site is to expose the tissues to the aerobic environment (in the case of cellulitis, to prevent progression to an abscess with anaerobic bacteria) and, in the case of an established abscess, complete decompression of the fluid collection and exposure of the anaerobic bacteria to an oxygen-rich environment. A lateral pharyngeal space abscess may be approached via various transcutaneous access sites and appropriate placement of one or more drains in all spaces affected (Fig. 17.18). In fact, there should be a low threshold for drain placement, even with an early onset infection (cellulitis phase), because this may prevent the development of an abscess and expedite resolution of a cellulitis. Surgical exposure and exploration of all involved spaces, establishment of drainage of the infection, and removal of the etiologic source of infection (tooth, tumor, fracture, foreign body) are of paramount importance in management, and co-medical management with antimicrobial coverage is considered adjunctive therapy (Fig. 17.19). It must be recognized that many head and neck infections may be *nonodontogenic* in origin, and infections of the head and neck may originate from other sources (Fig. 17.20).

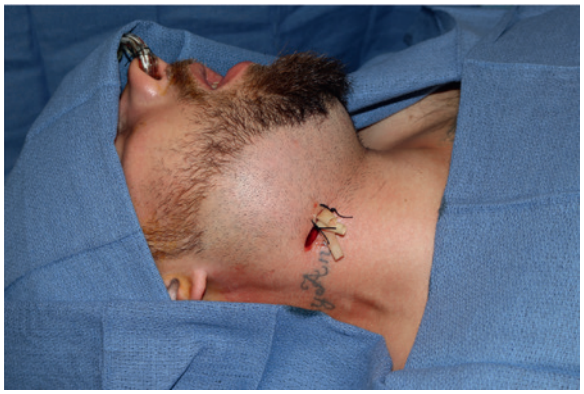
Specific Infections

Cavernous Sinus Thrombosis

One of the most severe complications of a maxillary odontogenic infection is cavernous sinus thrombosis. The cavernous sinuses are intracranial compartments that serve as bilateral venous drainage channels for the middle cranial fossa. These cavities (or "sinuses") absorb secretory fluid from the pituitary gland and are bordered by the superior orbital fissure anteriorly that contains the ophthalmic vein (Fig. 17.21). The superior and inferior ophthalmic veins drain the orbital region, and it is via these veins that orbital abscesses may spread to the cavernous sinus. The cavernous sinus is bordered laterally and superiorly by the dura mater. The cavernous sinus is drained by the superior and inferior petrosal sinuses. The contents of the cavernous sinus include cranial nerves II, III, IV, VI; the second division of cranial nerve V; and the internal carotid artery (see Fig. 17.21B). On clinical exam, any of the structures that receive innervation from these nerves may be affected, but the



• **Fig. 17.17** The retropharyngeal and the alar fascia fuse at a variable level between the C6 and T4 vertebrae, which forms a pouch at the inferior extent of the retropharyngeal space. If infection passes through the alar fascia to the danger space, the posterosuperior mediastinum will most likely soon become involved. The inferior boundary of the danger space is the diaphragm, which puts the entire mediastinum at risk.



• **Fig. 17.18** Transcervical approach to drainage of the lateral pharyngeal space with drains placed in all affected spaces.

abducens nerve (CN6) is most likely to be affected (lateral rectus muscle palsy) because its exposure in the cavernous sinus is greatest in the lateral compartment. Another early finding in cavernous sinus thrombosis is congestion of the retinal veins of the eye on the unaffected side that may be noted on a detailed ophthalmologic exam.

Necrotizing Fasciitis

Necrotizing fasciitis, known colloquially as flesh-eating bacterial infection due to the unique characteristic of the infection, does not obey the typical organization of the fascial planes of the head and neck. Cervical necrotizing fasciitis is often polymicrobial in nature, is strikingly destructive, and is often fatal with a mortality rate of 7% to 20%. When the infection progresses to the thoracic region as a descending necrotizing mediastinitis, the mortality rate rises dramatically. Management includes prompt, very aggressive debridement and removal of all affected soft tissues (Fig. 17.22). This will usually require the creation of a surgical airway and continued intensive care unit monitoring and management. Broad-spectrum empiric bactericidal intravenous (IV) antibiotics are generally always indicated in these cases because all involved tissues cannot be completely eradicated until specific culture and sensitivity results are available to guide specific antibiotic regimens. First described by Pearse in 1938, who reported a 49% mortality rate, the progression of cervical necrotizing fasciitis does not follow the normal fascia planes of the head and neck. This is due to the unusually aggressive nature of the disease process. Often patients are immunocompromised, leading to this unusual and complex clinical course and extensive progression of an odontogenic head and neck infection. The disease process is characterized by the rapid spread of the infection on the superficial surface of the anterior (investing) layer of the deep cervical fascia deep to the platysma muscle. Clinically there is necrosis of the platysma muscle and overlying skin due to thrombosis of the underlying muscles and soft tissues, as well as the dermal blood supply (Fig. 17.23). The extensive tissue necrosis, including the skin, must be debrided thoroughly to halt the continued spread of the disease process. Removal of the offending source of the infection, aggressive surgical debridement, the use of initial broad-spectrum empiric antibiotics, and medical optimization of the patient are of paramount importance.

Osteomyelitis

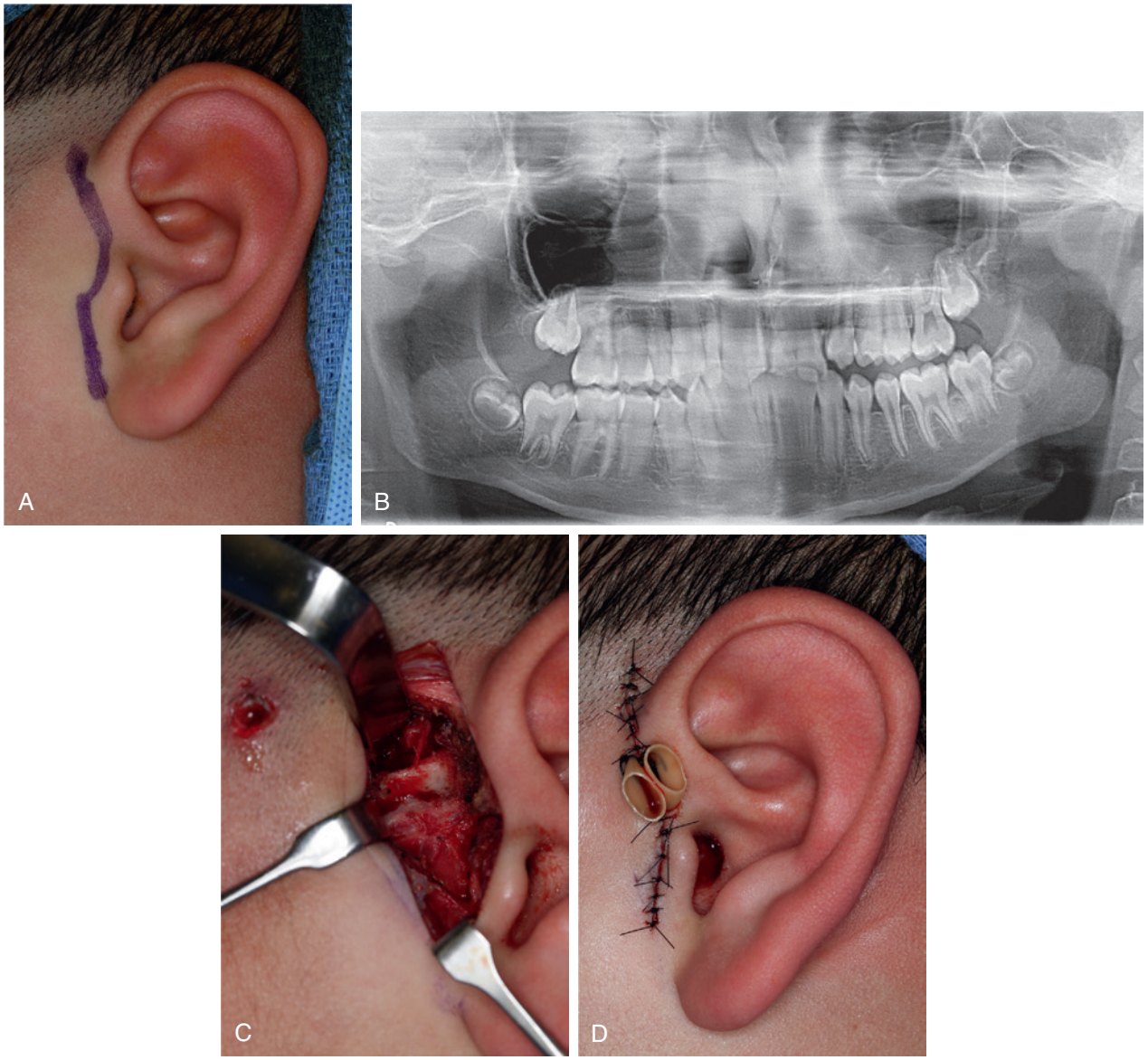
Osteomyelitis is defined as inflammation of bone; clinically, however, the term is synonymous with an "infection of the bone." There are numerous classification systems used for osteomyelitis, but the general categories of osteomyelitis of the jaws include suppurative, chronic sclerosing, and osteomyelitis with proliferative periostitis (Garre osteomyelitis). Osteomyelitis will usually originate and spread from the medullary spaces of the jaws. Inoculation of bacteria in the marrow spaces usually causes edema of the marrow, and because this space is confined by the cortical bony walls, the hydrostatic pressure rises, similar to that of an infected dental pulp, and once this pressure is greater than that of the feeding arterial vessels, soft tissue necrosis and pain usually ensue. The failure of the microcirculation of the cancellous bones of the jaws is crucial in the development of osteomyelitis, because oxygen and nutrients required for healing are unable to reach the marrow space. In addition, the body's blood-borne immune system has inhibited transport to the marrow space, resulting in proliferation and spread of the offending organism.

Osteomyelitis is more common in the mandible than the maxilla; this is due to the fact that the blood supply to the maxilla is multifocal and robust, which is in contrast with the mandible that primarily obtains its blood supply from the inferior alveolar artery and periosteum. In contrast, the periosteal blood supply to the maxilla penetrates its cortex to perfuse the underlying porous bone much easier than that of the much thicker cortex of the mandible. Though the marrow of the maxilla and mandible are often exposed to periapical pathogens, osteomyelitis is rare. This is because host defenses usually localize the infection to a periapical abscess and

• **Fig. 17.19** (A) Patient with multiple comminuted mandible fractures resulting in an acute and then severely chronic deep fascial space infection. The patient underwent incision and drainage of all affected spaces (B–D), resolution of the source of infection (reduction of mandible fractures using an external fixator (E), with good postoperative recovery.

limit the progression. However, in those individuals who are immunocompromised, such as those with human immunodeficiency virus infection, who have poorly controlled diabetes mellitus, or who use chronic corticosteroid regimens, as well as those who are chronic drug abusers, who suffer from chronic malnutrition, or who have an immunosuppressive disease, osteomyelitis may ensue due to the lack of intact host defense mechanisms.

Traditionally *Staphylococcus* species were the predominant bacteria involved as in the other bones of the body, although it is known now that several other organisms may contribute to the disease process. The microbiologic profile most often present in cases of osteomyelitis of the mandible includes *Streptococci* spp., as well as anaerobic bacteria, such as *Bacteroides* or *Peptostreptococcus*. Less commonly seen organisms include *Eikenella*, *Candida, Staphylococcus,*

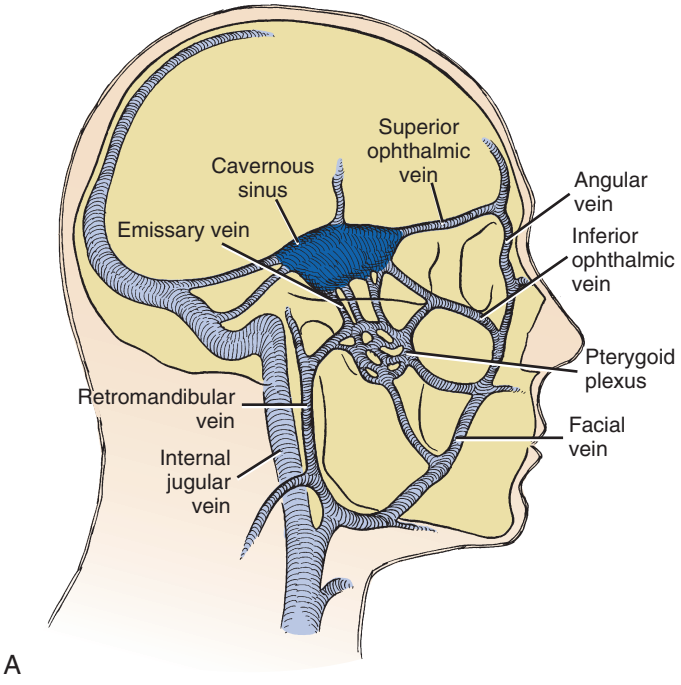


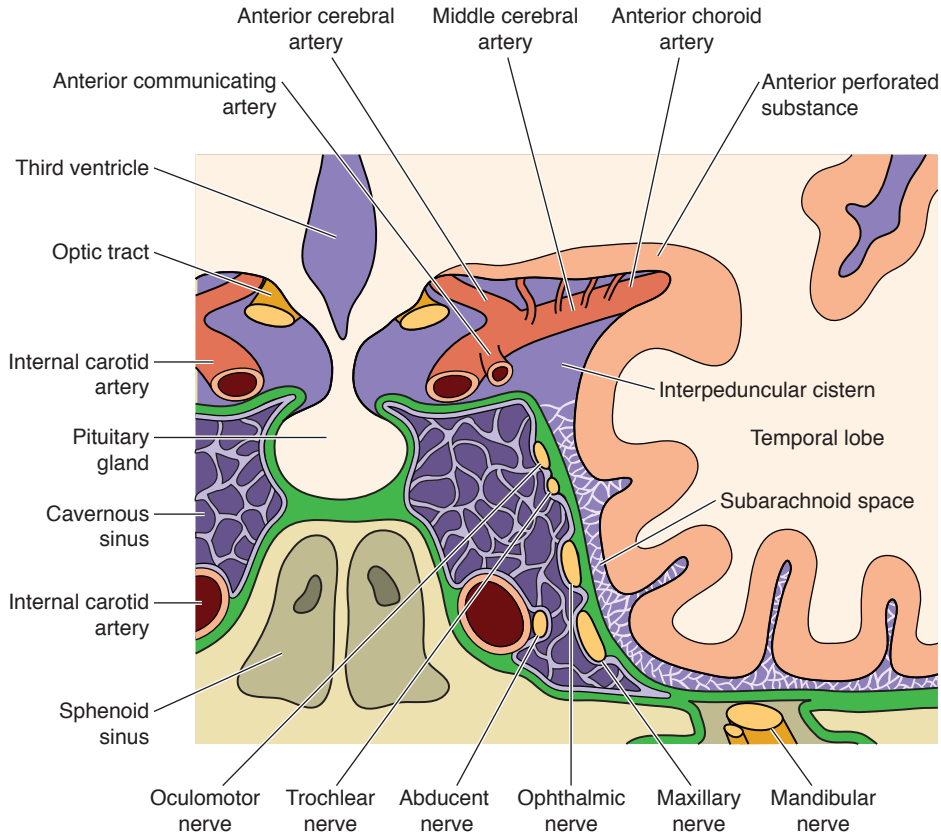
• **Fig. 17.20** (A–B) Eleven-year-old boy with a history of chronic otitis media with no odontogenic source of infection. (C) The temporomandibular space was incised and both the superior and inferior joint spaces were drained. (D) Drains were placed and the patient had an uneventful postoperative course.

Actinomyces, Bacteroides, Klebsiella, Fusobacterium, Lactobacillus, and *Haemophilus* spp. Ideally, specific (not empiric) antimicrobial therapy, based upon culture and sensitivity testing results, is used to prevent the development of bacterial drug resistance as well as adverse side effects. Osteomyelitis of the jaws is often polymicrobial in nature; therefore, culture and sensitivity testing often fails to identify one or more specific offending organisms. Penicillin remains the empiric antibiotic of choice for orofacial infections, followed by clindamycin and fluoroquinolones; these are used until speciation and sensitivity of cultures are performed. These antibiotics are preferred due to their efficacy and coverage for most of the usual odontogenic microbiota.

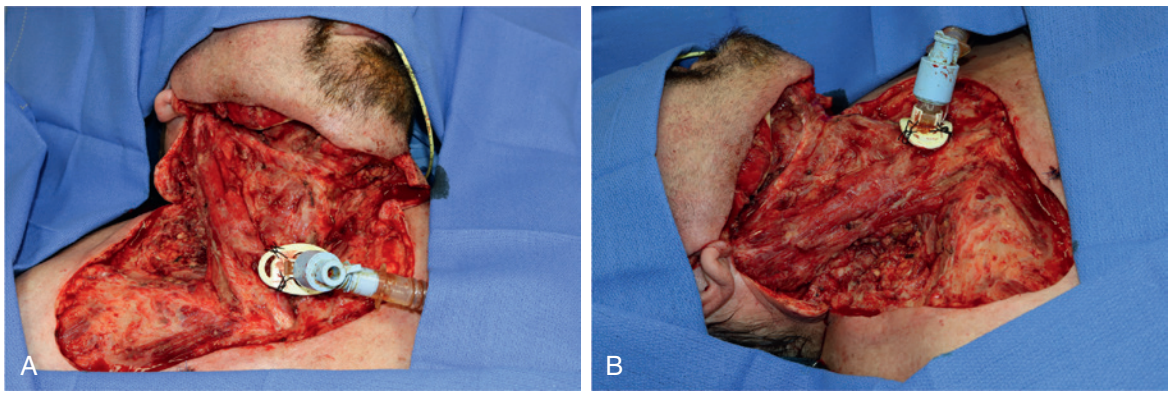
Acute Suppurative Osteomyelitis

Acute suppurative osteomyelitis is an infection of the medullary bone that also has associated production of purulence. This entity is often seen in osteoradionecrosis (ORN) or medication-related osteonecrosis of the jaws (MRONJ), where microorganisms colonize areas of necrotic bone. A key point here is that the organisms tend to colonize the surface of the bone initially, before they enter the medullary space, which is likely also necrotic in some instances. Clinical findings may include edema, restricted movement of the affected area, erythema, and pain. Most patients do not develop systemic manifestations from this process. In the acute phase, no radiographic findings are seen because there is minimal bone loss. When there are radiographic findings, destructive lesions are characterized by radiolucencies in the involved areas. There is often a moth-eaten appearance to the bone radiographically, which can be confused with malignancy. Within these radiolucencies there may be radiopaque areas of bone that have not yet been resorbed by the usual bone turnover mechanisms. These radiopaque areas are termed sequestra, and the surrounding radiolucent area is termed an involucrum. In the early phases, acute supportive osteomyelitis is managed surgically with aggressive debridement of the affected necrotic bone to expose normal bleeding bone, as well as the use of adjunctive empiric antibiotic therapy. The etiology of the infection





• **Fig. 17.21** (A) Hematogenous spread of infection from the jaw to the cavernous sinus may occur anteriorly via the inferior or superior ophthalmic vein or posteriorly via emissary veins from the pterygoid plexus. (B) Structures of the cavernous sinus. (From Gard G. An investigation into the regulation of intracranial pressure and its influence upon the surrounding cranial bones. *J Bodyw Mov Ther*. 2009;13[3]:246–254.)



• **Fig. 17.22** Patient with a long-standing history of chronic dental disease and infection who presented emergently with necrotizing fasciitis. The patient underwent extensive removal of the affected fascia, platysma, and overlying skin.

must also be addressed, and this often is a carious tooth, a failed root canal treatment, or dental implant, or, in the case of ORN or MRONJ, the precipitating necrotic bone. Often, if the disease process has progressed sufficiently, the mandible may fracture in the area of the necrotic bone (pathologic fracture). When possible, this mandible fracture should be reduced and fixated, but due to the poor healing potential in these cases, additional reconstructive procedures may be required (Fig. 17.24).

Chronic Suppurative Osteomyelitis

Long-standing, or chronic suppurative osteomyelitis, is treated in a manner similar to the acute form, with removal of the source of the infection. In addition, if the area of involvement has been treated previously with bone grafting or rigid fixation, all nonviable tissue and hardware should be removed. Standard management of chronic suppurative osteomyelitis should include culture and sensitivity testing of a bone biopsy, aggressive debridement of necrotic bone (may include large segments of the jaws), and high-dose intravenous antibiotic treatment. High-dose empiric IV antibiotics should be initiated, with more selective antibiotic administration once speciation and sensitivity has been established. The duration of antibiotic administration (generally a minimum of 6 weeks of outpatient IV antibiotics) is longer than used for common odontogenic infections because bone penetration of the antibiotic and resolution of bony colonization is more difficult. For more chronic, unresponsive types of osteomyelitis, coverage may require up to 6 months or more of IV antibiotic administration to prevent progression of the disease process.

Chronic Sclerosing Osteomyelitis

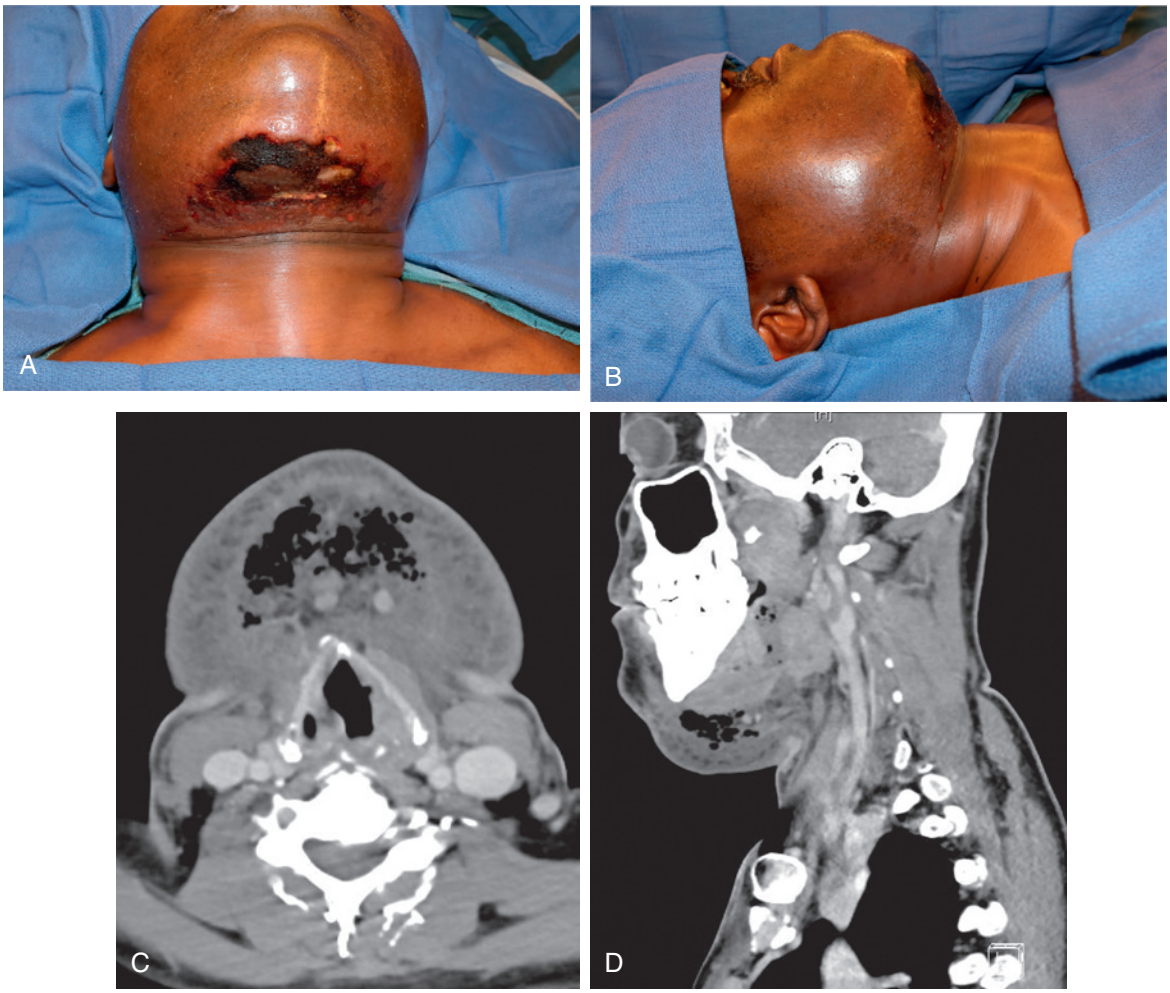
This rare form of osteomyelitis is an intramedullary bone infection with one of the *Actinomyces* species as well as *Eikenella corrodens* as the offending organisms. The combination of these two organisms produces a sclerosis and fibrosis of the medullary space. The pathognomonic clinical sign is intense pain. This pain may fluctuate along with acute exacerbations of mandibular expansion and soft tissue edema. Usually a chronic dull pain is always present. In general, there is no purulence of drainage present. Symptoms may persist for up to 5 years before recognition and establishment of a diagnosis. Radiographically an increased trabecular bone density is present in the alveolar and basal bone of the mandible. Although antibiotic therapy, combined with or without hyperbaric oxygen therapy, may mitigate the progression of the disease, surgical resection of the diseased bone is often required.

Osteomyelitis With Proliferative Periostitis (Garre Osteomyelitis)

Osteomyelitis with proliferative periostitis is a chronic disease that usually affects children due to their increased vascularity and regenerative capabilities. The most notable radiographic finding is paracortical bone formation ("onion-skinning") due to repetitive irritation of the periosteum usually associated with a periapical infection of the mandibular tooth (Fig. 17.25). Clinically there is expansion of the mandible with pain, but no purulence, drainage, or erythema. Though termed by some as periostitis ossificans, this is not an appropriate term because the periosteum does not become ossified. It is actually the chronic infection that causes an inflammation mediated deposition of new bone lifting the periosteum from the cortex. Removal of the infectious source is of paramount importance, and biopsy is considered when a source of infection is not identified because malignancy may have similar radiographic findings. Radiographically extracortical bone formation in the form of woven bone in layers parallel to the cortex connected by bridges of bone perpendicular to the cortex is seen. Routine treatment includes removal of the offending infectious source and, if needed in the acute phase, a short course of antibiotic therapy (penicillin, tetracycline, or clindamycin) until the bone inflammation resolves spontaneously. Long-term antibiotic therapy is not indicated for osteomyelitis with proliferative periostitis (Garre osteomyelitis).

Actinomycosis

Actinomycosis is a chronic but relatively uncommon, infectious process affecting the maxillofacial skeleton. The specific organisms involved are usually *Actinomyces israelii* or *A. naeslundii, A. odontolyticus, A. meyeri, or A. viscosus*. Actinomyces is endogenous anaerobic bacteria found in the oral cavity, and infection usually involves the soft tissues but may also involve bone (*Actinomyces* osteomyelitis). Clinical findings in cervicofacial actinomycosis include induration with and nodular fibrosis and intermittent spontaneous drainage tracts. This disease, though difficult to treat, is uncommon, with a low degree of virulence. This indolent course of progression often results in difficulty with establishing a clinical diagnosis. Because this organism usually causes no pathologic signs, it must seed itself in an area of susceptibility, such as an injured site, tooth extraction site, area of fracture, or other traumatic area in order to flourish. Initially cervicofacial actinomycosis will affect the soft tissues, and a key finding during the diagnostic workup will be the lack of respect for the normal anatomic planes of the head and neck. The



• **Fig. 17.23** (A–B) A patient who presented to the emergency department with bilateral chronic periapical odontogenic infections causing diffuse edema and overlying skin breakdown of the neck. (C–D) Computed tomography demonstrating destruction of the normal anatomic fascial planes of the neck.

infection will form a lumpy pseudotumor that forms a fistula to the cutaneous skin surface accompanied by a sulfur granule, such as discharge. As a result of this spontaneous drainage, the patient will often not experience severe pain. The preferred antibiotic is an intravenous penicillin in the acute phase followed by long-term oral penicillin. The patient with cervicofacial actinomycosis will often have recurrence, or persistence of the disease; therefore long-term oral penicillin therapy is recommended. Doxycycline or clindamycin may be used for the penicillin-allergic patient. In addition to antibiotic therapy, the patient may need surgical removal of the source of infection. Surgical placement of drains also eliminates the anaerobic environment.

Candidiasis

Although there are many fungal diseases of the head and neck region, the most common fungal disease evaluated by the dentist and dental specialist is candidiasis. *Candida albicans* is an endogenous organism normally present in the mouth; however, pathologic manifestations of the organism may present in the presence of an altered host's defense system. This yeast is opportunistic and will flourish on any mucosal or skin surface when the systemic immune system is altered, as in the case of an immunocompromised patient (e.g., acquired immunodeficiency syndrome [AIDS], diabetes mellitus, chemotherapy, and leukemia, or other blood dyscrasia), or with chronic antibiotic usage (Table 17.3). Although *C. albicans* is the most common cause of candidiasis, other commonly etiologic organisms include *C. krusei*, *C. tropicalis*, *C. glabrata*, *C. parapsilosis*, *C. pseudotropicalis*, and *C. guilliermondii*. The three most common forms of candidiasis are (1) pseudomembranous candidiasis, (2) erythromatous candidiasis, and (3) angular cheilitis. Pseudomembranous candidiasis presents as distinct white patches that can be wiped off easily to expose an underlying erythromatous mucosal surface. Erythromatous candidiasis appears to be a raw surface, such as that seen with the loss of filiform papillae of the tongue. Angular cheilitis appears as white ulcerated patches in the corners of the mouth. Traditionally candida may be diagnosed by skin or mucosa scrapings places on a smear of 20% potassium hydroxide.

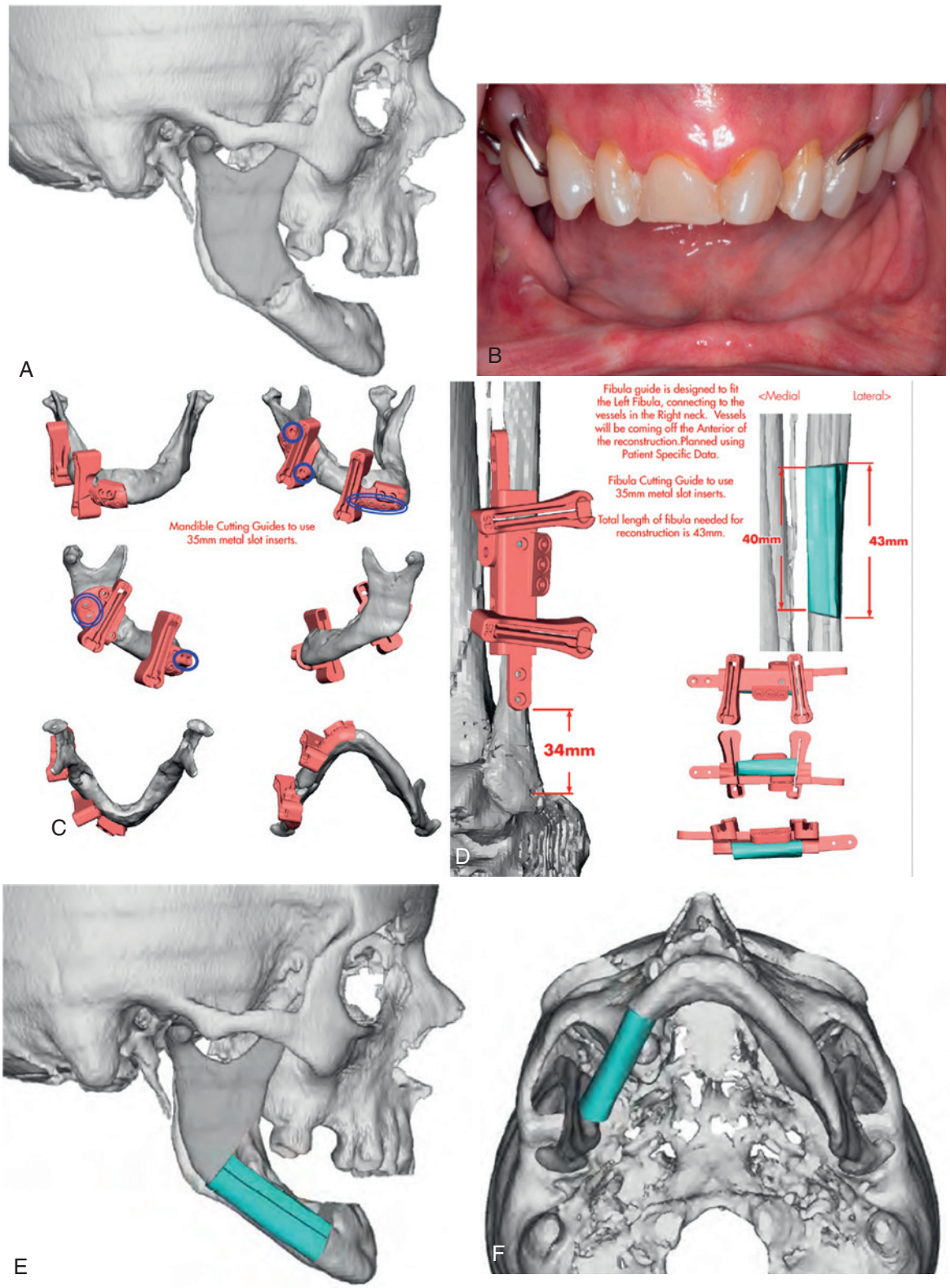
• **Fig. 17.23, cont'd** (E–G) The patient was taken for multiple surgical debridements after initial incision and drainage. (H) The patient at time of transcervical and tracheotomy scar revision, with healed wounds and no evidence of infection.

TABLE 17.3 Common Patient-Related Factors Associated With Oral Candidiasis

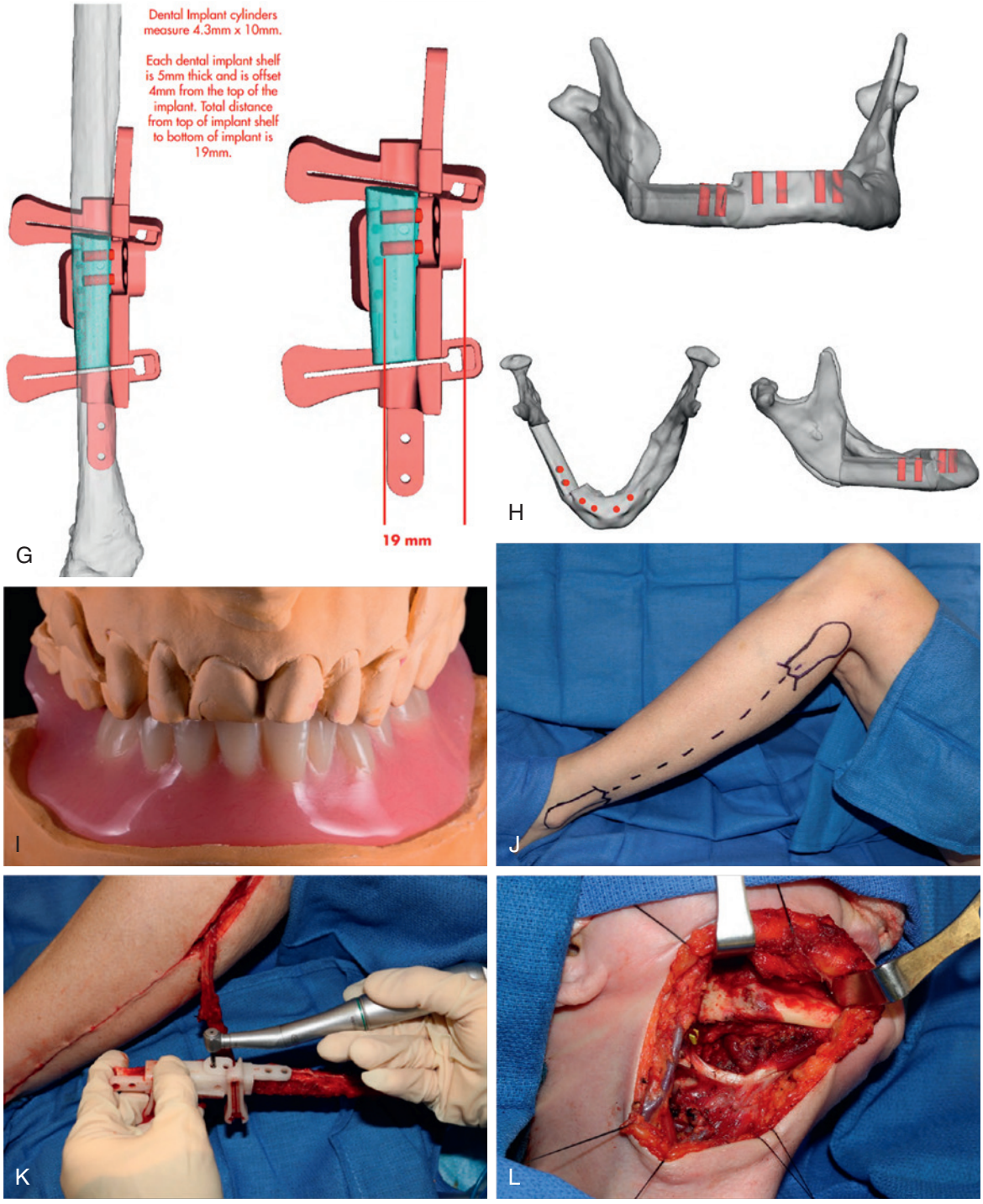
Local	Systemic
• Chronic lip licking • Chronic oral/topical antimicrobial use • Reduced occlusal vertical dimension causing overclosure of the lips • Chronic irrigation from a dental prosthesis • Significant dentofacial deformity	• Endocrine disorders (diabetes mellitus, hypoparathyroidism, hypoadrenalism) • Chronic illness requiring bedrest • Malnutrition • Human immunodeficiency virus and/or acquired immunodeficiency syndrome • Infants, elderly • Chronic topical or systemic corticosteroid exposure • Systemic antibiotic therapy • Systemic chemotherapy for cancer • Radiation treated surfaces • Diseases associated with xerostomia (Sjögren syndrome)

Microscopic analysis will reveal hyphae, or pseudohyphae, but this test is unreliable because it does not typically demonstrate tissue invasion. A more reliable method of diagnosis is a tissue biopsy with periodic acid Schiff staining, which can demonstrate the tissue invasion of the organisms.

Angular cheilitis most often affects patients with occlusal vertical dimension problems such as edentulous patients without appropriate prosthodontic support or patients with dentures with an inadequate vertical dimension or "freeway" space. The chronic moisture at the corners of the mouth is an optimal environment for *Candida* overgrowth. There may be erythema and white patches at the commissures of the mouth. This disease is often bilateral and often accompanied by an overlying *Staphylococcus aureus* infection. It is also seen in patients with folic acid, iron, riboflavin, thiamine, and vitamin B_{12} deficiencies. Treatment includes, when possible, elimination of the contributing local or systemic factors, as well as topical therapies such as nystatin oral suspension and clotrimazole troches. Nystatin suspensions or lozenges are preferred over clotrimazole because clotrimazole has a higher associated toxicity and contains sugar, which may contribute to caries in a xerostomic patient.



• **Fig. 17.24** (A–B) Patient with acute suppurative osteomyelitis of the mandible secondary to tooth extraction sustaining a pathologic fracture. (C–I) Virtual surgical planning was used to plan resection of the affected mandible, free fibula flap reconstruction, and dental implant placement and reconstruction plate placement (J–N).



• **Fig. 17.24, cont'd** (G–H) Virtual surgical planning. (I–K) Free fibula flap reconstruction. (L) Dental implant placement and reconstruction plate placement.

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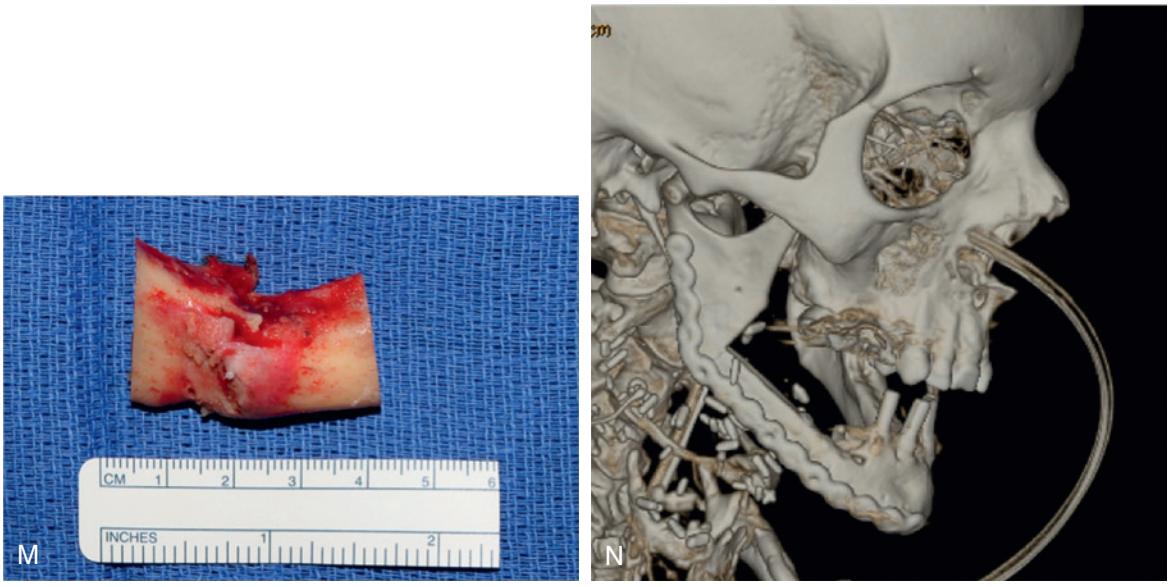
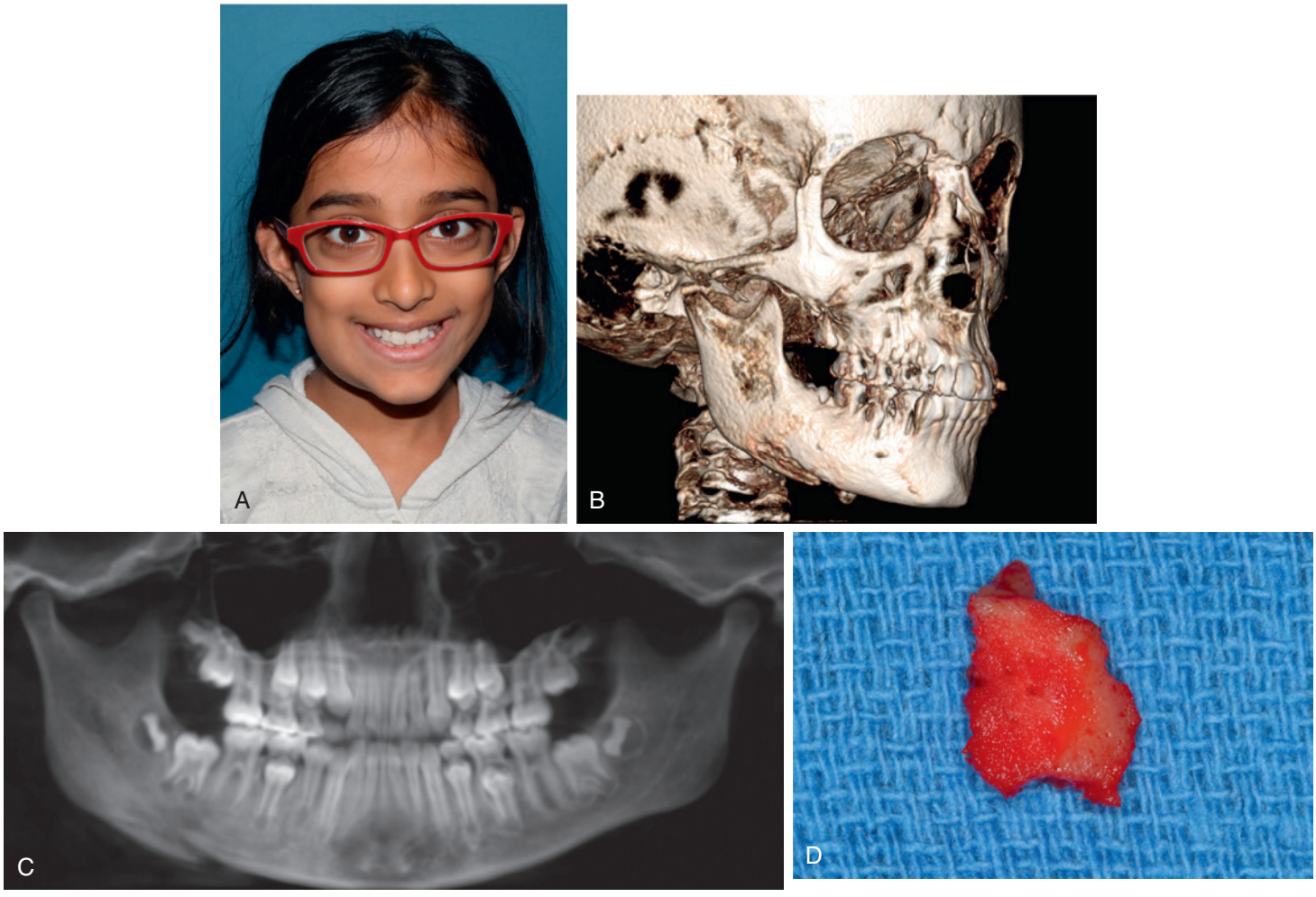


• **Fig. 17.24, cont'd** (M–N) Dental implant placement and reconstruction plate placement.



• **Fig. 17.25** (A) A 9-year-old girl presented with a 3-month history of chronic right-sided lower facial swelling. (B–C) Three-dimensional cone-beam computed tomography scan and its reconstructed orthopantomogram revealed paracortical bone formation at inferior border of the mandibular angle and body. Because no odontogenic source was identified, an incisional biopsy was performed to rule out malignancy, which clinically demonstrated extracortical bone formation (D).

Although patients often experience rapid resolution of their symptoms, they should be encouraged to continue their antifungal therapy for a minimum of 14 days because the infection tends to recur. In the scenario of ill-fitting dentures, the dentures should be trimmed and re-lined appropriately and placed in antiseptic solutions nightly to remove any colonized organisms from these prostheses.

Some cases that are recalcitrant to topical therapy may require systemic antifungal therapy. Commonly prescribed systemic antifungal agents include fluconazole, ketoconazole, itraconazole, or posaconazole, and these are often required when topical agents are ineffective, which may occur in immunocompromised patients. Also, these systemic agents are helpful for managing highly resistant strains of *C. albicans* or other species such as *C. glabrata*. However, these medications are expensive and have potentially serious side effects such as hepatotoxicity and adrenal insufficiency; therefore they are reserved for those cases that are unresponsive to topical therapy.

Acknowledgments

We recognize the contributions of Robert D. Marciani, DMD, and Thomas R. Flynn, DMD, to this chapter in prior editions of this book.

18

Principles of Endodontic Surgery

STUART E. LIEBLICH

CHAPTER OUTLINE

Endodontic surgery is the management of periradicular disease by a surgical approach. In general, this includes abscess drainage, periapical surgery, corrective surgery, intentional replantation, and root removal (Box 18.1).

Conventional endodontic treatment, also known as *orthograde endodontics,* is generally a successful procedure; however, in 10% to 15% of cases symptoms can persist or recur spontaneously.[1] Such findings as a draining fistula, pain on mastication, or the incidental finding of a radiolucency increasing in size indicate problems with the initial endodontic procedure. Many endodontic failures occur 1 year or more after the initial root canal treatment, often complicating a situation because a definitive restoration may have already been placed. This creates a higher "value" for the tooth because it now may be supporting a fixed partial denture.

Surgery has traditionally been an important part of endodontic treatment. However, until recently, little research has focused on indications and contraindications, techniques, success and failure (i.e., long-term prognosis), wound healing, and materials and devices

• BOX 18.1 Factors Associated With Success and Failure in Periapical Surgery

Success

- Dense orthograde fill
- Healthy periodontal status:
  - No dehiscence
  - Adequate crown-root ratio
- Radiolucent defect isolated to apical one-third of the tooth
- Tooth treated:
  - Maxillary incisor
  - Mesiobuccal root of maxillary molars
- Postoperative factors:
  - Radiographic evidence of bone fill following surgery
  - Resolution of pain and symptoms
  - Absence of sinus tract
- Decrease in tooth mobility

Failure

- Clinical or radiographic evidence of fracture
- Poor or lack of orthograde filling
- Marginal leakage of crown or post
- Poor preoperative periodontal condition
- Radiographic evidence of post perforation
- Tooth treated:
  - Mandibular incisor
- Postoperative factors:
  - Lack of bone repair following surgery
  - Lack of resolution of pain
  - Fistula does not resolve or returns

From Thomas P, Lieblich SE, Ward Booth P. Controversies in office-base surgery. In: Ward-Booth P, Schendel S, Hausamen J-E, eds. Maxillofacial Surgery. *2nd ed. London: Churchill Livingstone; 2007.*

to augment procedures. Because of this lack of information, referral for surgery—such as the routine correction of failed endodontic treatment, removal of large lesions believed to be cysts, or single-visit root canal treatment—may have been inappropriate. A decision on whether to approach the case surgically or to consider orthograde (through the coronal portion of the tooth) endodontic retreatment is dictated by various clinical and anatomic situations. Other treatment options, such as extraction of the tooth with placement of an implant, may be preferred and are associated with a higher long-term success rate. However, a consensus conference concluded that endodontic therapy and implant procedures are considered equally successful. Additional procedures on the tooth, whether orthograde retreatment or periapical surgery, may reduce the long-term success rate of the tooth because each treatment is associated with additional tooth structure removal. When surgery is indicated, under the correct clinical situations it can maintain the tooth and its overlying restoration. Fig. 18.1 is an algorithm to help guide the clinical decision regarding whether endodontic surgery is indicated.

This chapter presents the indications and contraindications for endodontic surgery, diagnosis and treatment planning, and the basics of endodontic surgical techniques. Most of the procedures presented should be performed by specialists or, on occasion, specially trained and experienced generalists. Surgical approaches are often in proximity to anatomic structures such as the maxillary sinus (Box 18.2) and inferior alveolar nerve, so expertise in working around these structures is mandatory. Nonetheless, the general dentist must be skilled in diagnosis and treatment planning and

• BOX 18.2 Categories of Endodontic Surgery

- Abscess drainage
- Periapical surgery
- Hemisection or root amputation
- Intentional replantation
- Corrective surgery

must be able to recognize the procedures indicated in particular situations. When referring a patient to a specialist for treatment, the general dentist must have sufficient knowledge to understand the potential success of the procedure. Studies show that apical surgery can have outcomes of greater than 85% over a 3-year period.[2] Knowing the likelihood of success allows the referring dentist to provide describe the surgical procedure as well as provide appropriate counseling to the patient. In addition, the generalist should assist in the follow-up care and long-term assessment of treatment outcomes. The final determination of success (e.g., as to when a definitive final restoration should be placed) is often the responsibility of the referring dentist.

Drainage of an Abscess

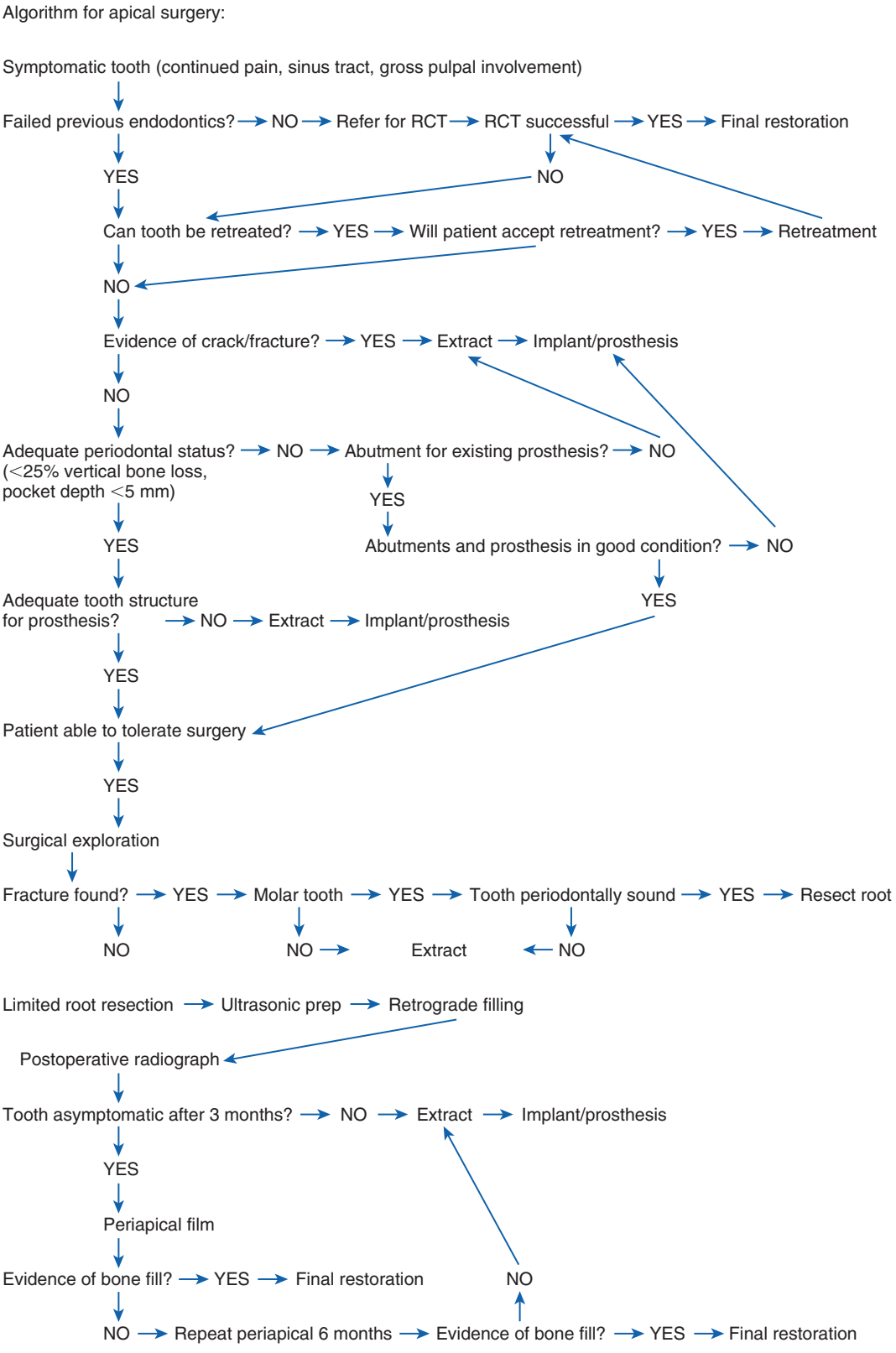
Drainage releases purulent or hemorrhagic transudates and exudates from a focus of liquefaction necrosis (i.e., abscess). Draining an abscess relieves pain, increases circulation, and removes a potent irritant. The abscess may be confined to bone or may have eroded through bone and the periosteum to invade soft tissue. Managing these intraoral or extraoral swellings by incision for drainage is reviewed in Chapters 16 and 17. Draining the infection does not eliminate the cause of the infection, so definitive treatment of the tooth is still needed.

An abscess in bone resulting from an infected tooth may be drained by two methods: (1) opening into the offending tooth coronally to obtain drainage through the pulp chamber and canal or (2) a formal incision and drainage (I&D), with or without placement of a drain. An I&D is indicated if the spread of the infection is rapid, if space involvement is evident, or if opening the tooth coronally does not yield obvious purulence. The decision regarding a drain is based on whether the abscess cavity will remain open on its own. Infections that have spread to multiple contiguous spaces often dictate the need to place a drain. In addition, if dependent drainage is not established, a drain should be considered. An I&D permits the dentist to obtain a sample of the pus for culture and sensitivity testing when indicated. Most community-acquired endodontic infections do not require culture and sensitivity testing unless the patient is medically compromised or has failed to respond to an empirical course of antibiotics or if the infection was acquired in a hospital setting, which predisposes to antibiotic-resistant forms of bacteria.

Periapical Surgery

Periapical (i.e., periradicular) surgery includes a series of procedures performed to eliminate symptoms. Periapical surgery includes the following:

1. Appropriate exposure of the root and the apical region
2. Exploration of the root surface for fractures or other pathologic conditions



• **Fig. 18.1** Algorithm for apical surgery. *RCT,* Root canal treatment.

3. Curettage of the apical tissues
4. Resection of the root apex
5. Retrograde preparation with the ultrasonic tips
6. Placement of the retrograde filling material
7. Appropriate flap closure to permit healing and minimize gingival recession

Indications

After the completion of endodontics, symptoms associated with the tooth may lead to the recommendation for periapical surgery. Most commonly, patients have a chronic fistula and drainage. Other signs can include pain and the sudden onset of a vestibular space infection. Incidental findings of an increasing radiolucent area found on routine radiographs may also lead to the decision to treat the periapical region surgically.

The success of apical surgery varies considerably depending on the reason for and nature of the procedure. With failed root canal treatment, retreatment often is not possible, or a better result cannot be achieved by a coronal approach. If the cause of the failure cannot be identified, surgical exploration may be necessary (Fig. 18.2). On occasion, an unusual entity in the periapical region requires surgical removal and biopsy for identification (Fig. 18.3). Indications for periapical surgery are discussed in the following sections (Box 18.3).

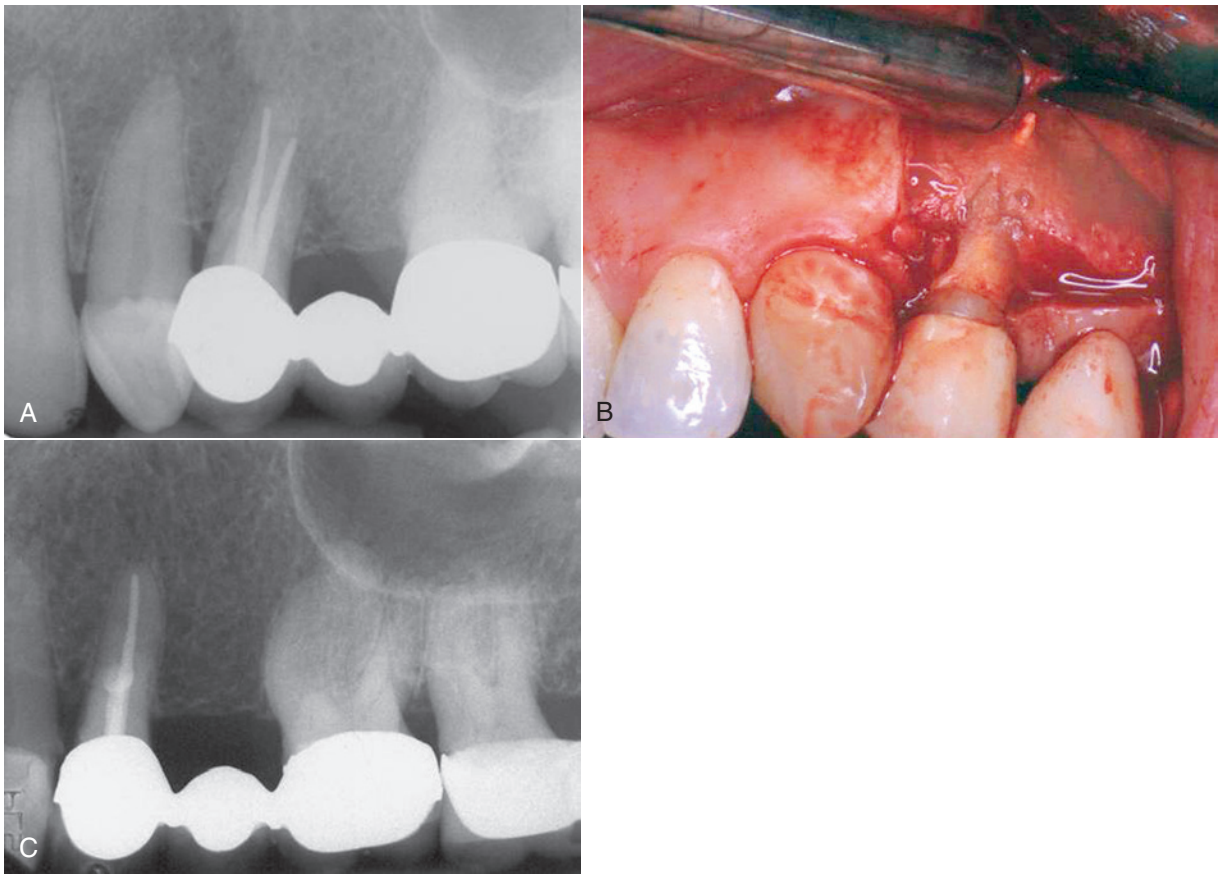
It is important to tell the patient preoperatively that endodontic surgery is exploratory. The precise surgical procedure is dictated by the clinical findings once the site is exposed and explored. For example, a fracture of a root may be noted, and the decision whether to resect the root or extract the tooth will need to be made intraoperatively. If the tooth is to be extracted, provisions for temporization must be made in advance if removal is an esthetic issue, or a decision must be made to close the flap and schedule a future extraction. The patient must also give preoperative consent for an extraction if it is deemed necessary intraoperatively.

Anatomic Problems

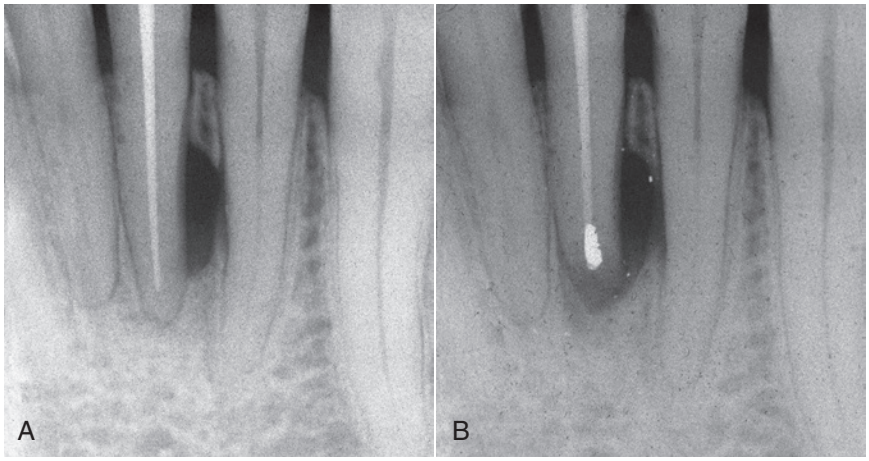
Calcifications or other blockages, severe root curvatures, or constricted canals (e.g., calcific metamorphosis) may compromise root

• BOX 18.3 Indications for Periapical Surgery

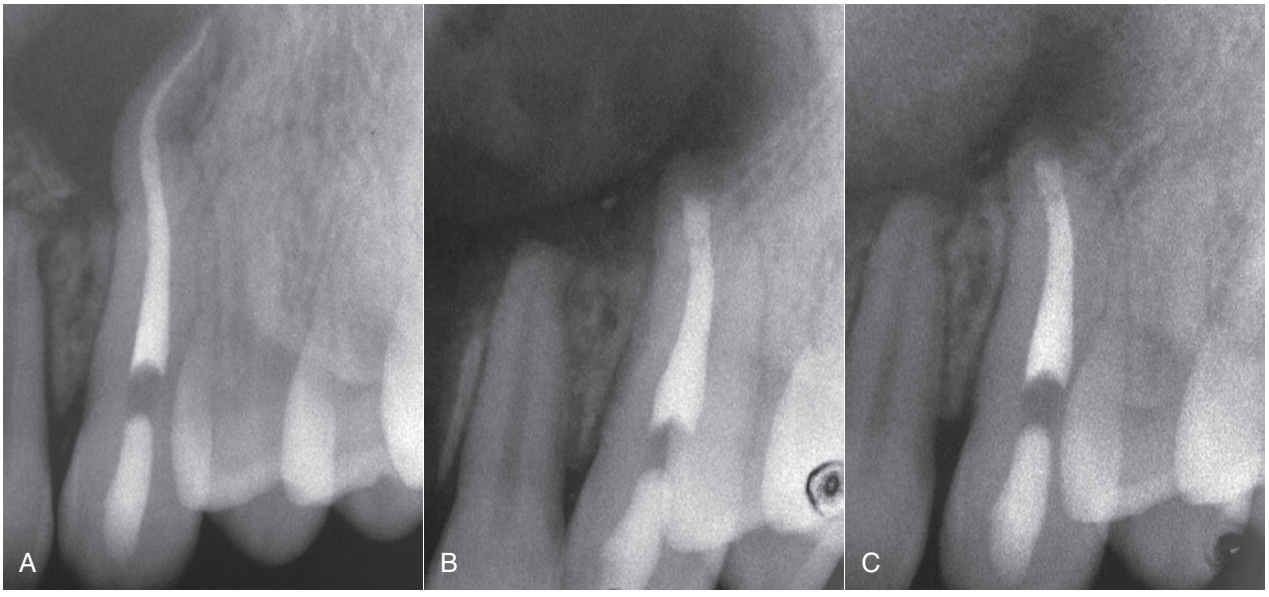
- Anatomic problems preventing complete debridement or obturation
- Restorative considerations that compromise treatment
- Horizontal root fracture with apical necrosis
- Irretrievable material preventing canal treatment or retreatment
- Procedural errors during treatment
- Large periapical lesions that do not resolve with root canal treatment



• Fig. 18.2 Surgical exploration. (A) The patient had persistent pain over the midroot region following what appears to be successful endodontic treatment. (B) Surgical exploration reveals perforation of the buccal root during the endodontic treatment with displaced gutta-percha. (C) Postoperative periapical film of surgical removal of the extruded gutta-percha and mineral trioxide aggregate seal.



• **Fig. 18.3** Surgical removal of pathosis. (A) The patient was referred for surgery because of an increasing radiolucent area after conventional endodontic treatment. Note the atypical nature of the radiolucent lesion, which indicates tissue submission should be done in conjunction with the apical surgery. (B) Treatment by apical surgery with amalgam retrograde seal, along with a biopsy of the associated tissue. The final diagnosis was cystic ameloblastoma.



• **Fig. 18.4** (A) Anatomic problem of a severe root curvature, for which surgery is indicated. (B) Apical resection and root end retrograde mineral trioxide aggregate the seal. (C) An image taken 4 months after surgery shows regeneration of bone.

canal treatment (e.g., prevent instrumentation, obturation, or both) (Fig. 18.4). A nonobturated and cleaned canal may lead to failure because of continued apical leakage.

Although the outcome may be questionable, it is preferable to attempt conventional root canal treatment or retreatment before apical surgery. If this is not possible, removing or resecting the uninstrumented and unfilled portion of the root and placing a root end filling may be necessary.

Restorative Considerations

Root canal retreatment may be risky because of problems that may occur from attempting access through a restoration such as a crown on a mandibular incisor. An opening could compromise retention of the restoration or perforate the root. Rather than attempt the root canal retreatment, root resection and root end filling may successfully eliminate the symptoms associated with the tooth.

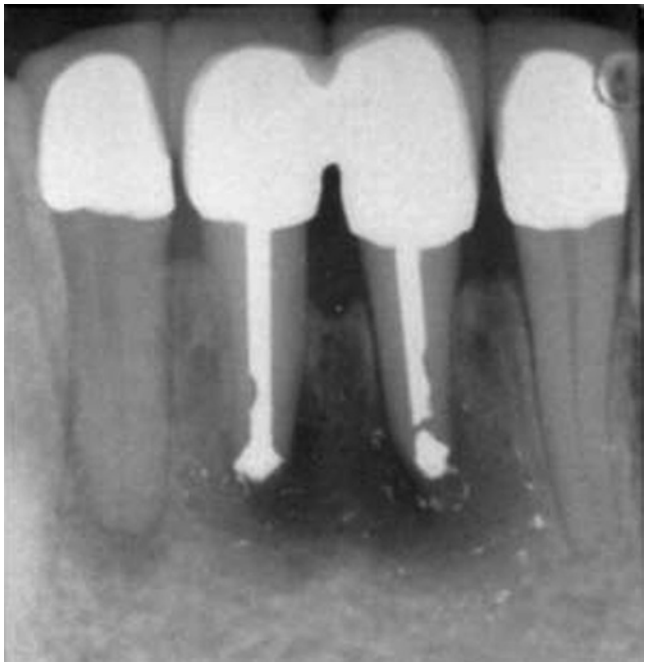
A common indication for surgery is failed treatment on a tooth that has been restored with a post and core (Fig. 18.5). Many posts are difficult to remove or may cause root fracture if an attempt at removal is made to retreat the tooth.

Horizontal Root Fracture

Occasionally, after a traumatic root fracture, the apical segment undergoes pulpal necrosis. Because pulpal necrosis cannot be predictably treated from a coronal approach, the apical segment is removed surgically after root canal treatment of the coronal portion (Fig. 18.6).

Irretrievable Material in the Canal

Canals are occasionally blocked by objects such as broken instruments (Fig. 18.7), restorative materials, segments of posts, or other foreign objects. If evidence of apical pathosis is found, those materials can be removed surgically, usually with a portion of the root (Fig. 18.8). A broken file can be left in the root canal system if the tooth remains asymptomatic and is not itself an indication for apical surgery.



• **Fig. 18.5** Irretrievable posts and apical pathosis. Root end resection and filling with amalgam to seal in irritants, likely from coronal leakage.

Procedural Error

Broken instruments, ledging, gross overfills, and perforations may result in failure (Figs. 18.9 and 18.10). Although overfilling is not itself an indication for removal of the material, surgical correction is beneficial in these situations if the tooth becomes symptomatic. Because the obturation of the canal is often dense in these situations, surgical treatment has an excellent prognosis.

Large, Unresolved Lesions After Root Canal Treatment

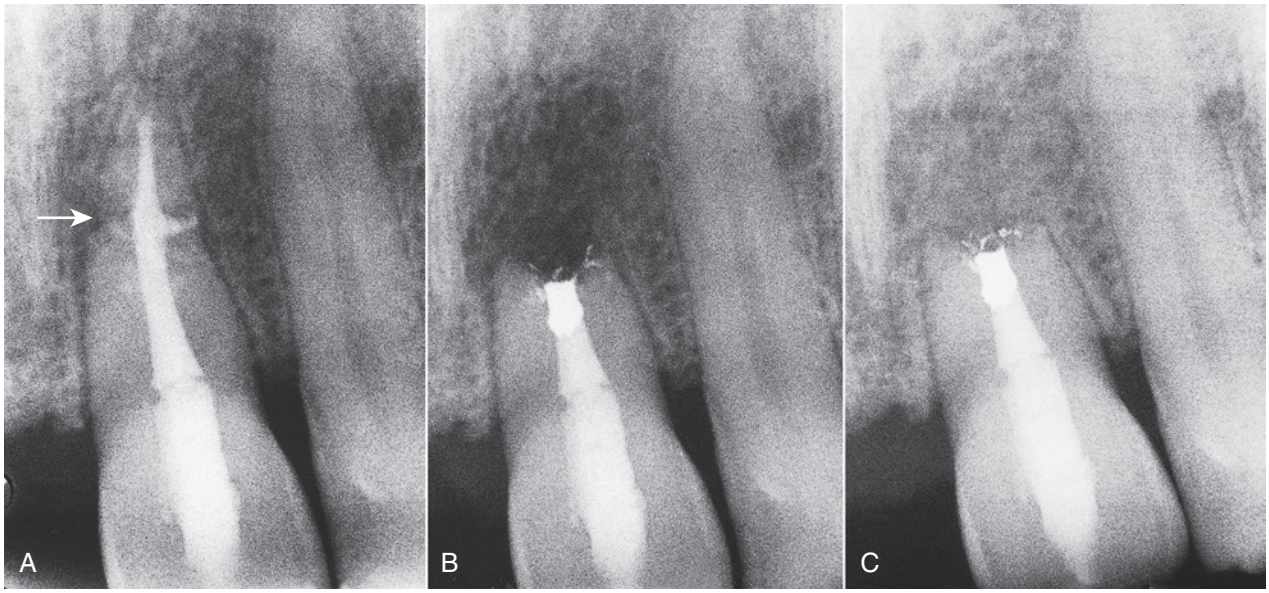
Occasionally, very large periradicular lesions may enlarge after adequate debridement and obturation. These lesions are generally best resolved with decompression and limited curettage to avoid damaging adjacent structures such as the mandibular nerve (Fig. 18.11). The continued apical leakage is the nidus for this expanding lesion, and root resection with the placement of an apical seal often resolves the lesion.

Contraindications (or Cautions)

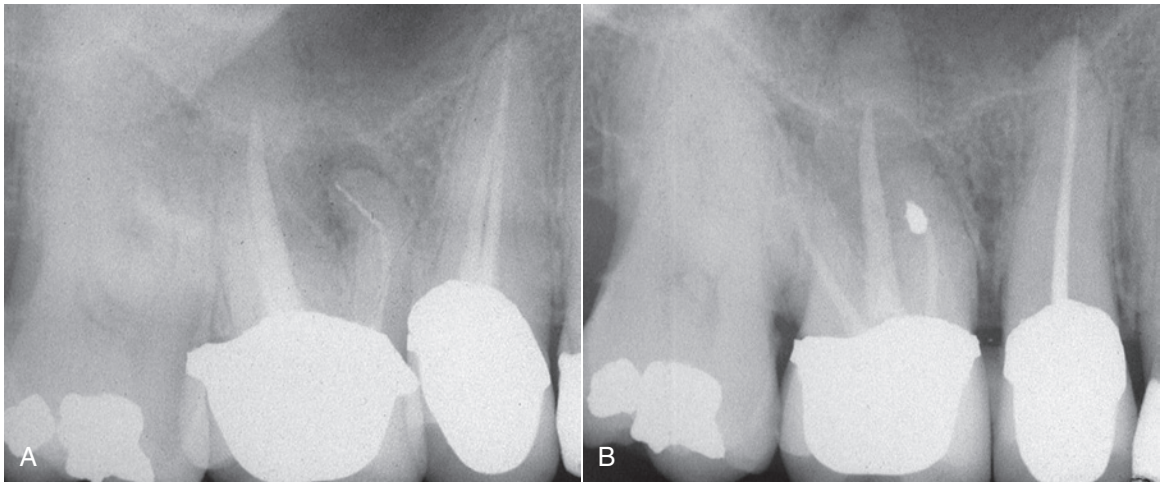
If other options are available, periapical surgery may not be the preferred choice (Box 18.4).

• BOX 18.4 Contraindications (or Cautions) for Periapical Surgery

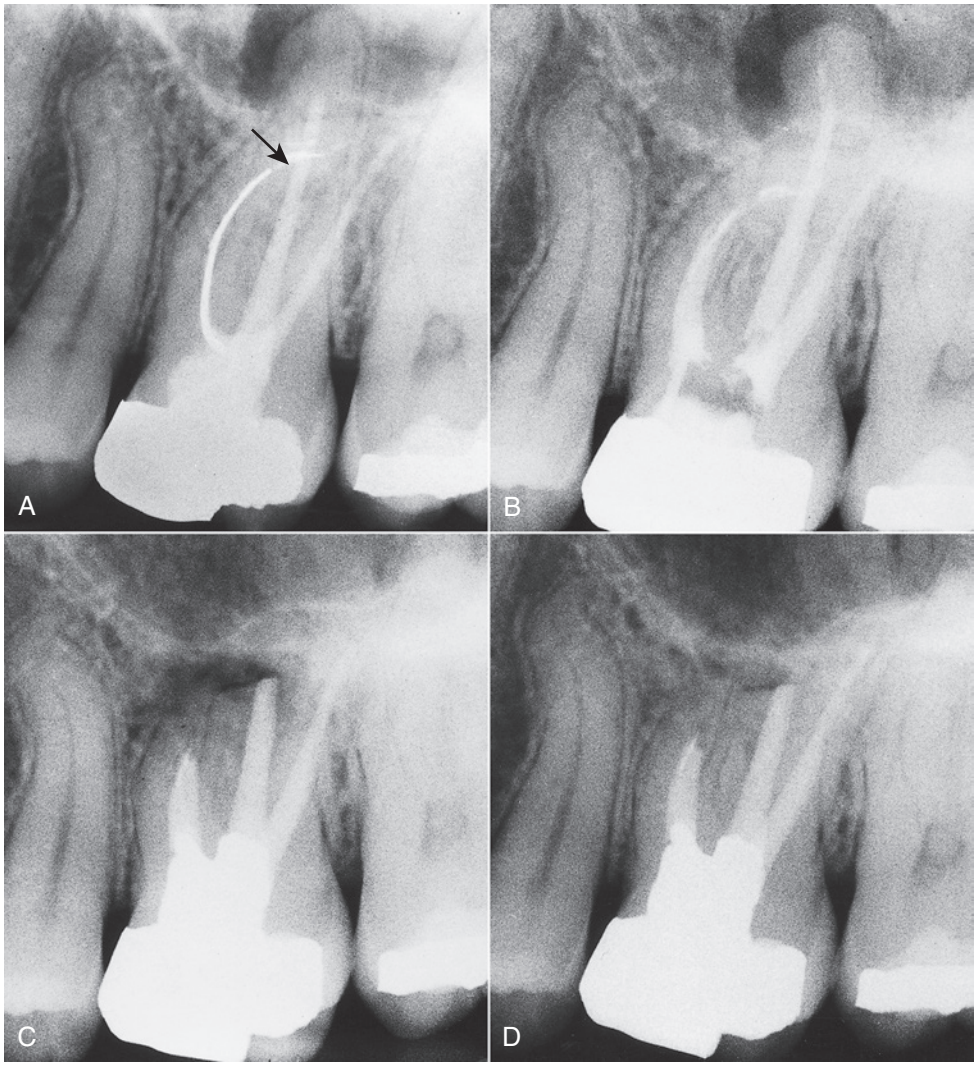
- Unidentified cause of root canal treatment failure
- When conventional root canal treatment is possible
- Combined coronal treatment and apical surgery
- When retreatment of a treatment failure is possible
- Anatomic structures (e.g., adjacent nerves and vessels) are in jeopardy
- Structures interfere with access and visibility
- Compromise of crown-root ratio
- Systemic complications (e.g., bleeding disorders)



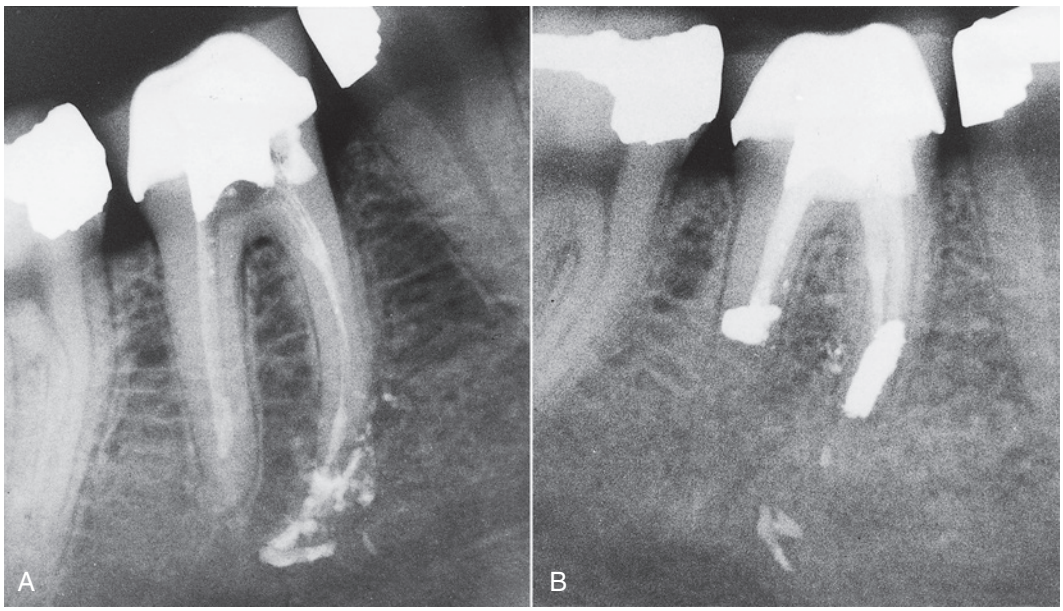
• **Fig. 18.6** (A) Horizontal root fracture *(arrow)*, with failed attempt to treat both segments. (B) The apical segment is removed surgically, and retrograde amalgam is placed. (C) Healing is complete after 1 year.



• **Fig. 18.7** (A) Irretrievable separated instruments in mesial-buccal canal. A separated instrument requires surgical intervention only if the tooth becomes symptomatic. (B) Following resection of root with fractured instrument and placement of amalgam seal.



• **Fig. 18.8** (A) Irretrievable material *(arrow)* in mesial and palatal canals and apical pathosis. (B) Canals are re-treated, but this has failed. (C) Treatment is root end resection to level of gutta-percha in the mesial and palatal aspects. (D) After 2 years, healing is complete.



• **Fig. 18.9** (A) Overfill of injected obturating material has resulted in pain and paresthesia as a result of damage to inferior alveolar nerve. (B) Corrected by retreatment, apicectomy, curettage, and a root end amalgam fill.

Unidentified Cause of Treatment Failure

Relying on surgery to correct all root canal treatment failures could be labeled indiscriminate. An important consideration is to (1) identify the cause of failure and (2) design an appropriate corrective treatment plan. Orthograde retreatment is often indicated and offers the best chance of success. Surgery to correct a treatment failure for which the cause cannot be identified is often unsuccessful. Surgical management of all periapical pathosis, large periapical lesions, or both is often not necessary because they will resolve after appropriate root canal treatment. This includes lesions that may be cystic; these also usually heal after root canal treatment.

When Conventional Endodontic Treatment Is Possible

In most situations, orthograde conventional endodontic treatment is preferred (Fig. 18.12). Surgery is not indicated simply because debridement and obturation are in the same visit, although there has been a long-held, incorrect notion that single-visit treatment should be accompanied by surgery, particularly if a periradicular lesion is present.

Simultaneous Root Canal Treatment and Apical Surgery

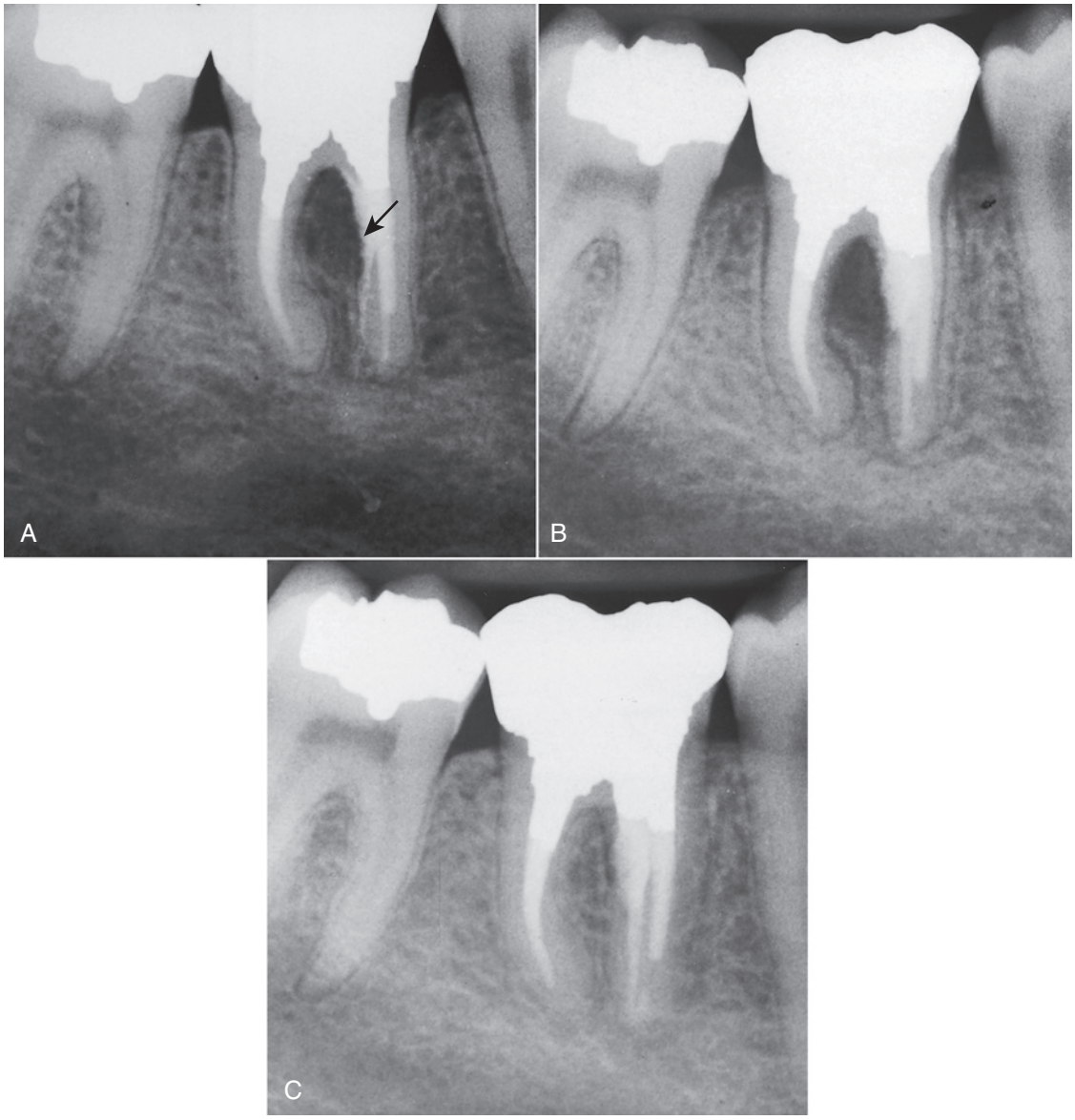
Few situations occur in which simultaneous root canal therapy and apical surgery are indicated. An approach that includes both of these as a single procedure typically has no advantages. It is preferable to perform only the conventional treatment without the adjunctive apical surgery because the surgery will not necessarily improve the outcome. In some patients the conventional root canal procedure is ineffective at eliminating symptoms. In this scenario, in spite of adequate instrumentation and antibiotics, purulent exudate from the tooth or a vestibular swelling is still present. A combined orthograde obturation with a simultaneous periapical surgery to curette the apical region and seal the tooth can be successfully coordinated and the symptoms resolved. The dentist can instrument and seal the tooth with the plan to see the surgeon that day for definitive periapical surgery. The endodontic filling material is densely condensed and can even be out the apex (to a reasonable degree, not impinging on local anatomic structures) if the surgeon will resect a small portion of the apical region and place a retrograde seal (Fig. 18.13A–C).

Anatomic Considerations

Although most oral structures do not interfere with a surgical approach, they must be considered. Expertise in operating around a structure such as the maxillary sinus or the mental nerve region is imperative before undertaking surgery in these regions. Exposure of the maxillary sinus, which occurs in most molar apical surgeries, is itself not a complication but a known consequence of the surgery (Fig. 18.14). Creating a sinus opening is neither unusual nor dangerous. However, caution is necessary not to introduce foreign objects into the opening and to remind the patient not to exert pressure by forcibly blowing the nose until the surgical wound has healed (for 2 weeks). Correct flap design is also crucial to prevent the development of an oral-antral communication. The sulcular flap keeps the incision line far from the sinus opening, thus allowing spontaneous healing.

Surgical procedures around the mental foramen require caution to avoid stretch injury or direct damage to the nerve. In my opinion, exposure of the mental nerve is safer than attempting to estimate its position. Careful subperiosteal reflection of the flap with adequate release allows the surgeon to identify the nerve where it exits from bone. Once identified, staying a safe distance above, anteriorly, or both is crucial to preventing an injury. Important to note is that the nerve may have an anterior loop of 2 to 4 mm, so that distance should be accounted for anteriorly.

When molar apical surgery is performed, the midroot of the molar should be identified by slow removal of bone, which should be carried inferiorly (Fig. 18.15A–C). Once reaching the apical region, cautious curettage of the soft tissue lesion is carried out to avoid mechanical injury of the inferior alveolar nerve as it passes under the molar roots (see Fig. 18.15D–G). As mentioned earlier, it is not necessary to remove the entire area of periapical granulation



• **Fig. 18.10** Repair of perforation. (A) Furcation perforation results in extrusion of material *(arrow)* and pathosis. (B) After flap reflection and exposure, the defect is repaired with mineral trioxide aggregate. (C) Evaluation at 2 years shows successful healing. (Courtesy Dr. L. Baldassari-Cruz, University of Iowa.)

tissue or cyst, if present, because treating the apical lesion and sealing of the root canal with the retrograde filling cause the apical lesion to heal.

Poor Crown-Root Ratio

Teeth with very short roots have compromised bony support and are poor candidates for surgery; root end resection in such cases may compromise stability. However, shorter roots may support a relatively long crown if the surrounding cervical periodontium is healthy (see Fig. 18.6).

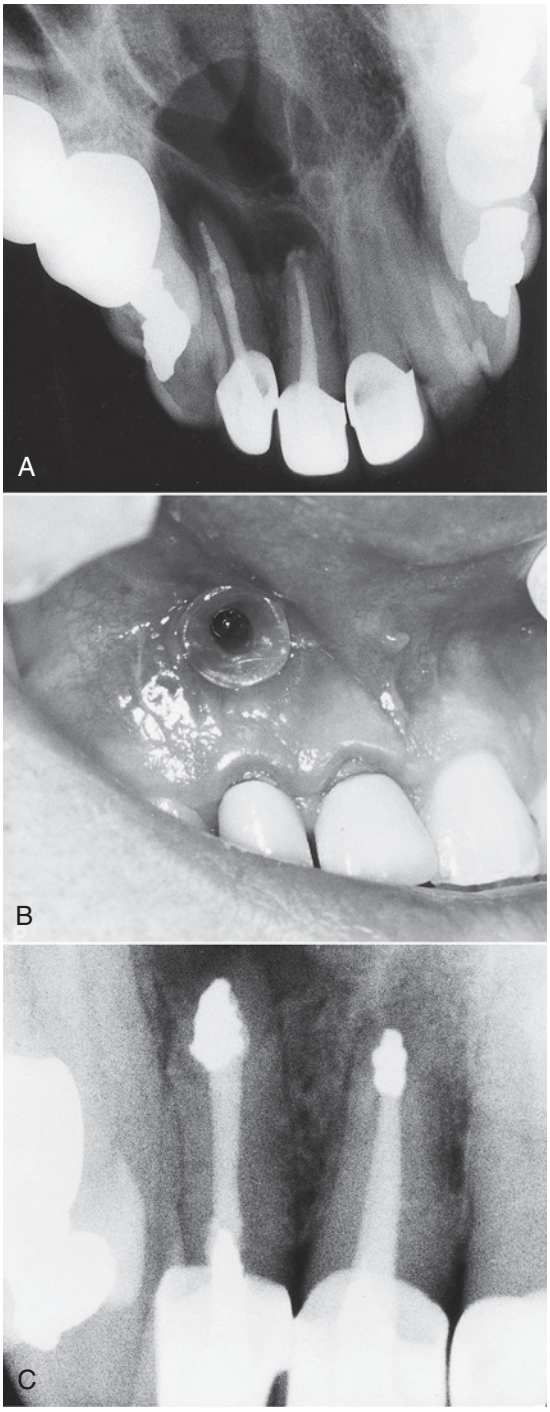
Medical (Systemic) Complications

The general health and condition of the patient are always essential considerations. Contraindications for endodontic surgery are similar to those for other types of oral surgery.

Surgical Procedure

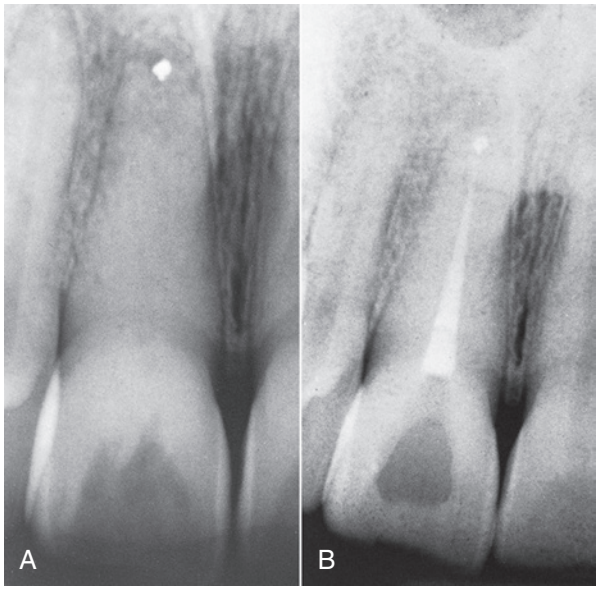
Antibiotics

Almost without exception, periapical surgery is performed in an area with mixed acute and chronic infection. Because of the nature of the surgery and the potential for the spread of infection into adjacent spaces, preoperative prophylactic administration of antibiotics should be considered. Risk for infection of the hematoma exists because of the amount of edema expected after the procedure. In addition, inadvertent opening of adjacent structures such as the maxillary sinus is expected to occur with molar surgeries. As discussed elsewhere in the text, the basics of antibiotic prophylaxis are that antibiotics are to be administered before surgery to have any protective benefit. The surgeon should consider a preoperative dose of penicillin V potassium (2 g) or clindamycin (600 mg) 1



• **Fig. 18.11** Decompression of large lesion. (A) Extensive periradicular lesion that has failed to resolve. Coronal leakage in either treated tooth is possible. (B) A surgical opening to defect is created; a polyethylene tube extends into the lesion to promote drainage. (C) After partial resolution, root end resection and filling with amalgam are performed.

hour before surgery. The need for postoperative dosing has not been clearly defined and may not be of benefit to the patient. Other adjuncts, such as the perioperative administration of corticosteroids, may reduce edema and speed recovery. However, the use of corticosteroids may increase the risk of infection, so prophylactic antibiotics may be necessary.



• **Fig. 18.12** (A) Inadequate root end resection and root end filling have failed to seal the apex. (B) Root canal treatment is readily accomplished, with good chance of success.

Flap Design

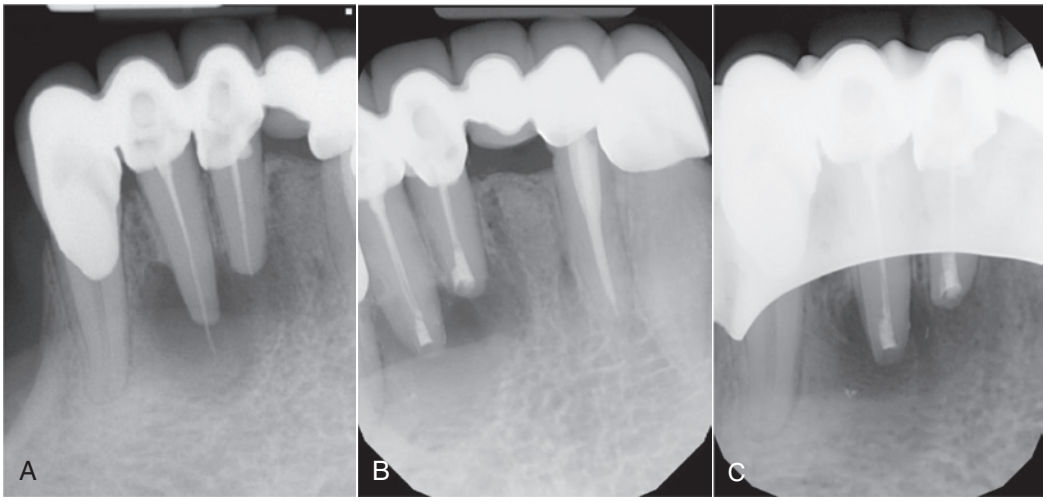
Surgical access is a compromise between the need for visibility of the surgical site and the potential damage to adjacent structures. A properly designed and carefully reflected flap results in good access and uncomplicated healing. The basic principles of flap design should be followed (see Chapter 3). Although several possibilities exist, the three most common incisions are (1) semilunar, (2) submarginal, and (3) full mucoperiosteal (i.e., sulcular). The submarginal and full mucoperiosteal incisions have either a three-corner (i.e., triangular) design or a four-corner (i.e., rectangular) design.

Semilunar Incision

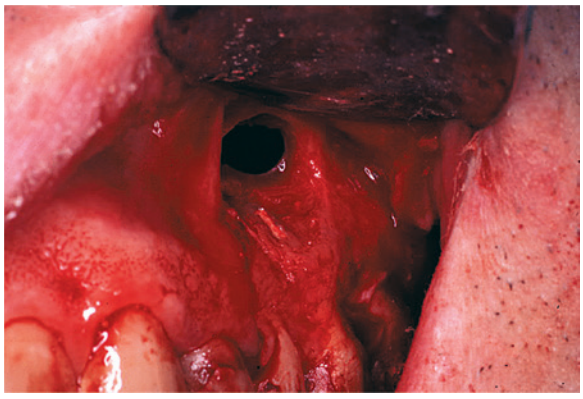
Although the semilunar incision is a popular incision among practitioners, this type of incision should be avoided because of the limitations and potential complications. This is a slightly curved half-moon horizontal incision in the alveolar mucosa (Fig. 18.16). Although the location allows straightforward reflection and quick access to the periradicular structures, it limits the clinician in providing full evaluation of the root surface. If a fracture is noted, performing a root resection through this incision or extracting the tooth is impractical. The incision is based primarily in the unattached or alveolar mucosa, which heals more slowly with a greater chance of dehiscence than a flap based primarily in attached or keratinized tissue. In addition, the flap design carries the flap over the inflamed surgical site, and this inflamed mucosa is at a high risk of breakdown. Other disadvantages to this incision include excessive hemorrhage, delayed healing, and scarring; therefore this design is contraindicated for most endodontic surgery.

Submarginal Incision

The horizontal component of the submarginal incision is in attached gingiva with one or two accompanying vertical incisions (Fig. 18.17). In general, the incision is scalloped in the horizontal line, with obtuse angles at the corners. The incision is used most successfully in the maxillary anterior region or, occasionally, with



• **Fig. 18.13** (A) Lower incisors with persistent symptoms despite reinstrumentation. The canals are densely filled and a slight overfill is inconsequential as the patient will see the surgeon the same day for apical surgery. (B) At the completion of the apical surgery with placement of a mineral trioxide aggregate retrograde seal. (C) Six months later the bony defect is nearly completely healed without the use of any graft.



• **Fig. 18.14** Sinus communication during root apical surgery of an upper molar. The closure with the sulcular incision is far away and unlikely to lead to an oral-antral communication.

maxillary premolars with crowns. Because of the design, prerequisites are at least 4 mm of attached gingiva and good periodontal health.

The major advantage of this type of incision is esthetics. Leaving the gingiva intact around the margins of crowns is less likely to result in bone resorption with tissue recession and crown margin exposure. Compared with the semilunar incision, the submarginal incision provides less risk of incising over a bony defect and provides better access and visibility. Disadvantages include hemorrhage along the cut margins into the surgical site and occasional healing by scarring compared with the full mucoperiosteal sulcular incision. The incision also provides limited access should a fracture be noted or other situation in which extraction or root resection is indicated.

Full Mucoperiosteal Incision

The full mucoperiosteal incision is made into the gingival sulcus, extending to the gingival crest (Fig. 18.18). This procedure includes elevation of interdental papilla, free gingival margin, attached gingiva, and alveolar mucosa. One or two vertical relaxing incisions may be used, creating a triangular or rectangular design.

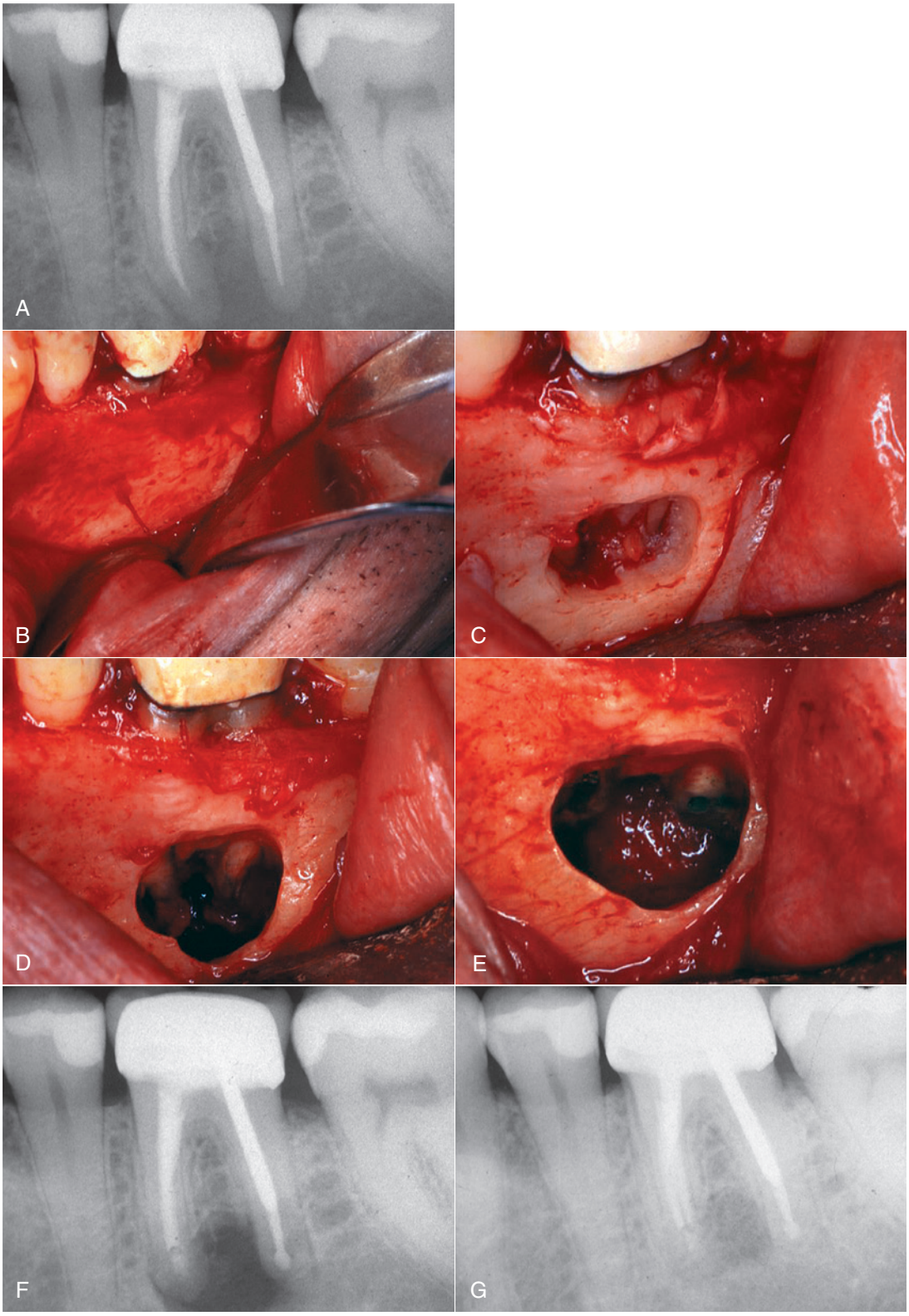
The full mucoperiosteal design is preferred over the other two techniques. The advantages include maximum access and visibility, not incising over the lesion or bony defect, lower risk for hemorrhage, complete visibility of the root, allowance of root planing and bone contouring, and reduced likelihood of healing with scar formation. The disadvantages are that the flap is more difficult to replace and to suture; in addition, gingival recession can develop if the flap is not reapproximated well, exposing crown margins or cervical root surfaces (or both).

As a general rule, flaps should be designed that are trapezoidal, having a broader base than edge (see Fig. 18.18A). A trapezoidal flap design creates a longer component in the nonkeratinized tissue. However, in cases when the vertical release crosses bony prominences over the roots of teeth and across the muscle frenum, the dental papilla just adjacent to the released flap may have a compromised blood supply and the potential for recession. In such cases, making the vertical release more perpendicular to the sulcus may permit the same amount of flap release (see Fig. 18.18B). The vertical incision should parallel the long axis of teeth and should be made between two teeth where the tissue is the thickest and has the best blood supply. The direct vertical incision makes sense because the blood supply to the gingiva follows the long axis and is oriented longitudinally.

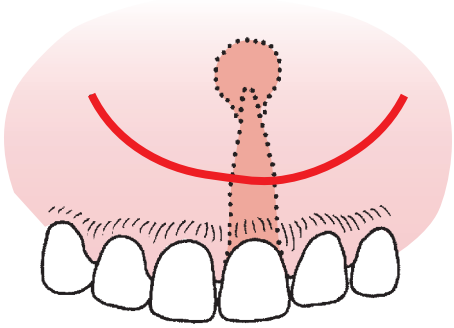
Anesthesia

For most surgical procedures, anesthetic approaches are conventional. In most mandibular regions, a block is administered; then local infiltration of an anesthetic with epinephrine is given to enhance hemostasis. Frequently, the patient is sensitive to curettage of the inflammatory tissue, particularly toward the lingual aspect. Some of the sensitivity may be decreased by a preemptive periodontal ligament or intraosseous injection, using a device specifically designed for this purpose. Placing a cotton pellet soaked with local anesthetic solution can also reduce this discomfort.

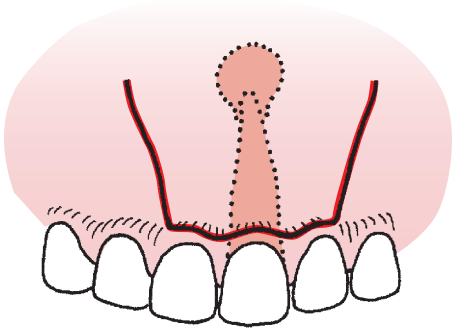
A long-acting anesthetic agent such as bupivacaine is recommended for the inferior alveolar nerve block. Bupivacaine 0.5% with epinephrine 1:200,000 has been shown to give long-lasting anesthesia and, later, provide a lingering analgesia. Long-acting



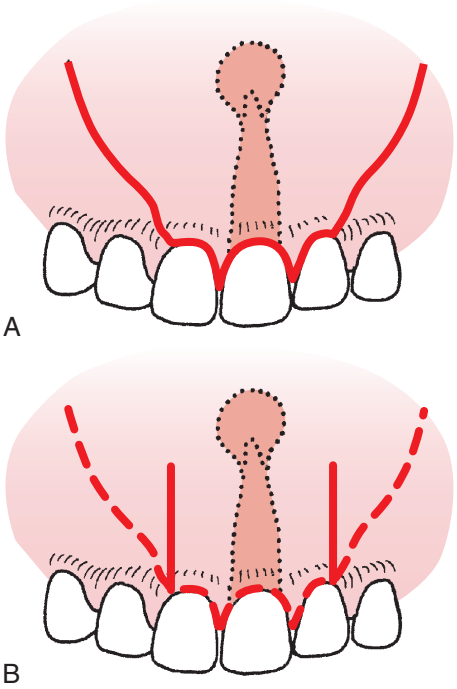
• **Fig. 18.15** (A) A preoperative radiograph showing the periapical pathologic condition amenable to apical surgery. (B) Full-thickness mucoperiosteal flap to expose lateral border of mandible. As is typical, no obvious bony perforation exists. (C) Careful removal of the thick buccal bone to expose the apical portion. (D) Apical one-third exposed before resection of root. (E) Both roots resected and mineral trioxide aggregate seal placed following ultrasonic preparation. (F) Immediate postoperative radiograph with mineral trioxide aggregate seal visible. (G) Five months after surgery, bone fill is evident.



• **Fig. 18.16** Semilunar flap incision, primarily horizontal and in alveolar mucosa. Because of limitations of access and poorer healing, this design is contraindicated.



• **Fig. 18.17** Submarginal incision is a scalloped horizontal line in attached gingiva, with one or two vertical components. This incision is usually confined to the anterior maxillary region.



• **Fig. 18.18** (A) Full mucoperiosteal (i.e., sulcular) incision. The horizontal incision is into the sulcus, accompanied by one (i.e., three-corner) or two (i.e., four-corner) vertical components. This represents the classic trapezoidal flap with the base broader rather than the peripheral edge. (B) In comparison, by making the vertical-releasing incision(s) along the long axis of adjacent teeth, the length of the flap in nonkeratinized tissue is decreased, which reduces pain and accelerates the healing.

local anesthetic agents such as bupivacaine do not diffuse well through tissue because they are highly protein bound, which limits their effectiveness for an infiltration-type injection.

Some patients request sedation because of their concern about having a surgical procedure. If active infection is present in the region, profound local anesthesia may not be possible to achieve, and these patients may be candidates for intravenous sedation or general anesthesia.

Incision and Reflection

A firm incision should be made through the periosteum to bone. Incision and reflection of a full-thickness flap is important to minimize hemorrhage and to prevent tearing of the tissue. Reflection is with a sharp periosteal elevator beginning in the vertical incisions and then raising the horizontal component. To reflect the periosteum, the elevator must firmly contact bone while the tissue is raised (Fig. 18.19). Reflection is to an apical level adequate for access to the surgical site, although still allowing a retractor to have contact with bone. Enough width and vertical release of the flap must be included to prevent the flap from being stretched, which can lead to tearing and slower healing.

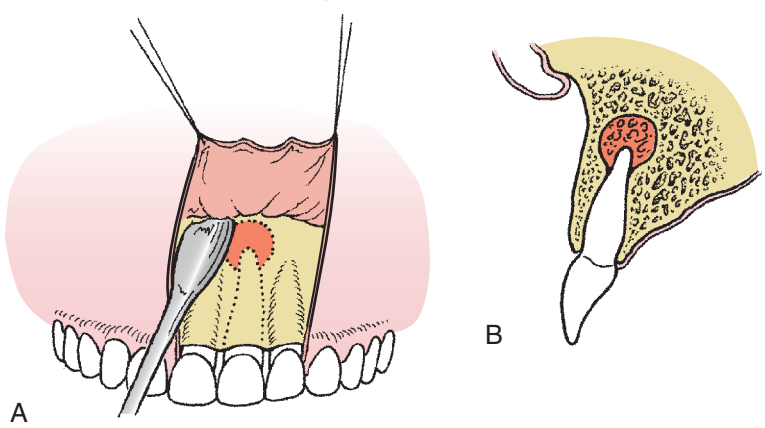
Postsurgical recession, especially around teeth in the esthetic zone, is a concern. Recession may be exacerbated in cases where preexisting full coverage crowns are present. In 2007, von Arx et al.[3] reviewed different types of incisions and the outcomes on periodontal health. They found that a sulcular incision without reflection of the interdental papilla and with direct, vertical-releasing (i.e., nontrapezoidal) incisions provides the best outcome.

Periapical Exposure

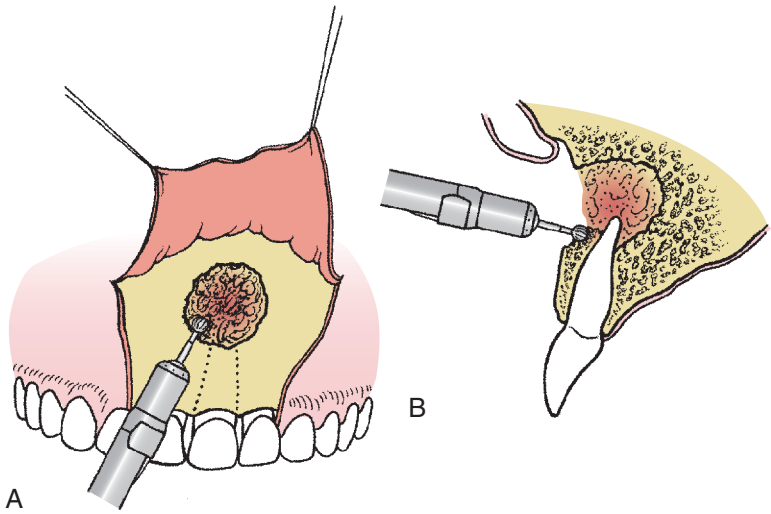
Frequently, cortical bone overlying the apex has been resorbed, exposing a soft tissue lesion. If the opening is small, it is enlarged using a large surgical round burr until approximately half the root and the lesion are visible (Fig. 18.20). With a limited bony opening, radiographs are used in conjunction with root and bone topography to locate the apex. A measurement may be made with a periodontal probe on the radiograph and then transferred to the surgical site to determine the apex location.

To avoid air emphysema, handpieces that direct pressurized air, water, and abrasive particles (or combinations) into the surgical site must not be used. Vented high-speed handpieces or electrical surgical handpieces are preferred during osseous entry and root end resection. Sealed-end air-pressurized handpieces direct air away from the surgical site, and handpieces that use nitrogen gas also prevent air emphysema. Regardless of the handpiece used, copious irrigation should be performed with a syringe or through the handpiece with sterile saline solution. Enough overlying bone should be removed to expose the area around the apex and at least half the length of the root. Good access and visibility are important; the bony window must be adequate. The clinician should not be concerned about the bone removal because once the infection resolves, bone will reform.

The exposure of the root is done before resecting the root to avoid the risk of blending the root in with bone and losing surgical orientation. This is especially critical in the mandible, where the bone is dense. Lower incisor roots are carefully exposed because proximity with adjacent teeth could lead to treatment of the wrong



• **Fig. 18.19** Full-thickness flap is raised with sharp elevator in firm contact with bone. Enough tissue is raised to allow access and visibility to apical area. (A) Frontal view. (B) Cross-section.



• **Fig. 18.20** Apical exposure. A large round burr is used to "paint" the bony window. Enough bone is removed to give good visibility and access to lesion and apex. (A) Frontal view. (B) Cross-section.

apex. The curvature of the root, particularly the maxillary lateral incisor, demands close attention to avoid surgical misadventures.

Curettage

Most of the granulomatous, inflamed tissue surrounding the apex should be removed (Fig. 18.21) to gain access and visibility of the apex, to obtain a biopsy for histologic examination (when indicated), and to minimize hemorrhage.

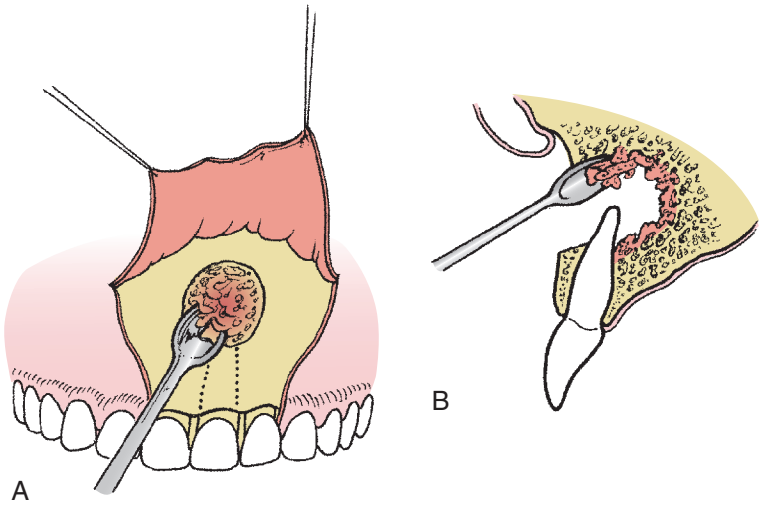
If possible, tissue should be enucleated with a suitably sized sharp curette, although total lesion removal usually does not occur. A cleaner bony cavity has the least hemorrhage and the best visibility. Often, extensive debris may have been forced out the apex of the tooth during the initial endodontic therapy. Cleaning out this debris removes what may have been the nidus for the acute or chronic infection. Tissue removal should not jeopardize the blood supply to an adjacent tooth. In addition, some areas of the lesion, such as on the lingual aspect of the root, may be inaccessible to curettes. Portions of inflamed tissue or epithelium may be left, without compromising healing; total removal is not necessary. As noted before, it is better to leave a small portion of this tissue than to damage the inferior alveolar nerve.

If hemorrhage from soft or hard tissue is excessive to the extent that visibility is compromised, homeostatic agents or other control techniques are useful, but the homeostatic agents should be removed after use. Hemorrhage control can be achieved by holding direct pressure over a bleeding site with gauze soaked in local anesthetic solution with epinephrine and by minimizing suction at the site of a bleeder.

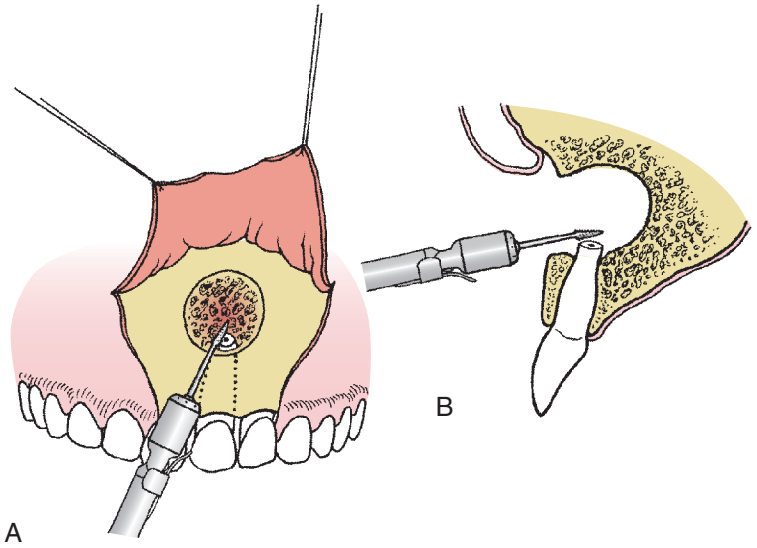
Root End Resection

Root end resection is indicated because it removes the region that most likely had the poorest obturation because of the distance from the coronal portion of the tooth. The presence of accessory canals increases at the apex as well, which may have not been initially cleaned and debrided, thus leaving a source of continued infection.

Before sectioning, a trough is created around the apex with a tapered fissure burr to expose and isolate the root end. The resection is done with the same tapered fissure burr. Depending on the location, a bevel of varying degrees is made in a faciolingual direction (Fig. 18.22). With the use of ultrasonic instruments to prepare the apex, a minimal bevel is needed, especially in anterior



• **Fig. 18.21** Curettage. Much of lesion that is accessible is removed with large curettes. Usually, remnants of tissue remain, which is not a problem. (A) Frontal view. (B) Cross-section.



• **Fig. 18.22** Root end resection. Approximately one third of apex is removed with tapered burr. Amount removed and degree of bevel varies according to situation. (A) Frontal view. (B) Cross-section.

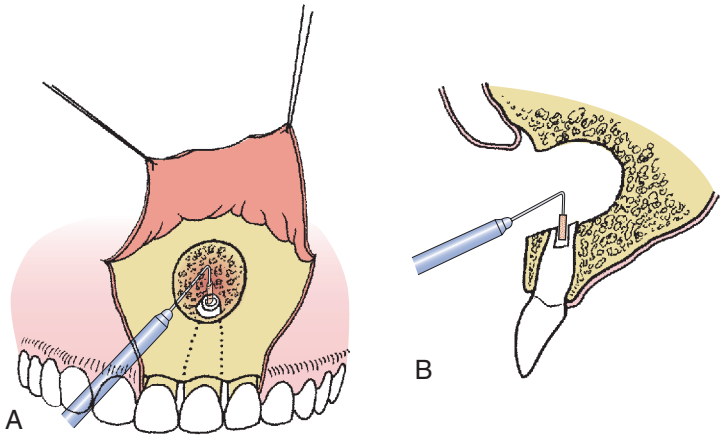
maxillary teeth. By minimizing the length of the bevel, fewer dentinal tubules are exposed, thus reducing leakage into the apical region.

The amount of root removed depends on the reason for performing the resection. Sufficient root apex must be removed to provide a larger surface and to expose additional canals. In general, approximately 2 to 3 mm of the root is resected—more, if necessary, for apical access or if an instrument is lodged in the apical region; less if too much removal would further compromise stability of an already short root.

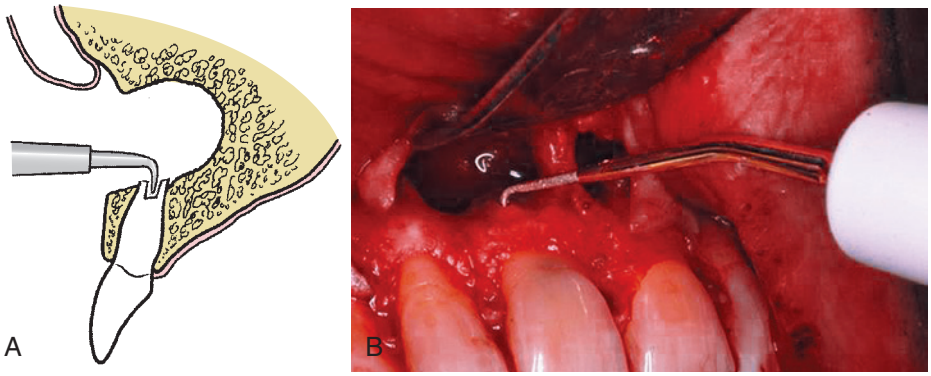
Root End Preparation and Restoration

A retrograde filling should be placed unless technical aspects prohibit it. The filling seals the canal system, preventing further leakage. The depth of the preparation must be at least 1 mm deeper than the length of the bevel to seal the apex adequately. In the past, root end preparation was done by slow-speed, specially designed microhandpieces (Fig. 18.23). The rotary instruments are too complicated to follow the root canal system, occasionally leading to misaligned preparations. Contemporary apical preparation uses ultrasonic tips (Fig. 18.24).

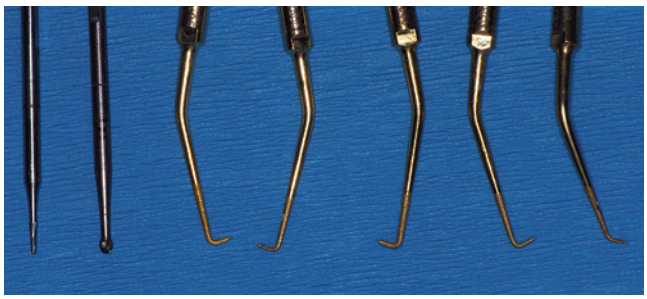
Ultrasonic instruments offer the advantages of control and ease of use; they also permit less apical root removal in certain situations (Fig. 18.25). Another advantage of the ultrasonic tips, particularly when diamond coated, is the formation of cleaner, better-shaped preparation. Evidence suggests that success rates are significantly improved with ultrasonic preparation. The ultrasonic tip can prepare the isthmus between the two canals of the mesiobuccal roots of upper first molars, which is a significant cause of conventional endodontic failure on these teeth. While preparing the apex with the ultrasonic instruments, constant saline irrigation is needed to avoid overheating, which causes fracture of these fine instruments. Various designs and shapes of tips are available to access different apices of each tooth in the oral cavity. The ease of use and special angulations require less of a bony opening and less beveling of the apical region and permit a deeper, denser fill.



• **Fig. 18.23** Root end preparation and retrograde filling material (mineral trioxide aggregate) placement. (A) Piezoelectric unit with 3-mm long tip to prepare the apical end. (B) Special carriers for delivering the mineral trioxide aggregate retrograde filling material.



• **Fig. 18.24** (A) Ultrasonic tips are good alternative for root end preparation. (B) These tips permit preparation with better control and less root removal and the need for less bevel, which exposes fewer dentinal tubules.



• **Fig. 18.25** Ultrasonic preparation tips are available in different shapes for accessing different teeth in the oral cavity compared with the diameter of the conventionally used rotary burrs.

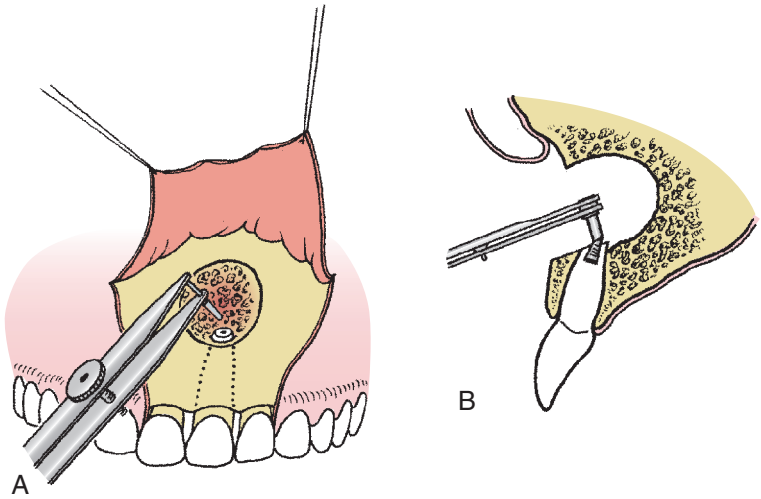
Root End–Filling Materials

The root end–filling material is placed into the cavity preparation (Fig. 18.26). These materials should seal well and should be tissue tolerant, easily inserted, minimally affected by moisture, and visible radiographically. Importantly, the root end–filling material must be stable and nonresorbable indefinitely.

Amalgam (preferably zinc free), intermediate restorative material, and super ethoxybenzoic acid cement have been commonly used materials. Gutta-percha, composite resin, glass ionomer cement, intermediate restorative material, Cavit, and different luting cements have also been recommended; these materials have less clinical documentation of success. Mineral trioxide aggregate (MTA) has shown favorable biologic and physical properties and ease of handling; it has become a widely used material. MTA has been shown to be conducive to bone growth over the apical region. MTA is a hydrophilic material, similar to Portland cement. MTA has a working time of approximately 10 minutes, although it takes 2 to 3 hours to reach final set, which is not an issue because the root apex is not a load-bearing region, at least not until bone fills in the defect. The surgeon must be careful not to irrigate MTA out after placement, so irrigation is done before placing the filling, and any excess is wiped with a just-dampened cotton pellet.

MTA, with its properties, may be placed in a field in which some hemorrhage has occurred; the final set is not adversely affected by blood contamination. Von Arx published a meta-analysis in 2010 that showed a higher success rate with the use of MTA as a filling material (91.4%) compared with other materials.

Each of these root end–filling materials has different, unique mixing and placement characteristics. The clinician should practice with each before placement in a patient. Special carriers for MTA have been designed and work well to deliver the material. A metal carrier with a disposable plastic sleeve contains the material and keeps it from contacting additional moisture as it is carried to the



• **Fig. 18.26** Special small carriers are used to place material, which is then packed with small condensers. Other cement types of materials are carried and compacted with paddles and burnishers. (A) Frontal view. (B) Cross-section.

surgical site. MTA can be condensed and added to so that the fill is complete.

Irrigation

The surgical site is flushed with copious amounts of sterile saline to remove soft and hard tissue debris, hemorrhage, blood clots, and excess root end–filling material. As mentioned with regard to MTA, the irrigation is done before the MTA is placed to avoid washing the filler out of the apical preparation.

Radiographic Verification

Before suturing, a radiograph is obtained to verify that the surgical objectives are satisfactory. If corrections are needed, these are made before suturing.

Flap Replacement and Suturing

Just before closure, the cervical region of the exposed teeth is gently scaled to remove any debris, preexisting calculus, and granulation tissue. This brief intervention speeds the reattachment and reduces greatly the chance for recession. The flap is returned to its original position and is held with moderate digital pressure and moistened gauze. This expresses hemorrhage from under the flap and gives initial adaptation and more accurate suturing. Absorbable monofilament sutures are typically used to permit ease of removal, if needed, and are associated with less wicking and retention of surface bacteria. A sling suture is ideal in the esthetic zone to avoid gingival recession (Fig. 18.27). After suturing, the flap should again be compressed digitally with moistened gauze for several minutes to express more hemorrhage. This limits postoperative swelling and promotes more rapid healing.

Postoperative Instructions

Oral and written information should be supplied in simple, straightforward language. The wording should minimize anxiety arising from normal postoperative sequelae by describing the ways in which the patient can promote healing and comfort. Instructions inform the patient of what to expect (e.g., swelling, discomfort, possible discoloration, and some oozing of blood) and the ways in which these sequelae can be prevented, managed, or both. The surgical site should not be disturbed, and pressure should be maintained (cold packs over the surgical area until bedtime might help). Oral hygiene procedures are indicated everywhere except the surgical site; careful brushing and flossing may begin after 24 hours. Proper nutrition and fluid intake are important but should not traumatize the area.

A chlorhexidine rinse, twice daily, reduces bacterial count at the surgical site. This may minimize inflammation and enhances soft tissue healing.

Analgesics are recommended, although pain is frequently minimal; strong analgesics are usually not required. No category of pain medication is preferred; selection depends on the clinician and the patient. Analgesics for moderate pain usually suffice and are most effective if administered before the surgery or at least before the anesthetic wears off. A protocol that works well is 400 mg of ibuprofen every 4 hours for 48 hours starting as soon as the patient returns home.

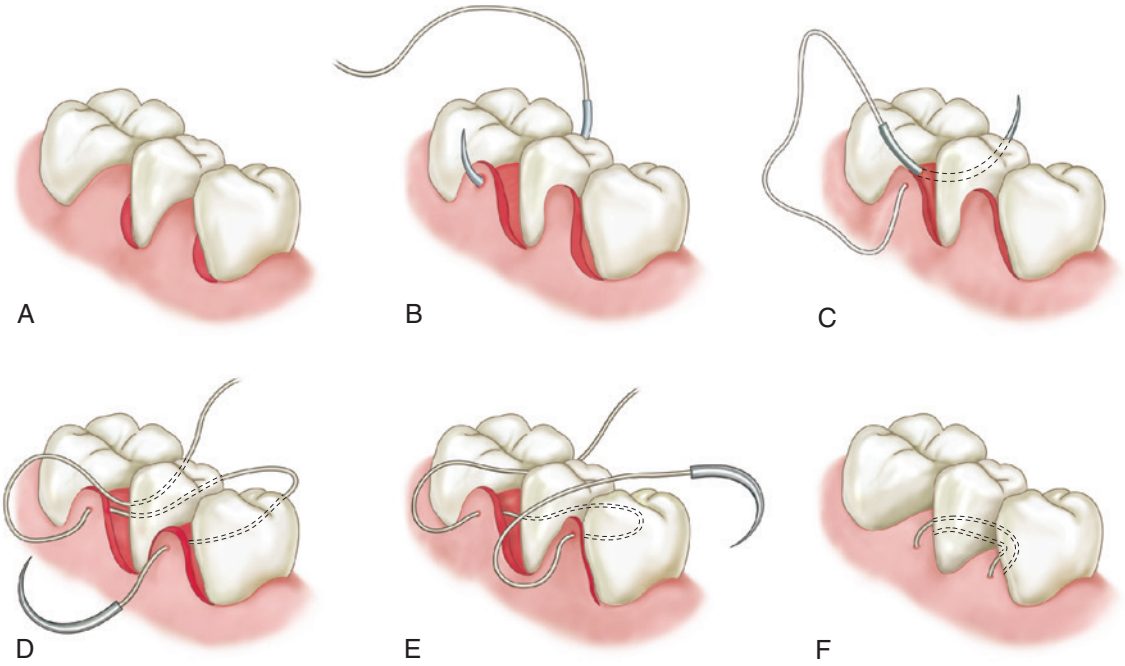
The patient is instructed to call if excessive swelling or pain is experienced. Postoperative complications are a response to injury from the procedure; infection after this type of surgical procedure is rare. However, the patient should be evaluated in person if difficulties arise. Occasionally, sutures have torn loose, a foreign body (e.g., a cotton pellet) is under the flap, or an overreaction of soft tissues occurs. Again, antibiotics are not indicated; palliative or corrective treatment usually suffices.

Suture Removal and Evaluation

Sutures ordinarily are removed in 5 to 7 days, if still present and not resorbed, with shorter periods being preferred to enhance healing. After 3 days, swelling and discomfort should be decreasing. In addition, evidence of primary wound closure must be present; tissues that were reflected should be in apposition. Occasionally, a loose or torn suture may result in nonadapted tissue. In these cases the margins are only readapted and resutured if in the maxillary anterior esthetic zone.

Corrective Surgery

Corrective surgery is the management of defects that have occurred by a biologic response (i.e., resorption) or iatrogenic (i.e., procedural) error. These defects may be anywhere on the root, from cervical



• **Fig. 18.27** (A–F) Schematic of sling suture for reapproximating a gingival flap. This type of suture is helpful to prevent recession around teeth and existing crowns. (Modified from Cohen ES. Sutures and suturing. In: *Atlas of Cosmetic Reconstructive Periodontal Surgery*. 2nd ed. Philadelphia: Lea & Febiger; 1994.)

• BOX 18.5 Corrective Surgery

Indications
- Procedural errors (e.g., perforations)
- Resorptive defects

Contraindications
- Anatomic impediments
- Inaccessible defect
- Repair would create periodontal defect

margin to apex. Many defects are accessible; others are difficult to reach or are in virtually inaccessible areas. Usually, an injury or defect has occurred on the root. In response to the injury, an inflammatory lesion may be present, or one may develop in the future. A corrective procedure is necessary. In general, the procedure involves exposing, preparing, and then sealing the defect. Usually included are removal of irritants and rebuilding of the root surface (Box 18.5).

Indications

Procedural Errors

Procedural errors are openings through the lateral root surface created by the operator, typically during access, canal instrumentation, or after space preparation (Fig. 18.28). The result is perforation, which presents a difficult surgical challenge, more so than repairing damage to a root end. Perforations often require restorative management and completion of the endodontic treatment, usually in conjunction with the surgical phase. The location of the perforation influences success; some are virtually inaccessible. If the defect is on the interproximal aspect, in the furcation, or close to adjacent teeth or to the lingual aspect, adequate repair may not be possible or is compromised. Defects that are too far posterior (particularly on the distal or lingual aspects) may be difficult to reach. The nature and location of the perforation should be determined with angled radiographs before the decision is made whether to repair surgically, to remove the involved root, or to extract.

Resorptive Perforations

Resorptive perforations may originate internally or externally (Fig. 18.29), resulting in a communication between the pulp and the periodontium. A more serious defect is one that extends to include cervical exposure to the oral cavity.

Resorption occurs for several reasons, but most cases include sequelae to trauma, internal bleaching procedures, orthodontic tooth movement, restorative procedures, or other factors causing pulp or periradicular inflammation. Occasionally, resorptions are idiopathic, with no demonstrable cause.

As with procedural errors, the considerations as to treatability and surgical approach are similar.

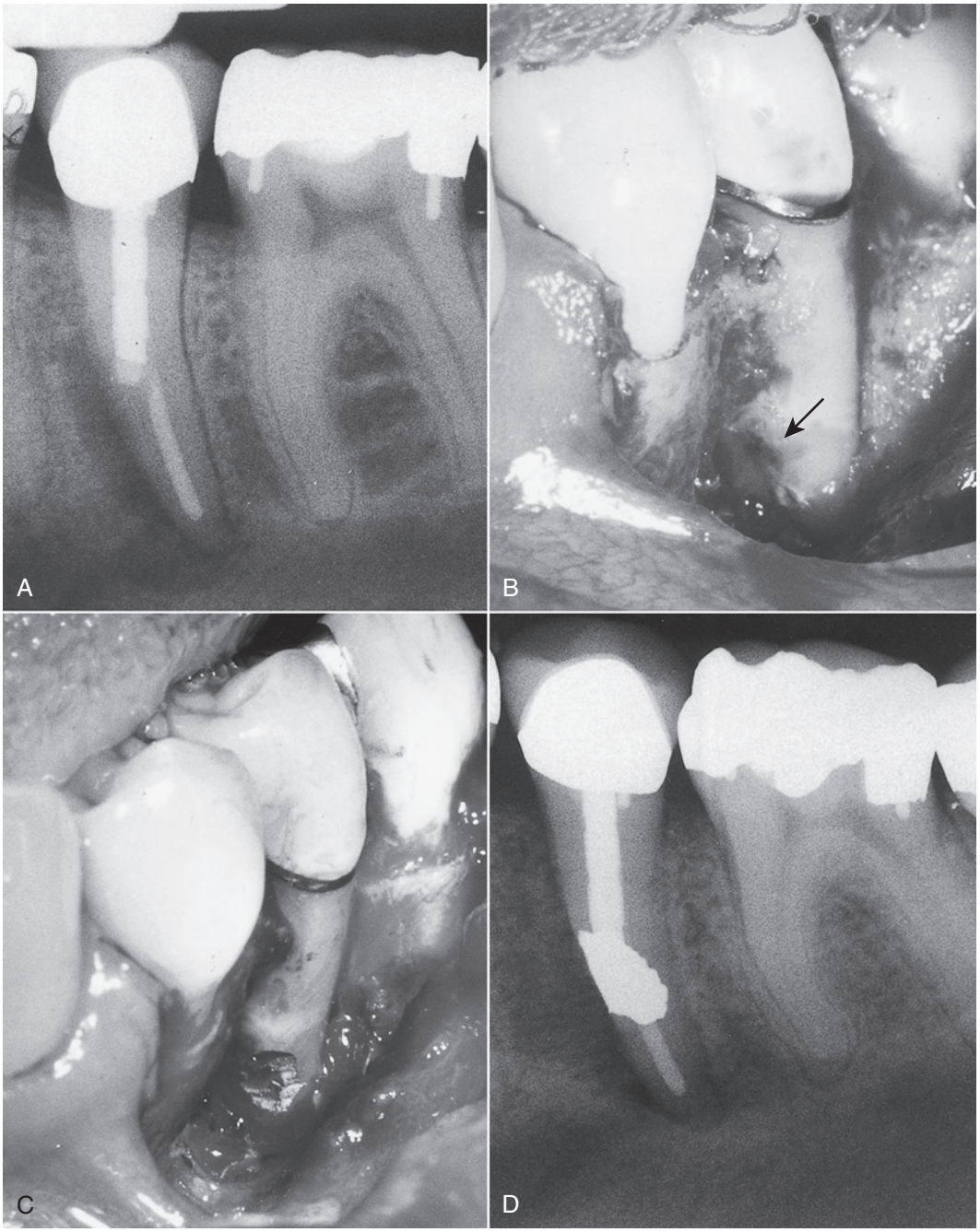
Contraindications

Anatomic Considerations

Consideration must be given to structural impediments to a surgical approach. Few impediments exist, and most can be managed or avoided. Included are various nerve and vessel bundles and bony structures such as the external oblique ridge.

Location of Perforation

As mentioned previously, the defect must be accessible surgically. This means the clinician must be able to locate and, ideally, readily visualize the surgical area.



• **Fig. 18.28** Postperforation repair. (A) A lesion developing lateral to the off-centered post suggests perforation. (B) The perforation is identified *(arrow)* on flap reflection. (C) The post is reduced to within the root. (D) The cavity is filled with amalgam.

Accessibility

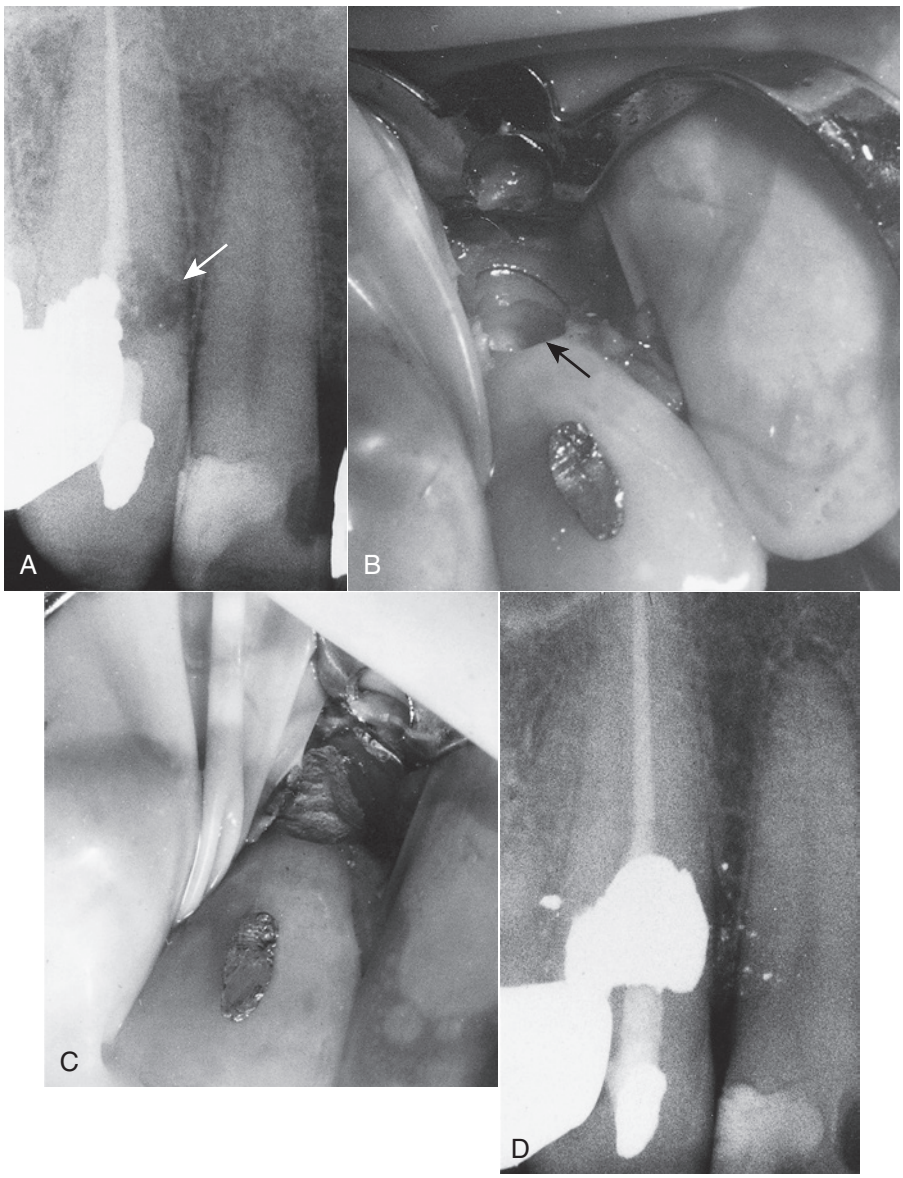
A handpiece or an ultrasonic instrument generally is necessary to prepare the defect. Therefore the defect must be reachable, without impedance by structures or by lack of visibility.

Considerations

Surgical Approach

Repair presents a unique set of problems. The defect may wrap from the facial to the proximal to the lingual aspect, creating not only difficulties in visualization but also problems with access and hemostasis and material placement. A general guideline is that the defect is larger and more complex than it appears on a radiograph.

In general, the defect must be enlarged to provide a sound cavosurface margin and to avoid knife-edge margins. Occasionally, the repair is internal (from inside the canal), with material being extruded through the defect. The excess is removed and contoured with burrs or sharp instruments. The objective is to seal and stabilize the defect with a restorative material. If a post or other material is perforating the root, it must be reduced with burrs to within root structure and a cavity prepared. The defect is then restored with one of the materials mentioned previously.



• **Fig. 18.29** External resorption repair. (A) The mesially angled radiograph shows the defect *(arrow)* to be lingual. (B) After flap reflection, crestal bone reduction, and rubber dam isolation, the defect is prepared *(arrow)*. Margins must be in sound tooth structure. (C) The cavity is filled with amalgam, and the flap is apically positioned. (D) Long-term radiographic and clinical evaluations are necessary; occasionally, resorption recurs.

Repair Material

External repair is often done with suitable materials such as MTA or super ethoxybenzoic acid. MTA, in particular, shows favorable biologic properties, and its white color blends in if there is thin tissue over the defect.

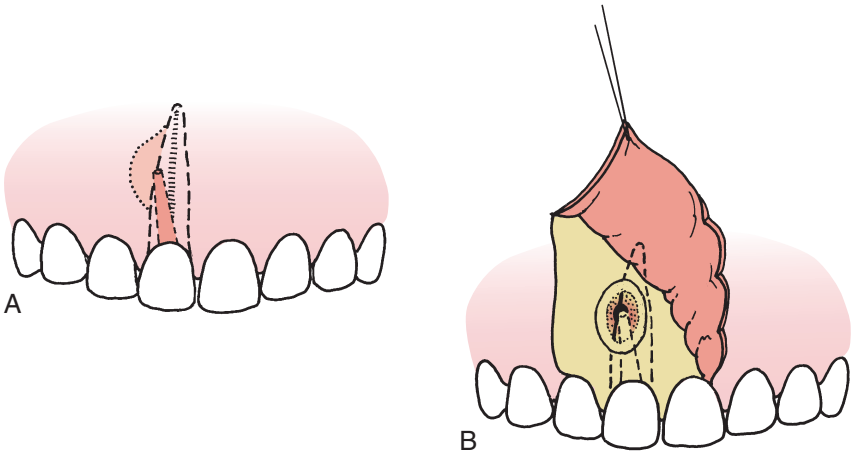
Prognosis

Repairs in the cervical third or furcation, in particular, have the poorest prognosis. Communication often is eventually established with the junctional epithelium, which results in periodontal breakdown, loss of attachment, and pocket formation. This means that a periodontal procedure (e.g., crown lengthening) would be required in conjunction with the defect repair.

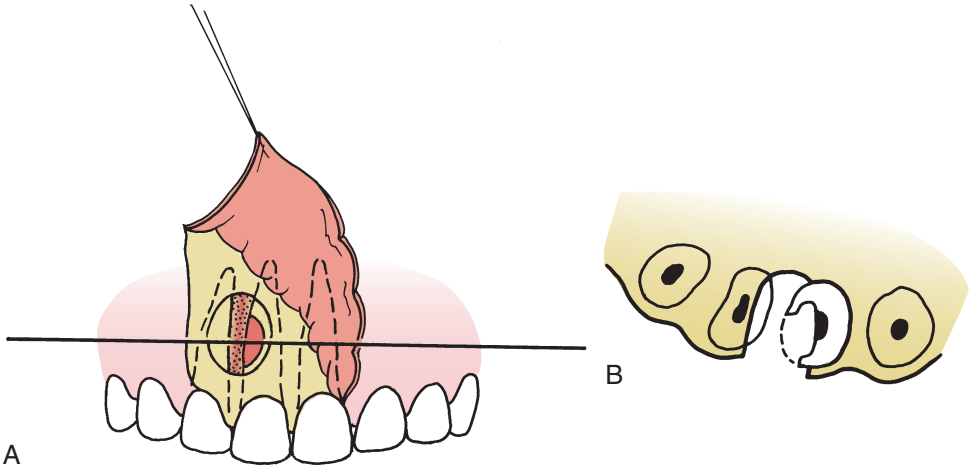
A defect in the middle or apical third that is properly prepared and sealed has a very good long-term prognosis.

Surgical Procedure

After the basic approaches with periapical surgery, the next step is to perform corrective surgery. Flap designs are similar but are more limited. A sulcular incision is usually required, with at least one vertical incision to form a three-cornered flap. A full-thickness flap is reflected, and bone is removed to expose the defect (Fig. 18.30). Bone removal must be adequate to allow maximal visualization and access. If possible, a rim of cervical bone should be retained to support the flap and possibly to enhance reattachment; this is frequently not possible with cervical defects.



• **Fig. 18.30** (A) The misdirected post is perforating distally. (B) The full mucoperiosteal (i.e., sulcular incision) three-corner flap is raised, and bone is removed to expose the defect.



• **Fig. 18.31** (A) The post is reduced to well within the root, and the cavity is prepared. (B) In this cross-section through the defect, a lingual wall to the preparation is evident.

The preparation of a facial or lingual defect is similar to that of a class 1 cavity preparation (Fig. 18.31). An interproximal defect resembles a class 2 preparation, with an opening from the facial (or lingual) aspect and including the interproximal wall but leaving a lingual wall (if possible).

The facial or lingual cavity is then filled by direct placement of the material. The material is carved flush with the cavity margins. Flap replacement, suturing, and digital pressure have already been described earlier. Suture removal should be within 3 to 6 days. Postoperative instructions are similar to those after periapical surgery.

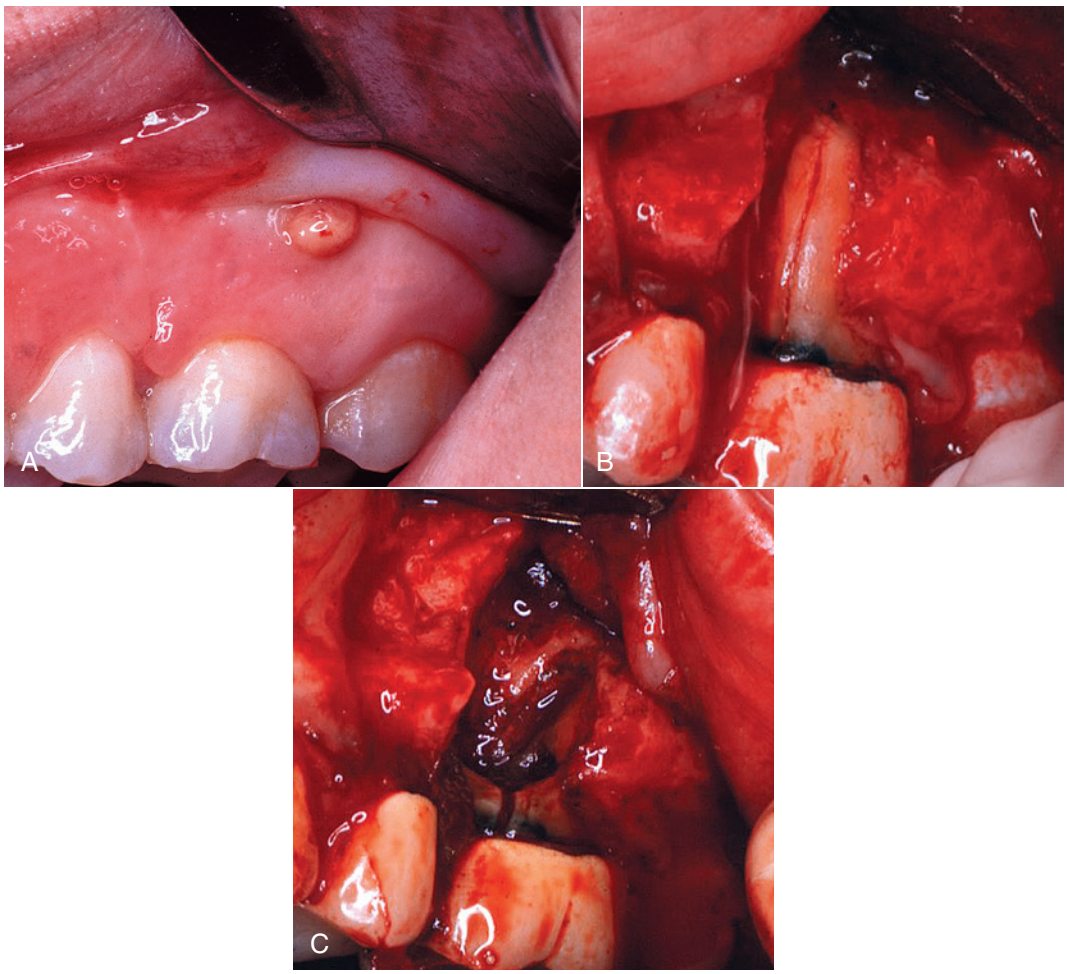
Fractured Teeth

Preoperative radiographs and a careful clinical examination should be done with a high index of suspicion of a vertical root fracture before undertaking surgery. Mandibular molars and maxillary premolars are the teeth that most frequently have occult vertical root fractures. Although surgical exploration may be needed to show the presence of a fracture definitively (Fig. 18.32), subtle radiographic signs may alert the surgeon that a fracture is present and that surgery is unlikely to be successful. Tamse et al. looked at radiographs of maxillary premolars for comparison with the clinical findings at the time of surgery.[4] Very few (1 out of 15) teeth with an isolated, well-corticated periapical lesion had a vertical root fracture. In contrast, halo-type radiolucency was almost always associated with a vertical root fracture (Fig. 18.33). This type of radiolucency is also known as a *J type* in which a widened periodontal ligament space connects with the periapical lesion creating the J pattern.

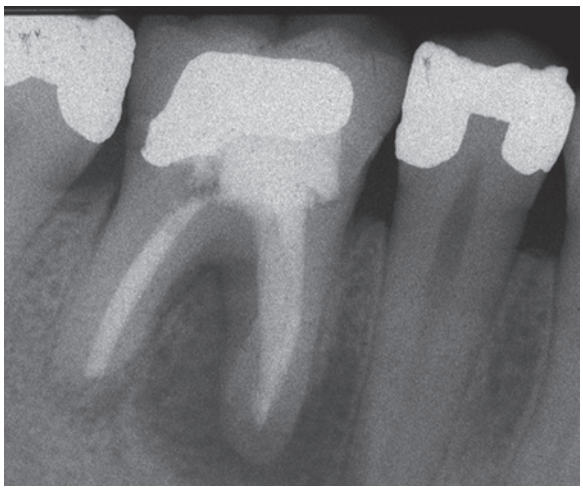
In patient discussions, it is critical to review the exploratory nature of the surgery, and the author of this chapter routinely uses that as a descriptor of the planned surgery. In cases of root fracture, a decision during surgery may need to be made either to resect a root or extract a tooth if a fractured root is found. Obtaining the appropriate preoperative consent and determining how the extracted tooth site will be managed (with or without a temporary removable partial denture) must be established before surgery commences.

Healing

Healing after endodontic surgery is rapid because most tissues being manipulated are healthy with a good blood supply, and tissue replacement enables repair by primary intention. Soft tissues (e.g., periosteum, gingiva, alveolar mucosa, and periodontal



• **Fig. 18.32** (A) A fistula on midbuccal portion of the mesiobuccal root of a molar. (B) A full-thickness sulcular incision reveals an unsuspected vertical root fracture. (C) Resection of the mesiobuccal root can be accomplished because a sulcular incision was used, as opposed to a semilunar type.



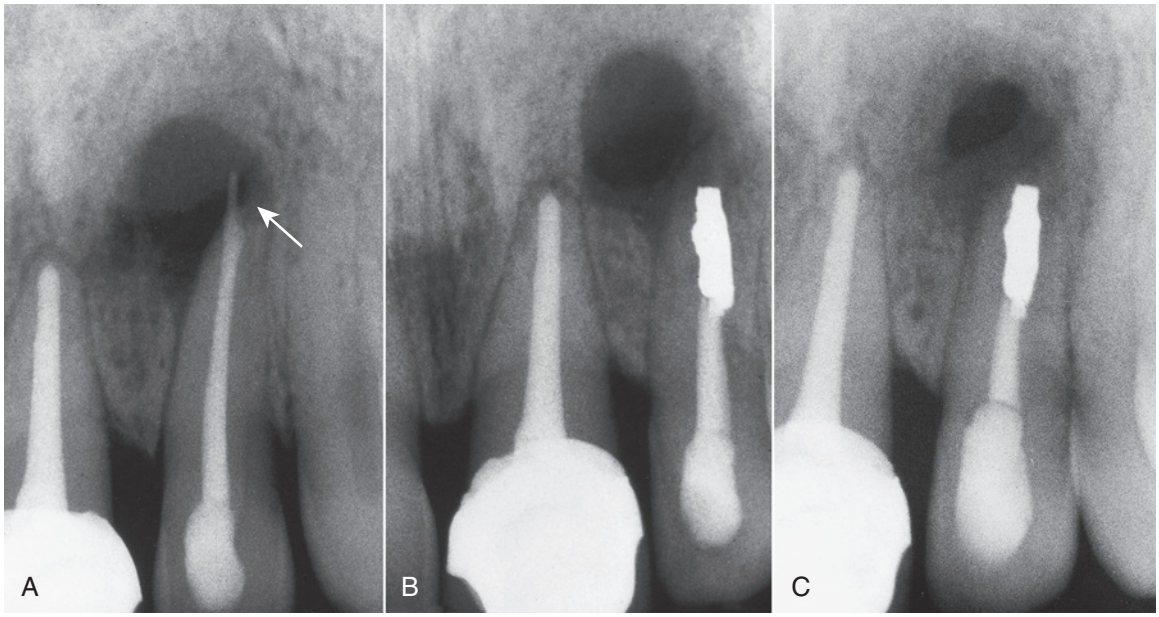
• **Fig. 18.33** The halo radiolucency involving the entire length of the root is often pathognomonic for a vertical root fracture.

ligament) and hard tissues (e.g., dentin, cementum, and bone) are involved. Time and mode of healing vary with each but involve similar processes. The specifics of short-term healing of soft and hard tissues are discussed in Chapter 4.

Recall

Recall evaluations to assess long-term healing are important. Some failures after surgery are evidenced only by radiographic findings. A 1-year follow-up is generally a good indicator. If, after 1 year, radiographic evidence shows no decrease in lesion size or the lesion size increases, it generally indicates a failure and persistent inflammation. A decrease in lesion size (indicating hard tissue formation) may lead to complete healing and requires evaluation at 6 to 12 months. Of course, persistent symptoms—such as pain or swelling (or both), presence of sinus tract, deep probing defects, or other adverse findings—also indicate failure. Healing by scar tissue formation after surgery occurs primarily in the maxillary incisors (Fig. 18.34). This is unusual and has a unique radiographic appearance with an irregular distinct outline, often separated from the root end. Healing by scar tissue formation is considered a successful outcome.

Frequently, structures over the apex do not regenerate to a normal appearance. At times, connective tissue or bony arrangements



• **Fig. 18.34** Healing by scar tissue formation. (A) Failed treatment because of transportation and perforation, leaving area of canal *(arrow)* undebrided and unobturated. (B) Root end resection, curettage, and root end filling. (C) After 2 years, an area of radiolucency is seen. Sharp border, separation from apex, and distinct radiolucency show this to be a scar.

leave a slightly "widened" periodontal ligament space. This should have relatively distinct, corticated margins and not be diffuse (which indicates inflammation and a failure).

To Perform a Biopsy or Not

A clinical controversy has ensued over the consideration as to whether all periapical lesions treated surgically should have soft tissue removed and submitted for histologic evaluation. An editorial by Walton questioned the rationale of submitting all soft tissue recovered for histologic examination, which then ignited a series of letters to the editor.[5] Some organizations, such as the American Association of Endodontists, have stated in their standards that if soft tissue can be recovered from the apical surgery, it must be submitted for pathologic evaluation.

On cursory review, it seems that it is easier to make this recommendation than to have the surgeon determine whether there is anything unusual about the case that warrants histologic examination. Walton makes a convincing argument against the submission of all tissues because similar-appearing radiolucencies that are not treated surgically do not have tissue retrieved for pathologic identification.[5] It also is accepted that the differentiation between a periapical granuloma or periapical cyst has no direct bearing on clinical outcomes and therefore cannot be used as a rationalization for the submission of tissue.

The dilemma falls back to the surgeon that if a rare lesion should present itself in the context of a periapical lesion and a biopsy is not performed in a timely manner, the surgeon may have exposure in a potential malpractice suit. Many surgeons have a case or two in their careers that have "surprised" them on the basis of the final pathologic diagnosis. However, careful review of these cases usually depicts a clinical situation inconsistent with a typical periapical infection.

An approach more logical than purely defensive is to set up guidelines on which to determine that submission of tissue is not indicated. These guidelines are listed in Box 18.6. It is recommended that the surgeon have documented in the record the rationale for electing not to submit tissue in each specific case. At a recent meeting of the American Association of Oral and Maxillofacial Surgeons, only 8% of those attending a symposium on endodontic surgery reported that they "always" submit tissue for histologic examination.

• BOX 18.6 Rationale in Decision for Biopsy of Periapical Lesions

- Was there evidence of preendodontic pulpal necrosis?
- Is the characteristic of the radiolucency "classic"?
- Will the patient return for follow-up radiographs?

If all of these criteria are met, the surgeon may decide to not submit routinely collected periapical tissue.

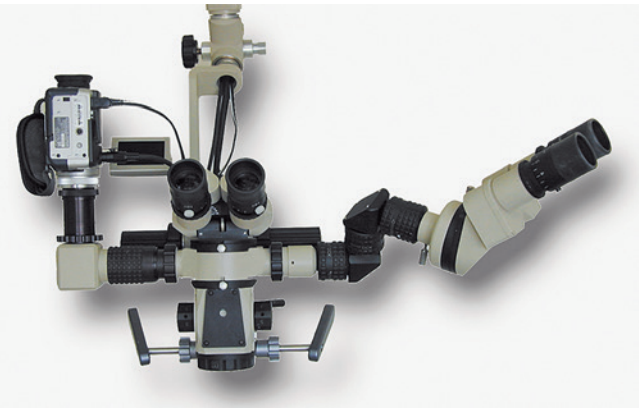
Adjuncts

Some of the newer devices and materials have enhanced and, in some cases, improved surgical procedures. These include the light and magnification devices and techniques of guided tissue regeneration.

Light and Magnification Devices

Surgical Microscope

The microscope has been adapted and used for surgery, as well as for other diagnostic and treatment procedures in endodontics (Fig. 18.35). Advantages of the microscope include magnification and in-line illumination. Microscopes also can be adapted for videotaping and to transmit the image to a television monitor for direct viewing



• **Fig. 18.35** Surgical microscope has been adapted for endodontic procedures, including surgery. Magnification and in-line illumination enhance visualization for diagnosis and treatment. Add-on binoculars for dental assistant are useful adjunct. (From Johnson WT. *Color Atlas of Endodontics*. Philadelphia: WB Saunders; 2002.)

or recording. These adaptations enhance the view of the surgical field, help identify previously undetected structures, and facilitate surgical procedures. Although some clinicians advocate and are excited about the use of these microscopes, as yet, substantial clinical benefits have not been demonstrated through long-term controlled studies. However, some evidence suggests that the microscope use improves surgical techniques and short-term outcomes.[6]

Fiberoptics

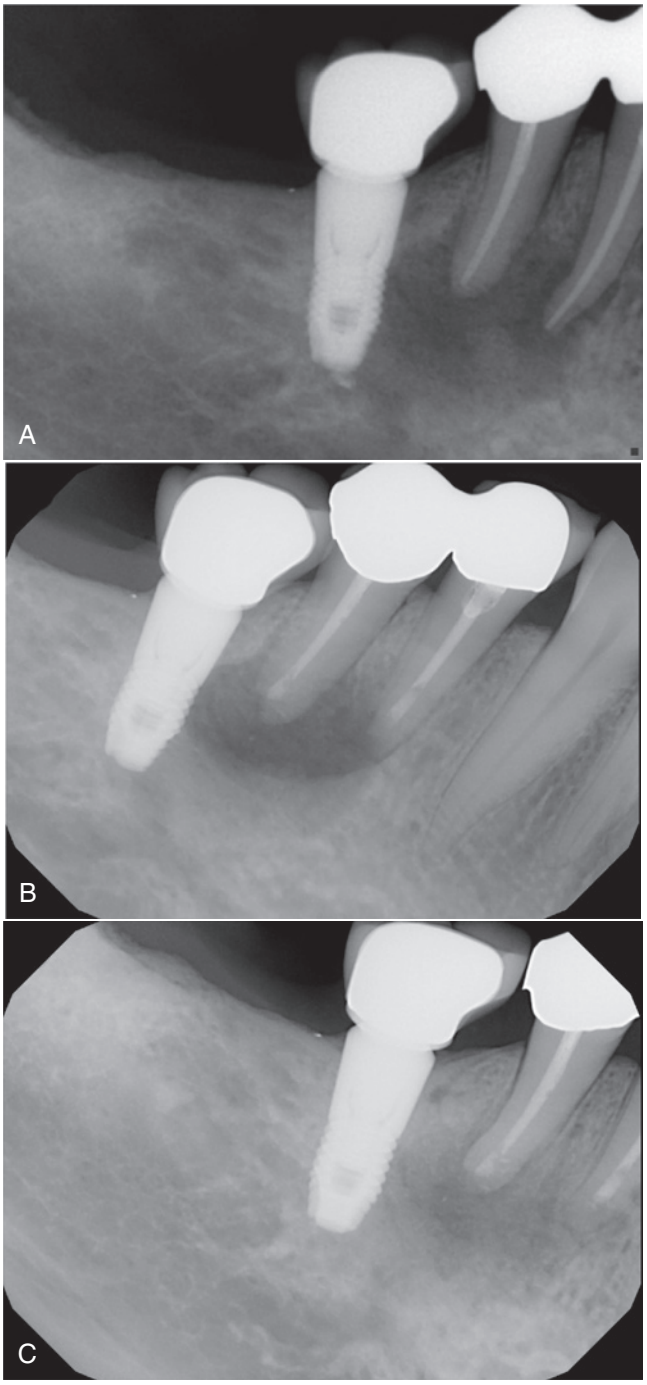
A new system, known as *endoscopy*, is available that uses a very small, flexible fiber bundle that contains a light and an optic system. The optics are connected to a monitor that permits visualization of precise details of the surgical site. This system also gives the clinician the option of videotaping and recording the procedures.

Guided Tissue Regeneration

Originally intended for periodontal surgery, guided tissue regeneration also has been applied to endodontic surgery. The membranes used in this procedure are applied where defects have extended to cervical margins or as a covering of large defects surrounded by bone. These membranes, particularly those that are resorbable, may prove useful in selected situations. However, evidence indicating their long-term effectiveness in endodontic surgery is incomplete, and studies have not shown an increase in bone density when a membrane is used. Whether use of membranes results in long-term, substantial benefits has not been demonstrated. This chapter author's opinion is that the elimination of the source of infection permits regeneration of the junctional epithelium and healing without the use of membranes.

Bone Augmentation

Various substances have been placed in the periradicular surgical cavities in the attempt to enhance bony healing. Because of the location of the cavity and because most of the periphery is encased in bone or the periosteum, spontaneous bone regeneration is predictable. Such augmentation materials are of minimal to no benefit and need not be placed. Because the materials are being placed in a site with active infection, these adjuncts may then act as a nidus for infection. Reviewing the literature provides some studies that show increased radiographic success with concomitant grafting, particularly with large lesions (>10 mm).[7] Other studies fail to show a benefit with grafting.[8] It is my experience that, as noted previously, elimination of the chronic infection by apical surgery will allow bone fill in even substantial defects (Fig. 18.36) without the need for bone grafting.



• **Fig. 18.36** (A) Large periapical lesion associated with teeth #27 and #28 in proximity with an implant. Apical surgery was performed (B) with a mineral trioxide aggregate seal; no graft or membrane was placed into the defect. (C) Bone fill after 3 months.

When to Consider Referral

Although many of the procedures presented in this chapter appear relatively straightforward, endodontic surgery is often complex and difficult to perform. Clinicians should carefully consider the problems before undertaking such surgeries.

Training and Experience

Most generalists do not have the advanced training, including didactic and clinical experience, necessary to perform surgical procedures. These procedures are a unique discipline and require special skills in diagnosis, treatment planning, and management; they also require a special armamentarium. Skill in long-term evaluation and resolution of failures or other complications is also important. With increased emphasis on standards of care and litigation problems, coupled with the availability of experienced specialists, general dentists should consider their own expertise as it relates to case difficulty. These procedures are often the last hope of tooth retention. Lack of training may result in inadequate or inappropriate surgery, loss of a particular tooth, and possible damage to other structures. One study has shown an improvement in success rates with a more experienced surgeon.[9]

Determining the Cause of Root Canal Treatment Failure

Two steps are critical to success, particularly if surgery is being considered: (1) identification of the cause of failure and (2) design of the treatment plan. Frequently, surgery is not the best choice, but when necessary, it must be done appropriately. A specialist is better able to identify these causes and approach their resolution. If the cause of the failure cannot be identified, these cases must be considered for referral.

Surgical Difficulties

In many situations, surgical accessibility is limited and even hazardous. For example, the neurovascular bundle near mandibular posterior teeth and maxillary palatal root apices presents the potential for creating paresthesia, excessive hemorrhage, or both. Complicating structures include overlying bone throughout the mandible and in the palate, the frena and other muscle attachments, fenestrations of cortical bone, and sinus cavities. These structures require care, the proper use of instruments, and surgical skill.

In summary, most of the procedures discussed in this chapter require greater training and experience than are provided in an undergraduate dental education program. If the clinician has not had additional postgraduate training and experience, referral should be considered.

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19

Management of the Patient Undergoing Radiotherapy or Chemotherapy

EDWARD ELLIS III

CHAPTER OUTLINE

Dental Management of Patients Undergoing Radiotherapy to the Head and Neck

Radiotherapy (i.e., radiation therapy and x-ray treatment) is a common modality for treating malignancies of the head and neck. Approximately 30,000 cases of head and neck cancer occur each year in the United States. The use of therapeutic irradiation to treat this cancer is ideally predicated on the ability of radiation to destroy neoplastic cells while sparing normal cells. In practice, however, this is never achieved, and normal tissues experience some undesirable effects. Any neoplasm can be destroyed by radiation if the dose delivered to the neoplastic cells is sufficient. The limiting factor is the amount of radiation that the surrounding tissues can tolerate.

Radiotherapy destroys neoplastic (and normal) cells by interfering with nuclear material necessary for reproduction, cell maintenance, or both. The faster the cellular turnover, the more susceptible the tissue is to the damaging effects of radiation. Thus neoplastic cells, which usually reproduce at higher rates than normal tissue, are selectively destroyed (relatively). In practice, normal tissues with rapid turnover rates are also affected to some degree. Therefore hematopoietic cells, epithelial cells, and endothelial cells are affected soon after radiotherapy begins.

Early in the course of radiotherapy the oral mucosa shows the effects of treatment. Most notable to dentistry are the changes in and around the oral cavity as a result of destruction of the fine vasculature. Salivary glands and bone are relatively radioresistant, but because of the intense vascular compromise resulting from

radiotherapy, these tissues are subject to considerable hardship in the long run.

Radiation Effects on Oral Mucosa

The initial effect of radiotherapy on the oral mucosa, which is seen in the first 1 or 2 weeks, is erythema that may progress to severe mucositis with or without ulceration. Pain and dysphagia may be severe and make adequate nutritional intake difficult. These mucosal reactions begin to subside after the completion of radiotherapy. The taste buds, also composed of epithelial cells, show similar reactions. Loss of the sense of taste is a prominent complaint early in treatment, but it gradually returns, depending on the quantity and quality of saliva that remains after treatment.

Relief from mucositis is not predictable. Antibiotic lozenges containing amphotericin, tobramycin, and neomycin may be of some benefit.[1] When symptoms are severe, viscous lidocaine may be useful.

The long-term effects of radiotherapy to the oral mucosa are characterized by a predisposition to breakdown and delayed healing, even after minor insult. The epithelium is thin and less keratinized, and the submucosa is less vascular, giving a pale appearance to the tissue. Radiotherapy induces submucosal fibrosis, which makes the mucosal lining of the oral cavity less pliable and less resilient. Minor trauma may create ulcerations that take weeks or months to heal. These ulcerations are often difficult to differentiate from recurrent malignant disease.

Radiation Effects on Mandibular Mobility

When irradiated, the pterygomasseteric sling and periarticular connective tissues become inflamed. Irradiated muscle becomes fibrotic and tends to contract, and the articular surfaces degenerate.[2] These factors herald the onset of trismus. Decreased ability to open the mouth may be insidious in onset, usually occurring over the first year after radiation therapy, and is painless. When the interincisal opening decreases to 20 mm, food intake becomes difficult. Additionally, inability to open the mouth wide makes it difficult to perform dental work and to provide a general anesthetic.

Radiation Effects on Salivary Glands

The salivary gland epithelium has a slow turnover rate; therefore, the salivary glands might be expected to be radioresistant. However, because of the destruction of fine vasculature by radiation, the salivary glands show considerable damage with resultant atrophy, fibrosis, and degeneration. This damage manifests clinically as xerostomia (decreased production of saliva) and causes dry mouth. The severity of xerostomia depends on which salivary glands were within the field of radiation. Dry mouth may be the patient's most significant complaint.

Loss of salivary function leads to a plethora of adverse sequelae, including difficulty tasting, chewing, and swallowing; difficulty sleeping; esophageal dysfunction, including chronic esophagitis; nutritional compromises; greater intolerance to medications; and increased incidence of glossitis, candidiasis, angular cheilitis, halitosis, and bacterial sialadenitis. In addition, there may be decreased resistance to loss of tooth structure from attrition, abrasion, and erosion; loss of buffering capacity; increased susceptibility to mucosal injury; inability to wear dental prostheses; and rampant caries.

The effects of xerostomia on the oral cavity are devastating. Because saliva is the principal protector of oral tissues, its absence results in serious complications. Salivary proteins such as peroxidase, lysozyme, and lactoferrin are antibacterial and limit the growth of cariogenic bacteria. The film of salivary mucins on teeth and mucosal surfaces is believed to protect these oral structures from wear. Histatins, a family of salivary proteins, have potent antifungal properties that limit the growth of oral yeast. These salivary components, in conjunction with mucosal tissues, form part of the innate immune system that continually protects the human body from infection. The oral cavity is also protected by secretory immunoglobulins A and M, which are produced locally by B cells within the salivary glands. These antibodies include those with specificity against oral cariogenic bacteria. When salivary volume is significantly reduced, patients are at risk for serious oral complications.

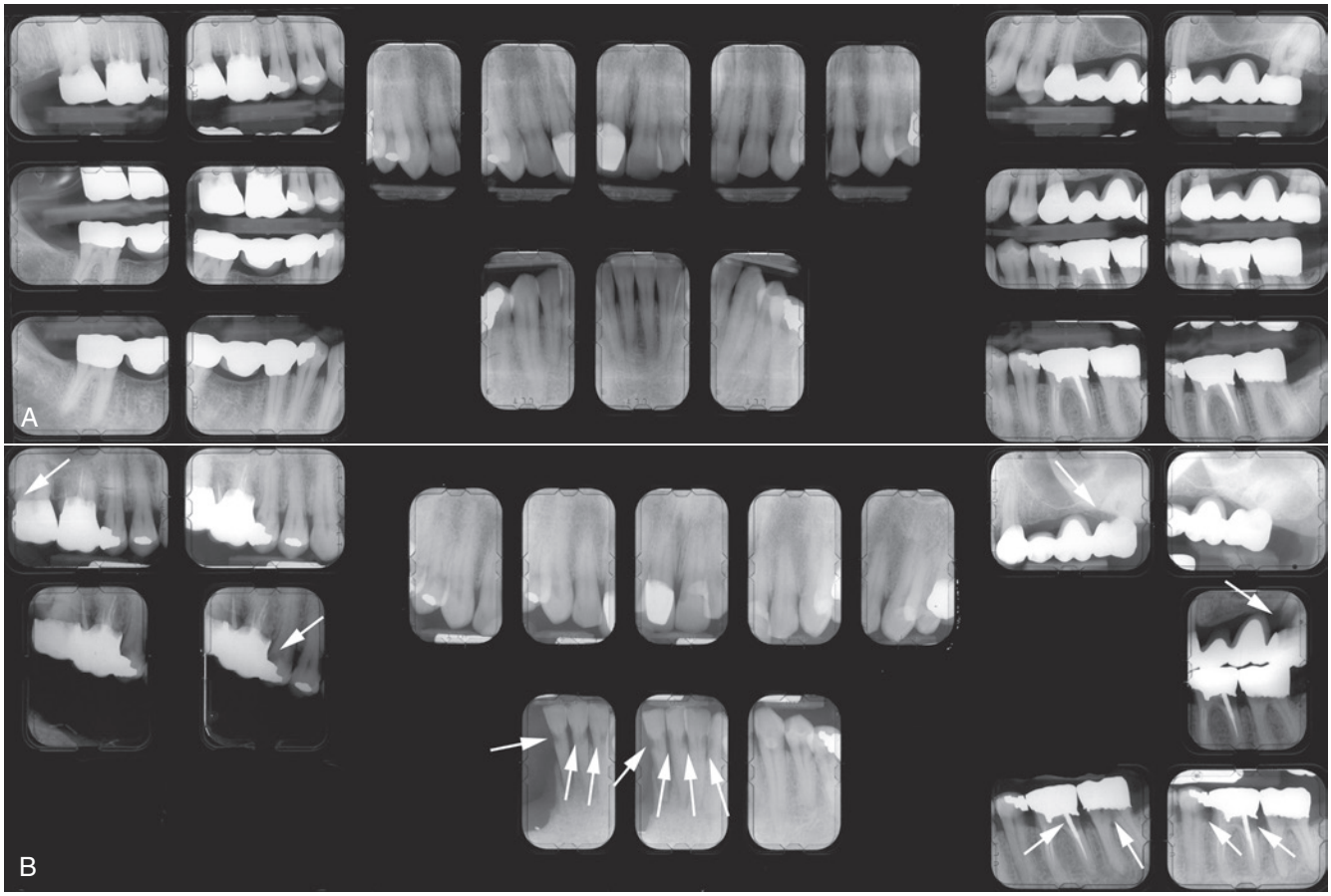
The xerostomia makes it difficult for patients to eat a normal diet because of dysphagia. Therefore patients may adopt a more cariogenic diet. Rampant radiation caries can swiftly destroy the remaining dentition and predispose the patient to severe infection of the jaws (Fig. 19.1). Teeth thus affected exhibit decay around the entire circumference of the cervical portion (Fig. 19.2). Periodontitis is accelerated in the absence of saliva. Dysgeusia, dysphonia, and dysphagia are also caused by xerostomia. Another sequela of low salivary flow is an increase in oral infections such as candidiasis.

Treatment of Xerostomia

After radiotherapy, patients often complain of chronic dry mouth. At present, there is no general agreement on how to prevent these changes. Unfortunately, in many cases, xerostomia never improves substantially, and exogenous replacement of saliva is necessary. For the simplest form of replacement, water can be sipped throughout the day. Sipping water during meals aids in chewing, swallowing, and taste perception. In addition, several saliva substitutes can be obtained without a prescription. These substitutes contain several of the ions in saliva and other ingredients (e.g., glycerin) to mimic the lubricating action of saliva. Patients should be advised not to use products containing alcohol or strong flavors, which may irritate the mucosa. Sugar-containing products should be avoided by these patients who have an increased susceptibility to dental caries. They should also avoid caffeine and over-the-counter antihistamines and decongestants because these agents can further decrease the production of saliva and worsen the symptoms. Many of the salivary substitutes available in the United States contain carboxymethylcellulose, but studies have shown that the animal-derived mucin-based products that are available in other countries are better able to reduce the severity of symptoms associated with xerostomia.[3,4]

Unfortunately the different types of artificial saliva available on the market do not possess the protective proteins present in the salivary secretions. Patients are therefore still prone to the problems induced by xerostomia. For comfort, however, many patients seem to find plain water just as satisfying as artificial saliva and keep small quantities available at all times to sip.

Efforts to stimulate patients' residual saliva have met with some success. Sugar-free chewing gum stimulates saliva production as long as some saliva is being produced.[5] The U.S. Food and Drug Administration has approved the use of two medications to stimulate the flow of saliva: (1) pilocarpine hydrochloride and (2) cevimeline hydrochloride; both have been shown to relieve symptoms of xerostomia.[6] Both drugs are parasympathomimetic agents that function primarily as muscarinic agonists, causing stimulation of exocrine gland secretion. This stimulation can increase the production of saliva even in patients whose salivary glands have been exposed to radiation. An oral dose of 5 mg of pilocarpine four



• **Fig. 19.1** Radiographs illustrating the rapidity with which dental caries can occur in an irradiated patient. (A) Periapical radiographs taken just before radiation therapy. (B) Periapical radiographs taken 16 months after radiation therapy. Note the prevalence and severity of the dental caries, which have occurred throughout the dentition *(arrows)*.

times a day or 30 mg of cevimeline three times a day has been shown to improve many symptoms of xerostomia without significant drug-related side effects.[7–12] The administration of these medications may prove to be beneficial for some patients with postradiation xerostomia.

Radiation Effects on Bone

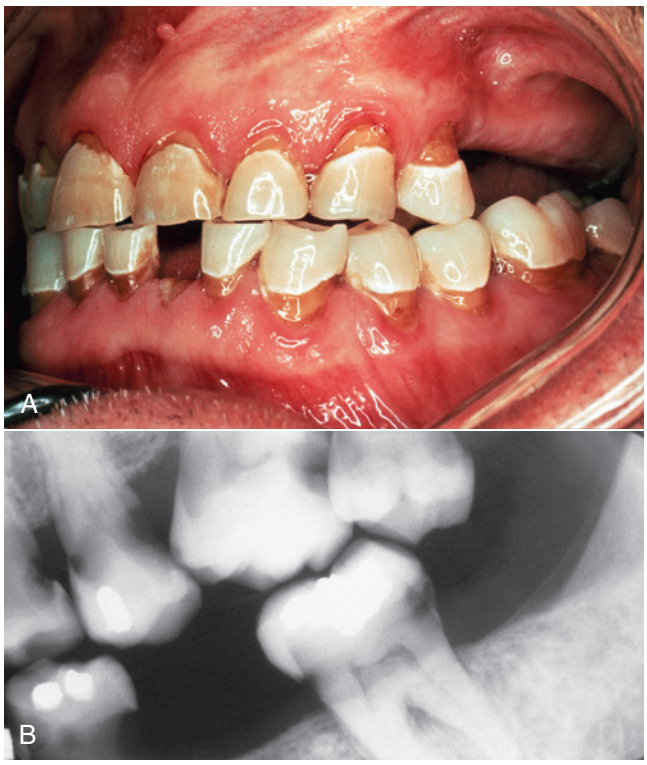
One of the most severe and complicating sequelae of radiotherapy for patients with head and neck cancer is osteoradionecrosis (Fig. 19.3). This involves the devitalization of bone by cancericidal doses of radiation. The bone within the radiation beam becomes virtually nonvital from endarteritis, which results in elimination of the fine vasculature within bone. The turnover rate of any remaining viable bone is slowed to the point of being ineffective in self-repair. The continual process of remodeling normally found in bone does not occur, and sharp areas on the alveolar ridge will not smooth themselves, even over considerable time (Fig. 19.4). The bone of the mandible is denser and has a poorer blood supply than that of the maxilla. Thus the mandible is the part of the jaw most commonly affected by nonhealing ulcerations and osteoradionecrosis.

Other Effects of Radiation

Patients undergoing radiotherapy may have an alteration in the normal oral flora with overgrowth of anaerobic species and fungi. Most researchers feel that oral flora colonizing the mucous membranes play an important role in the severity of mucositis and subsequent healing process.[13,14] *Candida albicans* commonly thrives in the oral cavities of patients who have been irradiated. It is not known whether the alteration in the flora is caused by the radiation itself or the resultant xerostomia. Patients frequently require the application of topical antifungal agents such as nystatin to help control the number of *Candida* organisms present. Another oral rinse frequently prescribed is 0.12% chlorhexidine (e.g., Peridex, Periogard). This agent has been shown to have potent in vitro antibacterial and antifungal effects. When used throughout the course of radiation treatment, it has been shown in at least one study to greatly reduce the prevalence and symptoms associated with radiation-induced mucositis.[15] Findings from other studies regarding the use of chlorhexidine have been equivocal.[13,16]

Evaluation of the Dentition Before Radiotherapy

The most feared side effect of radiotherapy is osteoradionecrosis. Most patients who have this complication have residual teeth throughout the course of radiotherapy. Thus the clinician may wonder what to do with such teeth before irradiation. Should they be extracted? This question has no definitive answer; however, several factors must be considered.[17–20]



• **Fig. 19.2** (A) Typical clinical appearance of radiation caries. (B) Typical radiographic appearance of radiation caries. Note the erosion around the cervical portion of the teeth.

Condition of the Residual Dentition

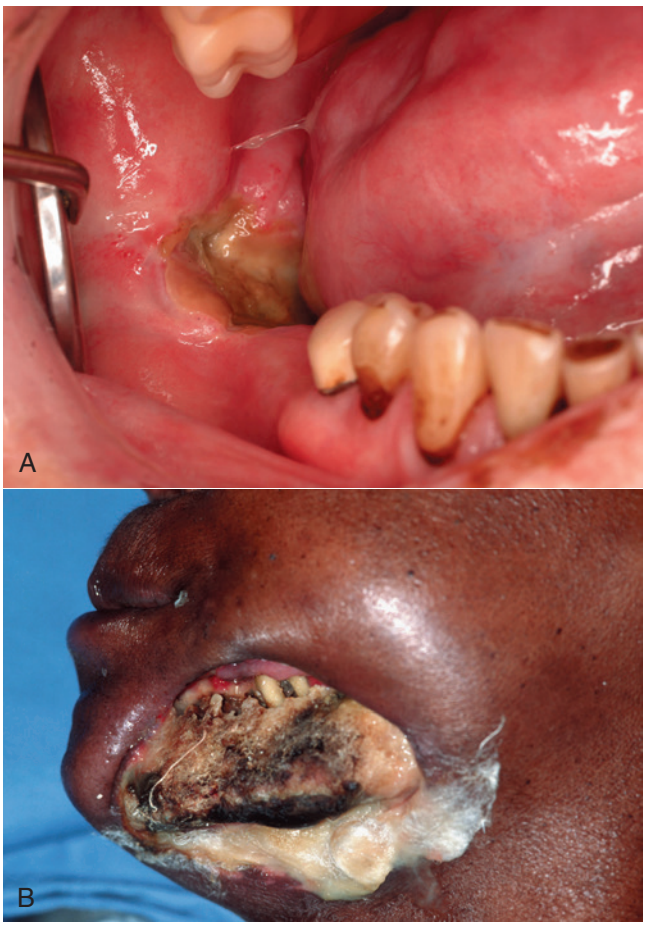
All teeth with a questionable or poor prognosis should be extracted before radiotherapy. The more advanced the periodontal condition, the more likely the patient is to have caries and continued periodontitis. Although this may not be in keeping with usual dental principles, the recommendation is "If in doubt, extract." Extraction in these cases may spare the patient months or years of suffering from osteoradionecrosis.

Patient's Dental Awareness

The present state of the dentition and periodontium is a good clue to the past care they have received. In patients with excellent oral hygiene and oral health, as many of the teeth as possible should be retained. However, if patients have neglected their oral health for years, chances are that they will continue to do so, especially in the face of severe xerostomia and oral pain, which will make oral hygiene even more difficult. Patient preparation prior to radiotherapy is similar to patient preparation prior to orthodontic procedures. If an individual cannot or will not care for his or her mouth before the application of the braces, it will be impossible for him or her to do so when faced with future obstacles.

Immediacy of Radiotherapy

If the radiotherapist feels that therapy must be instituted urgently, sufficient time may not be available to perform the necessary extractions and allow for initial healing of the extraction sites. In this instance, the dentist may elect to maintain the dentition; but he or she must work closely with the patient throughout the course of radiotherapy and thereafter in an attempt to maintain the patient's oral health as optimally as possible.



• **Fig. 19.3** Two cases of osteoradionecrosis of the mandible. (A) Bone exposure occurred 3 weeks after tooth extraction. (B) Severe osteoradionecrosis of the mandible with dehiscence of the facial soft tissues, exposing the necrotic bone externally.

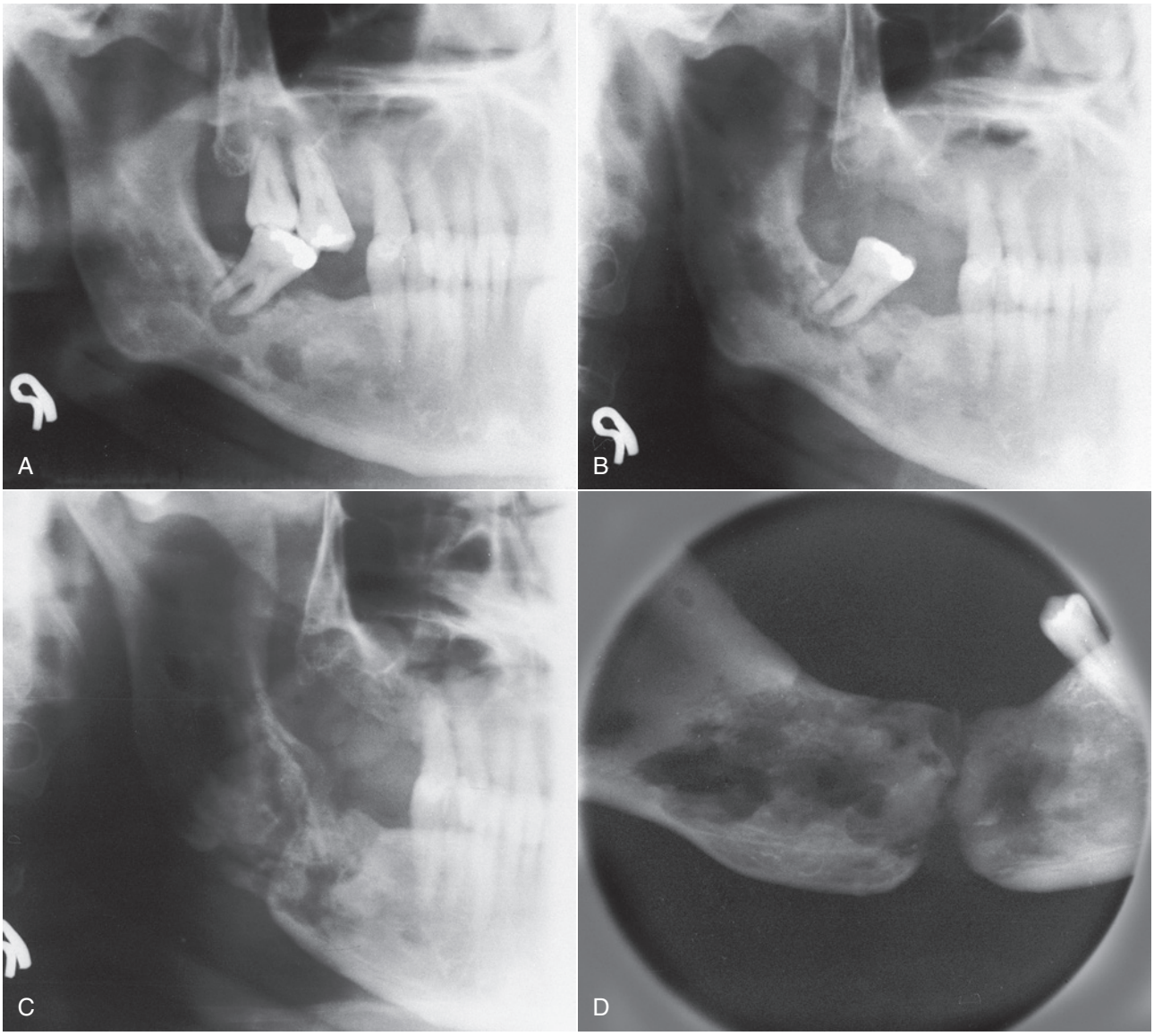
Radiation Location

The more the salivary glands and bone are involved in the field of radiation, the more severe are the resultant xerostomia and vascular compromise of the jaws. Thus the dentist should discuss with the radiotherapist the locations of irradiation and should estimate the severity of the probable xerostomia and bone changes. Xerostomia of itself may not result in severe problems if the dentition can be maintained because bone is still healthy. The combination of xerostomia and irradiated bone usually causes the problem. In individuals who will have radiation to the major salivary glands and a portion of the mandible, preirradiation extractions should be considered. Often the radiotherapist agrees to delay the institution of irradiation for 1 to 2 weeks if the dentist feels that such time is necessary to allow the extraction sites to begin to heal.

Radiation Dose

The higher the radiation dose, the more severe the damage to normal tissue. The radiotherapist should discuss with the dentist the amount of radiation planned for the individual. Frequently the dose is not maximal, and tissue damage may be minimized. This allows the dentist to be more conservative in preirradiation extraction considerations.

Squamous cell carcinomas of the oral cavity make up approximately 90% of malignant tumors for which radiation therapy is



• **Fig. 19.4** Progressive course of osteoradionecrosis. (A) Radiograph showing radiolucencies in the right mandible and around the apex of a molar tooth. (B) Six months later, during which time antibiotics and local irrigations were used, a radiolucent process is spreading into ramus. The molar was removed at this time. (C) Five months after tooth removal, the extraction site had not healed and the destructive process spread, resulting in pathologic fracture of the mandible. (D) Radiograph after removal of devitalized bone, showing the extent of the process. (Courtesy Dr. Richard Scott, Ann Arbor, MI.)

used. Unfortunately this cancer requires a large dose of radiation (>6000 rad [60 Gy]) to effect a result. Other malignancies such as lymphoma require much less radiation for a response, and the oral cavity is therefore less affected. When the total dose falls below 5000 rad (50 Gy), long-term side effects such as xerostomia and osteoradionecrosis are dramatically decreased.

Preparation of Dentition for Radiotherapy and Maintenance After Irradiation

Every tooth to be maintained must be carefully inspected for pathologic conditions and restored to the best state of health obtainable. A thorough prophylaxis and topical fluoride application should be performed before radiotherapy. Oral hygiene measures and instructions should be demonstrated and reinforced. Any sharp cusps should be rounded to prevent mechanical irritation. Impressions for dental casts should be obtained for fabrication of custom fluoride trays to be used during and after treatment. Because tobacco use and alcohol consumption irritate the mucosa, the patient should be encouraged to stop these before commencing radiation therapy.

During radiation treatment, the patient should rinse the mouth at least 10 times a day with saline rinses. The patient should be placed on chlorhexidine mouth rinses twice a day to help minimize bacterial and fungal levels within the mouth. The dentist should see the patient each week during radiotherapy for observation and oral hygiene evaluations. Nystatin or clotrimazole topical applications will bring any overgrowth of *C. albicans* under control relatively rapidly. The patient's ability to open the mouth should be carefully monitored throughout the course of radiation treatment. Radiation causes progressive fibrosis within the muscles of mastication, which

makes it difficult for the patient to open the mouth adequately. Patients should be instructed in physiotherapy exercises to maintain the preirradiation interincisal dimension. All patients must be weighed weekly to determine whether they are maintaining an adequate nutritional status. The combination of mucositis and xerostomia makes oral intake extremely uncomfortable. However, malnutrition causes further difficulties by delaying the healing of oral tissues and giving the patient an overall feeling of illness. In severe cases it may be necessary to feed the patient via nasogastric tube to maintain a reasonable nutritional status.

Following radiation treatment, the dentist should see the patient every 3 to 4 months. A prophylaxis is performed during these postirradiation visits, and topical fluoride is applied. The patient should be fitted with custom trays to deliver topical fluoride applications. The patient should be instructed in the use of the trays and in daily self-administration of topical fluoride applications. The use of a 1% fluoride rinse for 5 minutes each day has been found to decrease the incidence of radiation caries.[21] Over-the-counter fluoride rinses currently available can be used without a customized delivery splint; these have been shown to be successful and seem to have better patient acceptance.

All patients should also be monitored for the possible onset of trismus. It is easier to prevent trismus than to treat it. The patient should perform mouth-opening exercises with any decrease in the maximum interincisal dimension. For more established cases, the patient can use jaw-exercising applications (e.g., Therabite).

Method of Performing Preirradiation Extractions

If the decision has been made to extract some or all teeth before radiotherapy, the question becomes "How should the teeth be extracted?" In general the principles of atraumatic exodontia apply. However, the concepts of bone preservation are disregarded, and an attempt is made to remove a substantial portion of the alveolar process along with teeth and achieve a primary soft tissue closure. With the onset of radiotherapy, the normal remodeling process is inhibited; if any sharp areas of bone exist, ulceration occurs with bone exposure. Thus teeth are usually removed in a surgical manner, with flap reflection and generous bone removal.

Atraumatic handling of the mucoperiosteal flaps is necessary to ensure rapid soft tissue healing. Burrs or files should be used to smooth the bony edges under copious irrigation because the remodeling capability of the tissues is greatly decreased after radiotherapy. Prophylactic antibiotics are indicated under these circumstances. It should be noted that the dentist is in a race against time. If the wound fails to heal, the radiotherapy will be delayed. If the radiation is delivered before the wound heals, healing will take months or even years.

Interval Between Preirradiation Extractions and the Beginning of Radiotherapy

There is no definitive answer to the question of how much time should be allowed after extractions before beginning radiotherapy. Obviously the sooner radiotherapy is begun, the more beneficial it may be for treating the malignancy. Thus, when soft tissues have healed sufficiently, radiotherapy may begin. Traditionally, 7 to 14 days between tooth extraction and radiotherapy have been suggested.[17,22,23] Most authors base their recommendations on the clinical impression that reepithelialization has occurred in this period. However, if possible, radiotherapy should be delayed for 3 weeks after extraction. This helps ensure that sufficient soft tissue healing has occurred. The radiotherapy should be delayed further, if possible, if a local wound dehiscence has occurred. In this instance, daily local wound care with irrigations and postoperatively administered antibiotics are mandatory until the soft tissues have healed.

Removal of Impacted Third Molar Before Radiotherapy

If the patient has a partially erupted mandibular third molar, removal may be prudent to prevent pericoronal infection. In general, however, allowing a tooth that is totally impacted within the bone of the mandible to remain in place is more expeditious than removing it and waiting for it to heal.

Methods of Managing Carious Teeth After Radiotherapy

Teeth that develop postradiotherapy caries must be cared for immediately in an attempt to prevent the further spread of infection. Composites and amalgam are the materials of choice to repair the defects caused by caries. Full crowns are probably not warranted because recurrent caries is more difficult to detect under such restorations. Oral hygiene measures, including fluoride application, must be reinforced in any patient who has postirradiation caries.

If a tooth has a necrotic pulp, endodontic intervention with systemic antibiotics can be carefully performed, and the tooth can be ground out of occlusion and maintained. Frequently root canal treatment is difficult because of a progressive sclerosis of the pulp chamber that occurs in irradiated teeth. In such instances, the tooth can simply be amputated above the gingiva and left in place.

Tooth Extraction After Radiotherapy

Can teeth be extracted after radiotherapy, and if so, how? These are probably the most difficult questions to answer. Each dentist has a view on this subject, and the literature includes conflicting reports. Postirradiation extractions are also the most undesirable extractions the dentist will ever perform because the outcome is always uncertain.

The answer to the question of whether extractions can be done after radiotherapy is certainly yes. The more important question is how? If the tooth is to be extracted, the dentist can perform a routine extraction without primary soft tissue closure or a surgical extraction with alveoloplasty and primary closure. Either of these techniques yields similar results, with a certain concomitant incidence of osteoradionecrosis. The use of systemic antibiotics is recommended.

An adjunctive technique that has been shown to be effective is the use of hyperbaric oxygen (HBO) before and after tooth extraction. HBO therapy is the administration of oxygen under pressure. HBO has been shown to increase the local tissue oxygenation and vascular ingrowth into the hypoxic tissues.[24,25] The usual protocol for such treatments is to have between 20 and 30 HBO dives before extraction and 10 more dives immediately after extractions. HBO chambers are not available in all communities; when present, they are usually located in select hospitals. A physician who is experienced in hyperbaric medicine manages the patients referred to these facilities. The patient usually undergoes one HBO session each day. Therefore it takes 4 to 6 weeks to get the 20

to 30 treatments before surgery and 2 weeks of treatment after surgery. In a prospective clinical trial comparing this regimen with the use of prophylactically administered antibiotics before dental extraction without hyperbaric oxygenation, Marx et al. found a significant decrease in the incidence of osteoradionecrosis (5.4% compared with 30%).[26] Others have disputed the need for HBO before and after postirradiation extractions and perform them without it.[27,28]

Because considerable controversy exists regarding the management of surgical extraction in a patient who has undergone irradiation, few hyperbaric oxygenation chambers are available for use. The incidence of severe complications is relatively high; therefore it is recommended that an oral-maxillofacial surgeon manage the patient who has received irradiation and requires extractions.

Denture Wear in Postirradiation Edentulous Patients

Patients who were edentulous before radiotherapy manage nicely with well-constructed dentures. However, patients rendered edentulous just before or after radiotherapy exhibit more problems with mucosal ulcerations and subsequent osteoradionecrosis. The normal remodeling process of alveolar bone cannot smooth out even the most minor irregularities left by extraction. With denture wear, these minor irregularities cause ulceration of the mucosa.

Soft denture liners might seem an ideal solution for patients who have received irradiation. However, silicone soft liners have been shown not to be particularly useful for several reasons. At present, patients are probably best served with ordinary dentures.

Denture fabrication for patients who were previously edentulous can proceed once the acute effects of irradiation have subsided. In the case of patients who underwent extractions just before or after radiotherapy, it is prudent to see them frequently after delivery of their dentures so that adjustments can be made before sore spots develop and cause mucosal breakdown and bone exposure.

When dentures are constructed, the dentist must be certain that the denture base and occlusal table are designed such that forces are distributed evenly throughout the alveolar ridge and that lateral forces on the denture are eliminated.

The ideal treatment of patients whose jaws have been irradiated is to use an appliance supported by dental implants to avoid any contact between the appliance and the mucosa, the ulceration of which can lead to osteoradionecrosis.

Use of Dental Implants in Irradiated Patients

The dental rehabilitation of the edentulous patient who has received radiation therapy is among the greatest challenges facing the reconstructive dentist. Many patients who have had ablative surgery for malignancy do not have the normal anatomy that makes denture wear possible. No vestibules may remain to accommodate a denture flange.

Often, portions of the tongue may have been removed. The patient may have hard and soft tissue defects and deficits. When reconstructed, bone may have poor form for support of a tissue-borne prosthesis. Frequently such patients have thick, nonpliable soft tissue flaps that have been grafted from distant areas and are not adherent to underlying bone. All of these combine to make conventional denture fabrication challenging. In such instances, the use of implant-borne prostheses is preferred from a functional standpoint.

For years, however, a history of irradiation has been a relative contraindication to the placement of dental implants.[29,30] The effects of radiation on bone and soft tissue present a formidable challenge to the use of implanted metallic devices. A 19% reduction of bone-to-implant contact of cylindrical titanium plasma–sprayed implants has been demonstrated in rabbit tibiae after 4050 rad of irradiation during the initial healing time.[31] Not surprisingly, numerous clinical studies evaluating the success rates of intraoral endosseous implants placed in previously irradiated bone beds, with or without adjunct HBO treatment, have demonstrated success rates slightly to substantially less than those in nonirradiated patients.[32–43]

However, the benefits that can accrue from providing this group of patients with a functional and esthetic dental reconstruction are significant. Such patients have been through a great deal of hardship. They have lost portions of their anatomy, are frequently deformed, and suffer from the uncomfortable effects of radiation therapy such as xerostomia, dysphagia, and dysgeusia. They welcome the prospect of being able to chew solid food with a functional dentition. Implant-borne prostheses can help achieve this goal in these difficult situations. However, the unpredictable reaction of soft and hard tissues in an irradiated patient and the surgical trauma of treatment have combined to promote caution in such cases.

Many variables must be evaluated when considering placement of dental implants into irradiated bone, including the type, dose, sites of radiation, elapsed time since the treatment, protection provided to bone during treatment, and the patient's own physiologic responses (which are themselves affected by age, sex, genetics, smoking, and systemic considerations). Other critical factors are whether the implants will be placed into irradiated host mandibular bone, irradiated bone grafts, or bone that has been transplanted after the radiation therapy. In the last instance, if the mandible was reconstructed using a microvascular graft in which the blood supply to bone is brought in from a distant source and has not been altered by the previous radiation therapy, no adverse tissue reaction should be expected after the placement of dental implants.

When dental implants are to be placed into irradiated host or grafted bone, the dentist must proceed with caution. Consultation with the radiotherapist is recommended to determine the amount of radiation that has been delivered to the area of the jaws where the proposed implants will be placed. Studies have provided insight into the use of implants in irradiated bone. In general, they have shown the following:

1. The more the radiation delivered, the higher is the failure rate for endosseous implants.[28,33,42]
2. The longer the time between radiation treatment and implantation, the higher the failure rate.[39]
3. When implants in irradiated patients fail, they usually fail early, before prosthetic reconstruction, indicating failure of osseointegration.[39]
4. The combination of radiation and chemotherapy has a particularly negative effect on the outcome for osseointegration.[39,42]
5. Implant survival in irradiated patients tends to be higher in the maxilla than in the mandible.[38–44]
6. Shorter implants have the worst prognosis.[39]
7. HBO treatment may[38] or may not[45] reduce implant failure rates.

It has been demonstrated that the success of implant retention is directly and positively correlated with the amount of radiation to which bone has been exposed.[33,39] If the amount of radiation

is less than approximately 4500 rad (45 Gy), implants may be placed with care. When the amount of radiation exceeds this amount, preoperative (20 to 30 Gy) and postoperative (10 Gy) HBO treatments should be considered. HBO treatments have been shown to be beneficial in some studies[39,46]; however, a randomized controlled study found that no benefit of HBO could be established.[45] Some use HBO under the principle that it will do no harm and perhaps will help.

The time required for osseointegration will be prolonged in irradiated patients because of the lower metabolic activity in bone, so the implants should not be loaded for at least 6 months after placement. The dentist must pay particular attention to oral hygiene in such patients because their tissues will not be as able to resist bacterial invasion as tissues in patients who have not been irradiated. The prosthetic design, therefore, should be made as cleanable as possible, with frequent use of overdentures. However, prostheses that do not allow contact of denture flanges with oral soft tissues help prevent ulceration. No matter what type of prosthesis is fabricated, these patients require more careful follow-up and hygiene measures.

In spite of the fear that implants placed into irradiated bone will lead to osteoradionecrosis, the condition is rarely reported in the literature (Fig. 19.5).[47,48] However, the duration of experience has not been sufficient to predict the long-term outcome of implant prosthetics in the patient who has undergone radiation.

Management of Patients Who Have Osteoradionecrosis

Most mucosal breakdown and subsequent osteoradionecrosis occur in the mandible (see Fig. 19.4). These conditions occur most often in mandibles that have received radiation in excess of 6500 rad (65 Gy) and do not usually occur in mandibles that have received radiation doses less than 4800 rad (48 Gy).[49–51] Severe pain may be caused by osteoradionecrosis. The patient should discontinue wearing any prosthesis and try to maintain a good state of oral health. Irrigations should be instituted to remove necrotic debris. Systemic antibiotics are necessary only occasionally because osteoradionecrosis is not an infection of bone but rather a nonhealing hypoxic wound.[24] Because of the decreased vascularity of tissues, systemic antibiotics do not readily gain access to the area to perform the function for which they are intended. However, in acute secondary infections, antibiotics may be useful to help prevent the spread of the infection. Any loose sequestra are removed, but no attempt is made initially to close the soft tissue over exposed bone. Most wounds smaller than 1 cm eventually heal, although this may take weeks to months.

For nonhealing wounds or extensive areas of osteoradionecrosis, surgical intervention may be indicated. In this instance, resection of exposed bone and a margin of unexposed bone and primary soft tissue closure can be attempted (Fig. 19.6). This treatment is successful in many cases. Greatly improved results have recently been obtained with the use of HBO therapy in conjunction with surgical intervention.[24]

Reconstructive efforts with bone grafts used for continuity defects can also be undertaken successfully in many patients who have undergone irradiation. Free microvascular grafting techniques are becoming more popular for restoring continuity defects in patients who have received radiotherapy. These bone grafts have their own blood supply from a reconnection of blood vessels and are therefore less dependent on the local tissues for incorporation and healing.

Dental Management of Patients Receiving Systemic Chemotherapy for Malignant Disease

Destruction of malignant cells by tumoricidal chemotherapeutic drugs has proved an effective treatment for a variety of malignancies. Like radiotherapy, the antitumor effect of cancer chemotherapeutic agents is based on their ability to destroy or retard the division of rapidly proliferating cells such as tumor cells nonspecifically. Unfortunately normal host cells that have a high mitotic index are also adversely affected. Normal cells most affected are the epithelium of the gastrointestinal tract (including the oral cavity) and the cells of bone marrow. The most common oral side effects are altered taste sensation, xerostomia, and mucositis.[52]

Effects on Oral Mucosa

Many chemotherapeutic agents reduce the normal turnover rate of the oral epithelium, which results in atrophic thinning of the oral mucosa, manifesting clinically as painful, erythematous, and ulcerative mucosal surfaces in the mouth. The effects are most noted on the unattached mucosa and are rarely seen on gingival surfaces. These changes are seen within 1 week of the onset of the administration of the antitumor agents. The effects are usually self-limiting, and spontaneous healing occurs in 2 to 3 weeks after cessation of the agent.

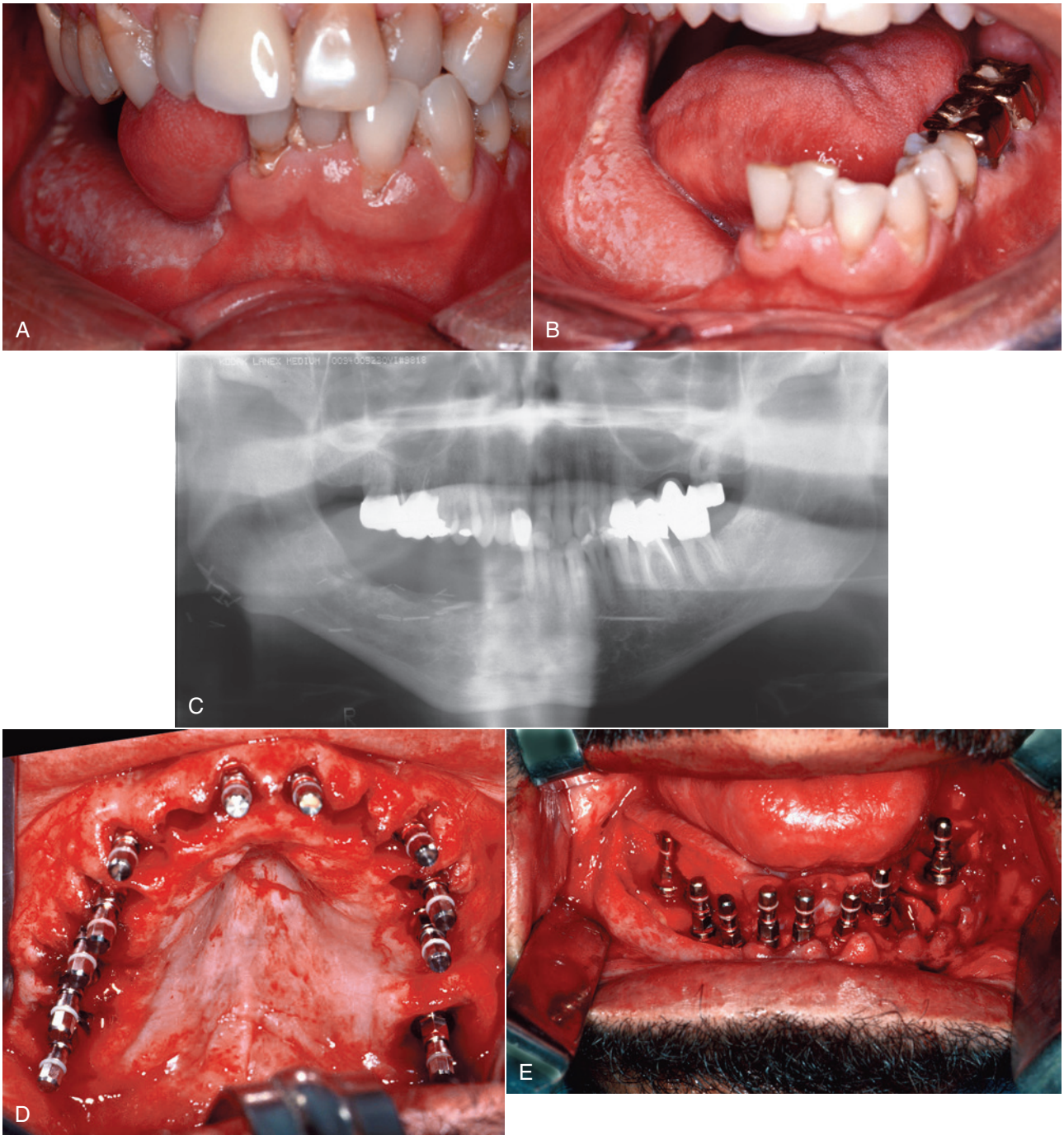
Effects on the Hematopoietic System

Myelosuppression—which manifests as leukopenia, neutropenia, thrombocytopenia, and anemia—is a common sequela of several forms of cancer chemotherapy. Within 2 weeks of the beginning of chemotherapy, the white blood cell count falls to an extremely low level. The effect of myelosuppression in the oral cavity is marginal gingivitis. Mild infections may develop, and bleeding from the gingiva is common. If the neutropenia is severe and prolonged, severe infections may develop. The microorganisms involved in these infections may be overgrowths of the usual oral flora, especially fungi; however, other microorganisms may be causative. Thrombocytopenia can be significant, and spontaneous bleeding may occur. This is especially common in the oral cavity after oral hygiene measures. Recovery from myelosuppression is usually complete 3 weeks after cessation of chemotherapy.

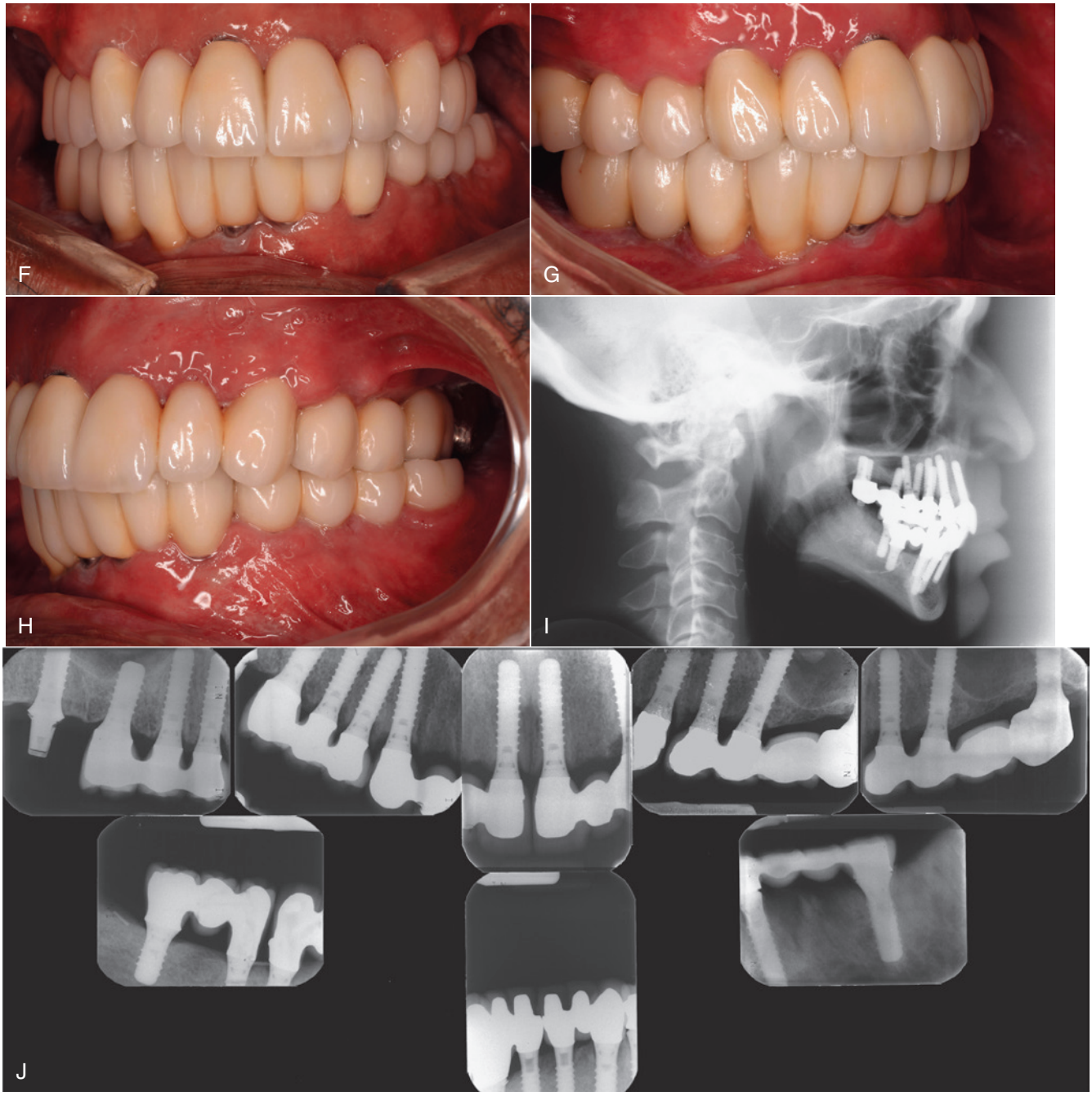
It is important to determine the type of neoplasm for which the patient is being treated. The type of neoplasm dictates the type of chemotherapeutic agents to be used. Many hematologic neoplasms (e.g., leukemia) are treated with chemotherapeutic agents that result in profound alterations in the function and number of bone marrow elements. Comparatively, chemotherapeutic management of some nonmarrow solid tumors may not be associated with as severe a marrow aplasia as is found in patients with hematologic neoplasms.

Effects on Oral Microbiology

Because of their immunosuppressive side effects, chemotherapeutic agents cause profound changes in the oral flora. For example, overgrowth of indigenous microbes, superinfection with gram-negative bacilli, and opportunistic infections are common sequelae and lead to discomfort and morbidity. Systemic infections are responsible for about 70% of the deaths in patients receiving



• **Fig. 19.5** Dental implant reconstruction in a patient who had full-course radiation treatment for squamous cell carcinoma. (A–C) His existing dentition developed rampant dental caries within 1 year of radiation therapy. (D–E) After hyperbaric oxygen treatment, his teeth were extracted and implanted. After a waiting period of 6 months, full-fixed prosthetic restorations (crowns and bridges) were fabricated.



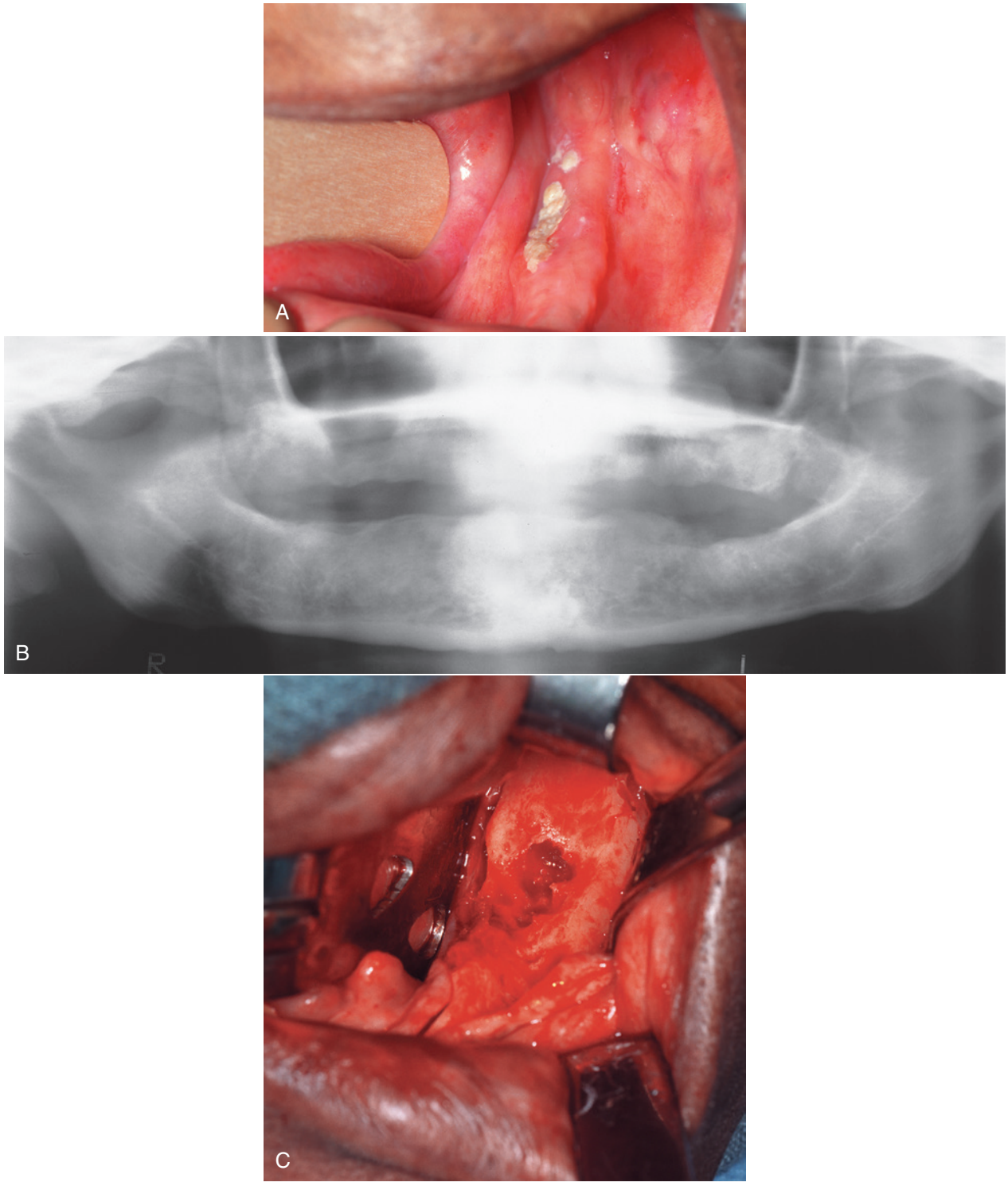
• **Fig. 19.5, cont'd** His prosthesis (F–H) and lateral cephalometric radiograph (I) 1 year after placement of his prostheses. (J) Bone levels have been maintained around all of the implants.

myelosuppressive cancer chemotherapy.[53,54] Oral microorganisms have been shown to be a common source of bacteremia in these patients.[51] Thus most patients who are receiving chemotherapy are treated concomitantly with systemic antimicrobial agents. However, in spite of these regimens, patients frequently have overgrowth of some organisms, most commonly the *Candida* species.[55–57]

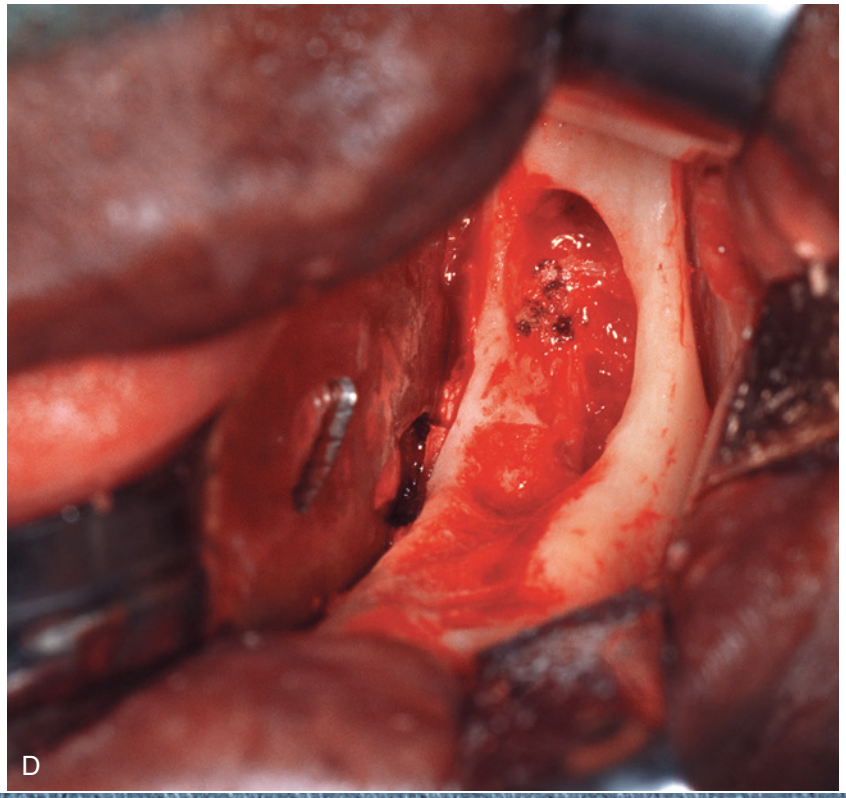
General Dental Management

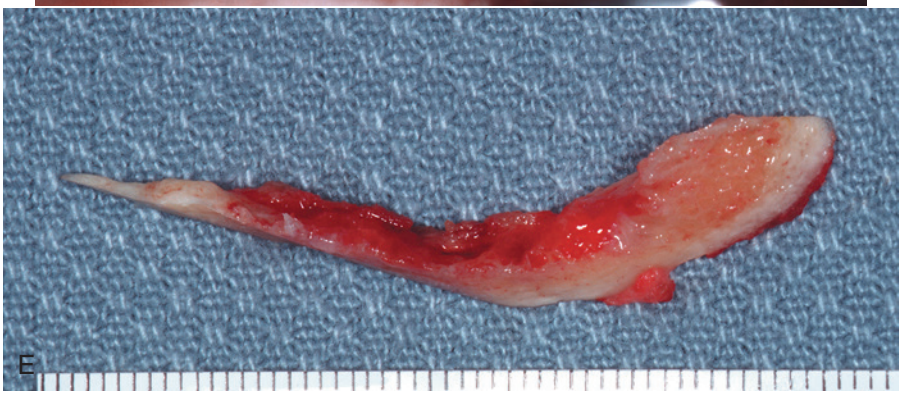
In general, the principles of dental management for the patient who has had or will have radiotherapy apply equally well to the patient who has had or will have chemotherapy.[58,59] However, because of the intermittent nature of the chemotherapy delivered in many instances, the minimal effects on the vasculature, and the almost normal state of the individual between chemotherapeutic administrations, dental management can be much easier. The effects of chemotherapy are almost always temporary; with the passage of time, systemic health improves to optimal levels, which allows almost routine dental management.

The primary concerns for the dentist should be the severity and duration of bone marrow suppression. The dentist must be aware of the dates of chemotherapy and the hematologic status of the patient before beginning dental care. If the patient is being



• **Fig. 19.6** Osteoradionecrosis of the left mandible. This patient had a full course of tumoricidal radiotherapy for squamous cell carcinoma. The dentition was removed at the time of cancer resection. This patient was prepared for treatment of the osteoradionecrosis with preoperative and postoperative hyperbaric oxygen treatments. (A) Exposed devitalized bone along alveolar ridge of the left mandible. (B) Panoramic radiograph showing diffuse irregularity without good cortication of the alveolar crest. (C) Surgical exposure of the area shows devitalized bone margins and a central crater devoid of bone. Osteoradionecrosis of the left mandible is seen.





• **Fig. 19.6, cont'd** (D) The bone of the alveolar crest is removed, and the remainder is smoothed with a burr until bleeding bone is encountered. The central crater is similarly burred out. (E) Resected specimen of the alveolar crest. Osteoradionecrosis of the left mandible is evident.

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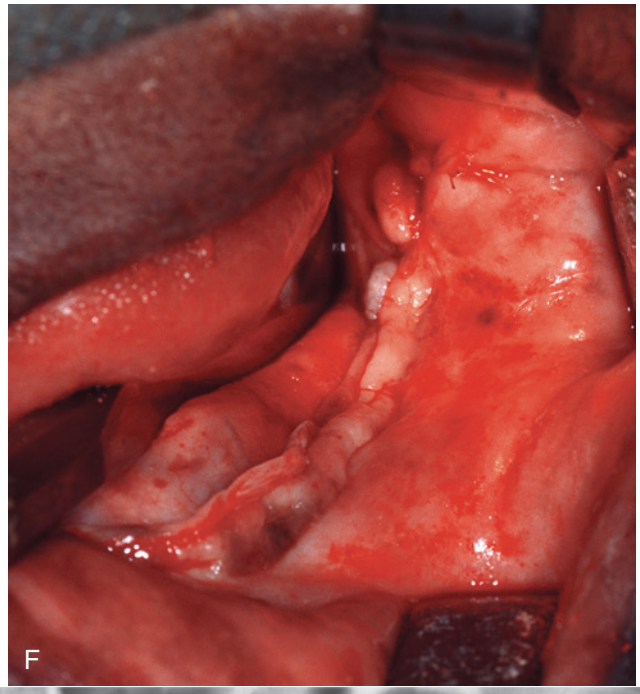
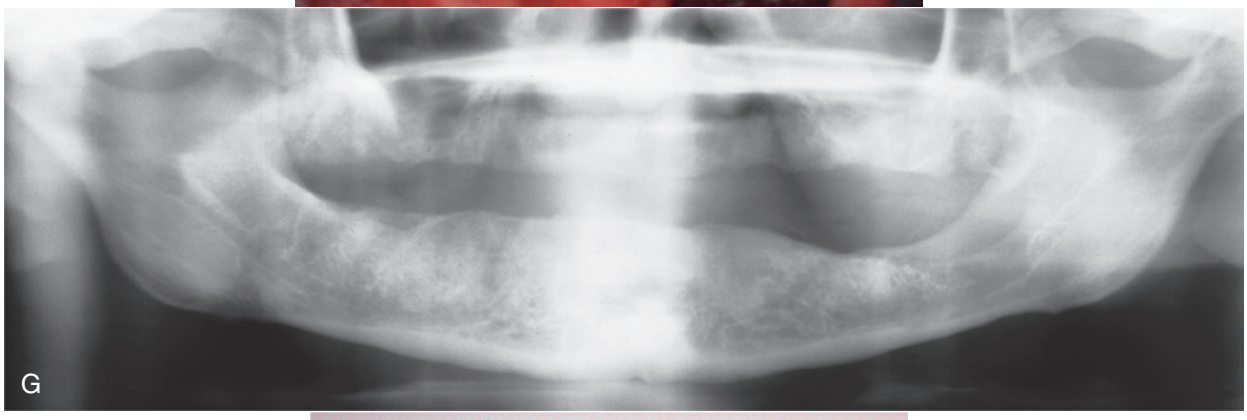
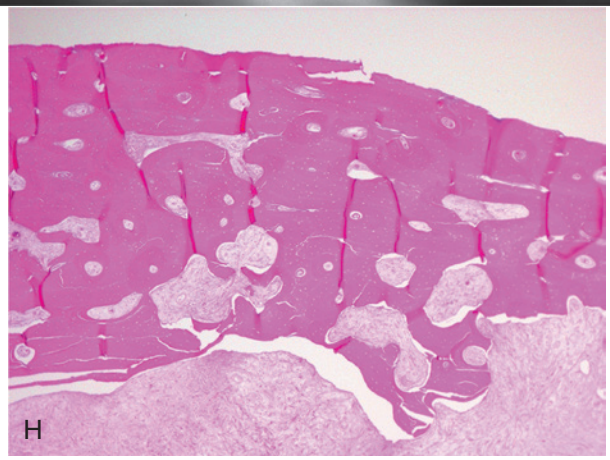






• **Fig. 19.6, cont'd** (F) Closure of the soft tissues. (G) Panoramic radiograph 8 months after surgery showing slight remodeling and healing of the bone. (H) Histology of the resected specimen shows osteoradionecrosis and fibrosis in the marrow area of the haversian systems.

treated for a hematologic neoplasm (e.g., leukemia), both the disease and the chemotherapy lead to decreases in the functional blood elements. Therefore these patients may be at great risk for infection and hemorrhage at any time in the course of their disease. Consultation with the patient's physician in these instances is mandatory. In most cases of nonhematopoietic neoplasm, the patient is at risk for infection and hemorrhage only during the course of the chemotherapy, after which recovery of the blood elements occurs.

The decision of when to extract teeth before treatment is based on the condition of the residual dentition, the patient's past dental hygiene practices, the immediacy of the need for chemotherapy, and the overall prognosis of the malignant disease.

Prechemotherapy dental measures that should routinely be performed are a thorough prophylaxis, fluoride treatment, and any necessary scaling. Unrestorable teeth should be removed before chemotherapy begins.

Patients who have begun chemotherapy must maintain scrupulous oral hygiene. This is difficult in the face of mucositis and ulceration, which frequently occur. No dental procedures should be performed on any patient receiving chemotherapy when the white blood cell and platelet status is unknown. In general patients who have a white blood cell count greater than or equal to 2000/mm^3, with at least 20% polymorphonuclear leukocytes and a platelet count greater than or equal to 50,000/mm^3, can be treated in routine fashion. Antibiotics should be administered prophylactically if the patient has had chemotherapy within 3 weeks of dental treatment. If the white blood cell count and platelet levels fall below those specified, minimal oral care should be practiced because infection, severe bleeding, or both can occur. The patient may even need to avoid flossing and to use an extremely soft toothbrush during these periods. Any removable dental appliance should be left out at these times to prevent ulceration of the fragile mucosa.

Treatment of Oral Candidiasis

Initial treatment of candidiasis is with topical application of an antifungal medication.[55] The advantage of using topical medication is that systemic side effects are minimized. Similarly, in patients with persistent infection, an advantage can be gained by continuing topical agents in addition to systemic medications. The use of this combination may allow a reduced dose and duration of systemic administration of the antifungal medication and also may reduce potential side effects.

Topical agents are available as oral rinses, oral tablets, and creams. In general, oral rinses provide a short contact time for the drug and are therefore less effective. The tablets are among the most accepted forms of topically treating candidiasis because they can be dissolved slowly in the mouth and provide increased exposure time of the drug with the oral flora. The cream forms of topical antifungals are helpful to treat candidiasis of the oral commissures or for application to the oral surfaces of prosthetic devices to prolong medication exposure.

The two most commonly administered topical medications for oropharyngeal *Candida* infections are clotrimazole and nystatin, which are available in several forms and should be applied 4 times daily. Therapy should continue 2 weeks after cessation of clinical signs and symptoms. Clotrimazole troches are available and are dissolved in the mouth 4 or 5 times a day.

For more stubborn cases, ketoconazole or fluconazole (i.e., systemic antifungal medications) can be prescribed. However, the dentist must be careful about systemic administration of these antifungal medications because of their toxic side effects. These side effects vary widely with the type of medication and can be serious.

Another widely prescribed medication for oral candidiasis is chlorhexidine mouth rinse. Chlorhexidine has been shown to have potent antibacterial and antifungal properties in vitro. The in vivo effects of chlorhexidine are less well documented, especially for use against *Candida* species in immunosuppressed individuals.[13,60] However, chlorhexidine is used in most such patients on the basis that it probably does no harm and may prove beneficial.

Dental Management of Patients With Medication-Related Osteonecrosis of the Jaws

Recently a new oral complication of cancer and osteoporosis treatment that looks similar to osteoradionecrosis, with exposure of devitalized areas of the bone of the jaws, has been identified. However, the complication is seen in patients who have not had any radiation treatment, and the methods used to treat osteoradionecrosis do not seem to be effective for the treatment of these lesions. This oral lesion is called *medication-related* or, more appropriately, *medication-induced, osteonecrosis of the jaws* (MRONJ),[61] because what patients with these lesions have in common is that they are taking an antiresorptive medication, usually as an adjunct to chemotherapy for malignant disease.[62]

MRONJ is a condition of chronically exposed necrotic bone; it is usually painful and often primarily or secondarily infected. Bone exposure might occur spontaneously or more commonly following an invasive dental procedure.[63] Patients complain of halitosis and have difficulty eating and speaking.

Clinically, the lesions appear as oral mucosal ulcerations that expose the underlying bone and frequently are extremely painful. The lesions are persistent and do not respond to conventional treatment modalities such as debridement, antibiotic therapy, or HBO therapy.

Three main classes of medications that can cause MRONJ, as described below.

Bisphosphonates

Bisphosphonates are a class of agents used to treat osteoporosis and malignant bone metastases. Bisphosphonates inhibit bone resorption and thus bone renewal by suppressing the recruitment and activity of osteoclasts, thereby shortening their life span. Millions of postmenopausal women are taking bisphosphonates to stabilize bone loss caused by osteoporosis, thus reducing their risk of pathologic fractures.[64] Besides osteoporosis, bisphosphonates are used to manage Paget disease of bone and hypercalcemia of malignancy. Bisphosphonates are given to patients with cancer to help control bone loss resulting from metastatic skeletal lesions.[65,66] The mechanism of action of bisphosphonates is that they bind to bone mineral, where they are concentrated and accumulate over time. Bisphosphonates are potent inhibitors of osteoclastic activity, which is why they are usually prescribed.[63] Depending on the duration of the treatment and the specific bisphosphonate prescribed, the drug may remain in the body for years.[66] Physiologic bone deposition and remodeling are severely compromised in patients receiving bisphosphonate therapy.[67,68] Bisphosphonates also have antiangiogenic properties and may be directly tumoricidal, which makes them an important agent in cancer therapy.[69,70]

Many bisphosphonate medications are available, some given intravenously (pamidronate, zoledronic acid, clodronate) and some orally (alendronate, etidronate, risedronate, tiludronate, ibandronate; Table 19.1). The choice varies with the type of medical condition being treated and the potency of the drug required. For example, orally administered bisphosphonates often are used in patients with osteoporosis, whereas the injectable bisphosphonates are used in patients with cancer who have primary lesions of bone or skeletal metastasis.

RANK Ligand Inhibitors

RANK ligand inhibitors (denosumab; Prolia) are antiresorptive agents that exist as a fully humanized antibody against RANK ligand (RANK-L) and inhibits osteoclast function and associated bone resorption. In contrast to bisphosphonates, RANK-L inhibitors do not bind to bone and their effects on bone remodeling are mostly diminished within 6 months of treatment cessation.

Antiangiogenic Medications

Angiogenesis inhibitors interfere with the formation of new blood vessels by binding to various signaling molecules disrupting the angiogenesis signaling cascade. These novel medications have demonstrated efficacy in the treatment of various tumors.

Mechanism of Action of Antiresorptive Medications

Of all three medications that can induce MRONJ, bisphosphonates are clearly the most commonly prescribed; therefore most cases will be caused by this medication. Bisphosphonates, and other antiresorptives such as denosumab, inhibit osteoclast differentiation and function and increase apoptosis, all leading to decreased bone resorption and remodeling.[61] Bisphosphonates bind to bone and are incorporated in the osseous matrix. During bone remodeling, the drug is taken up by osteoclasts and internalized in the cell cytoplasm, where it inhibits osteoclastic function and induces apoptotic cell death.[71] Bisphosphonates also inhibit osteoblast-mediated osteoclastic resorption and have antiangiogenic properties.[65,72,73] As a result, bone turnover becomes profoundly suppressed, and over time bone shows little physiologic remodeling.[68,74] Bone becomes brittle and unable to repair physiologic microfractures that occur in the human skeleton with daily activity.[75,76] The need for repair and remodeling is greatly increased with infection in the maxilla or the mandible and when an extraction is performed. Therefore MRONJ results from a complex interplay of bone metabolism, local trauma, increased demand for bone repair, infection, and hypovascularity.

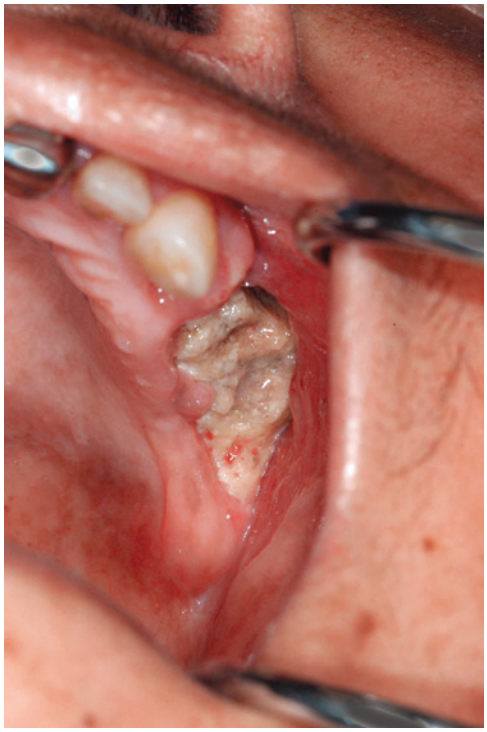
Patients receiving bisphosphonates intravenously clearly are more susceptible to MRONJ than are those receiving the drug orally. Thus it is not common to see MRONJ in patients taking bisphosphonates orally for prevention or treatment of osteoporosis; however, beginning in 2006, cases began to be reported in the literature and now number several hundred. Other metabolic factors that may play a role in the development of MRONJ include diabetes mellitus and the concomitant use of steroids, anticancer chemotherapeutic agents, and smoking.

Clinical Signs and Symptoms of MRONJ

Apparently, MRONJ affects the jaws exclusively.[77] The most common clinical presentation associated with MRONJ is an ulcer with exposed bone in a patient who has had a dental extraction (Fig. 19.7).[62,63,78–81] An ulcer caused by an ill-fitting prosthetic device has also been implicated in the initiation of this pathologic process. However, spontaneous bone exposures that cannot be associated with any injury or infection occur in many cases.[81] Similar to osteoradionecrosis, no radiographic manifestations can be seen in the early stages of oral MRONJ. Patients may be asymptomatic but may have severe pain after the necrotic bone is exposed to the oral environment and becomes infected secondarily. The osteonecrosis

TABLE 19.1 Antiresorptive Medications Available in the United States

Generic Name	Brand Name	Type of Medication	Manufacturer	Route of Administration
Alendronate	Fosamax	Bisphosphonate	Merck	Oral
Clodronate	Bonefos	Bisphosphonate	Schering AG	Intravenous
Etidronate	Didronel	Bisphosphonate	Procter and Gamble	Oral
Ibandronate	Boniva	Bisphosphonate	GlaxoSmith Kline	Oral
Pamidronate	Aredia	Bisphosphonate	Novartis Pharmaceuticals	Intravenous
Risedronate	Actonel	Bisphosphonate	Procter and Gamble	Oral
Tiludronate	Skelid	Bisphosphonate	Sanofi-Synthe Lab	Oral
Zoledronate	Zometa	Bisphosphonate	Novartis Pharmaceuticals	Intravenous
Denosumab	Xgeva Prolia	RANK ligand inibitor	Amgen	Subcutaneous injection
Sunitinib	Sutent	Antiangiogenic	Pfizer	Oral
Sorafenib	Nexavar	Antiangiogenic	Bayer	Oral
Bevacizumab	Avastin	Antiangiogenic	Genentech	Intravenous
Sirolimus	Rapamune	Antiangiogenic	Pfizer	Oral



• **Fig. 19.7** Bisphosphonate-related osteonecrosis of the maxilla. This area of exposed bone occurred 2 weeks after extractions. Sharp areas were debrided, but the wound had not healed after several months.

often is progressive and may lead to extensive areas of bony exposure and dehiscence (Fig. 19.8).

In cancer patients taking intravenous forms of bisphosphonates, the median time from starting therapy to developing necrosis of bone in the jaws was reported to be 25 months, although many cases do occur earlier.[82] However, anyone taking intravenous bisphosphonates for over 12 months is at serious risk.[61,83] In addition, older adults (>65 years) also may have increased risk.[84,85] The most common dental comorbidity in these patients reportedly is clinically and radiographically apparent periodontitis.[81] Other local factors associated with MRONJ are infected teeth, dental abscesses, previous endodontic treatments, and tori.

In patients in whom MRONJ develops spontaneously, the most common initial complaint is the sudden presence of intraoral discomfort and roughness of the exposed bone, which may progress to traumatize the oral soft tissues surrounding the area of necrotic bone.

Often, a purulent discharge and local swelling may occur in adjacent soft tissue, with trismus and regional lymphadenopathy. One must differentiate MRONJ from simple cases of transient mucosal ulcerations (in patients who have not been taking bisphosphonates) associated with ill-fitting prosthetic appliances, traumatic dental extractions, or spontaneously occurring denudation of bone in areas where the overlying mucosa is thin and prone to abrasion (e.g., mylohyoid ridge and tori). These areas heal spontaneously once the irritation has been removed, but lesions of MRONJ will not.

Dental Care for Patients About to Start Taking an Antiresorptive Medication

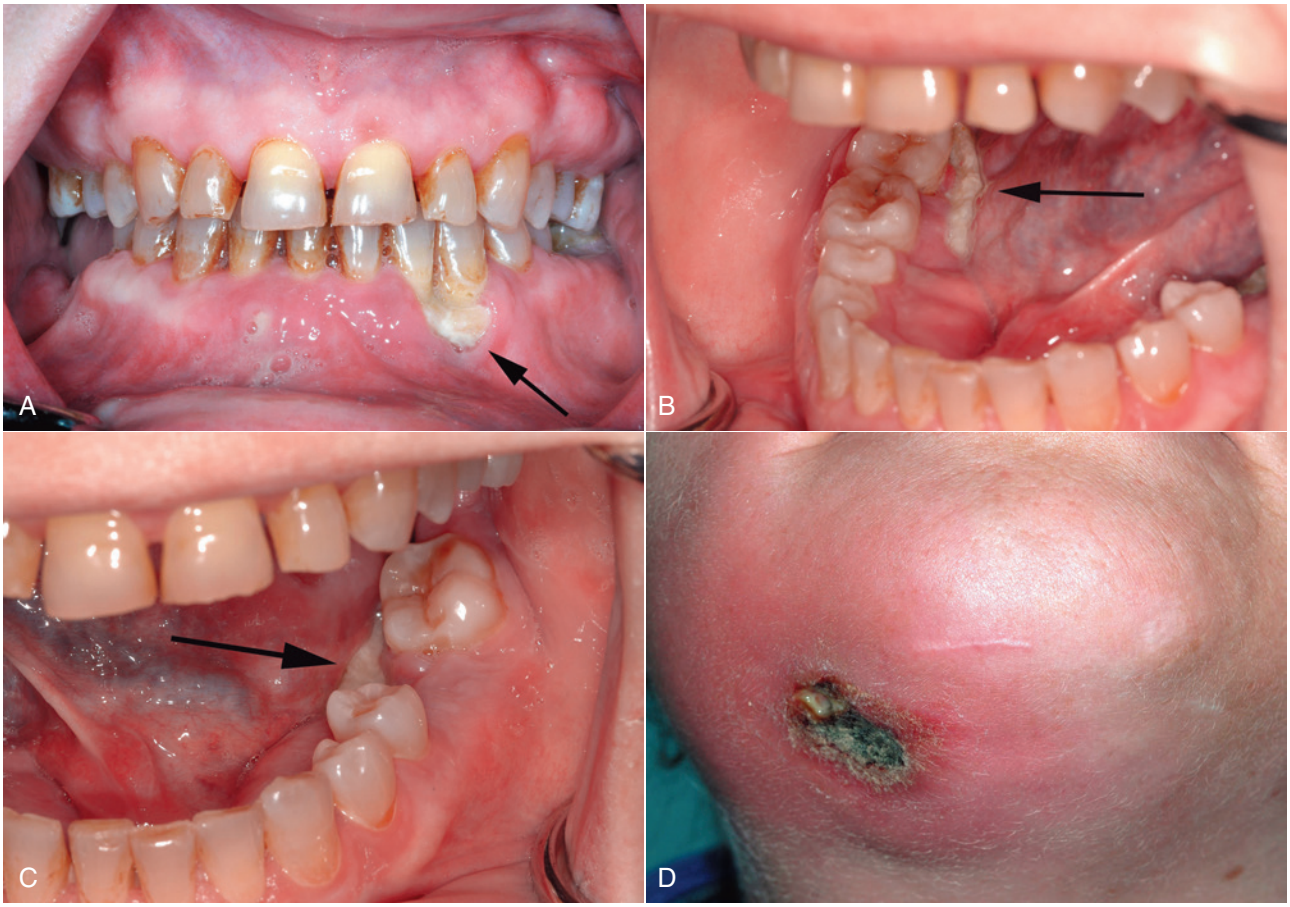
Because MRONJ is a newly documented oral complication, consistently effective therapeutic measures have not yet been identified. Although several reports of this drug-associated complication have been published, no consensus exists on treatment strategies that yield predictable resolution and healing of MRONJ. This presents a dilemma for both patients and clinicians. The inability to manage lesions of MRONJ worsens the patient's medical status as the patient becomes more and more nutritionally compromised. Prevention of this condition is therefore critical for these patients so that they can receive the anticancer therapies they require.

As with the management of patients about to receive radiation treatment, the dentist should see all patients before antiresorptive therapy begins. The main emphasis at this time should be to minimize the risk of occurrence of MRONJ. Most reports of MRONJ occur after the patient has been taking antiresorptive medications for 6 months or more, so it may be possible to provide dental care early in the treatment without unduly risking the development of MRONJ from dental treatment.[62,81] Although a small percentage of patients receiving these medications have MRONJ spontaneously, the majority of affected patients experience this complication following routine dentoalveolar surgery (i.e., extraction, dental implant placement, or apical surgery). Therefore teeth with a poor prognosis should be removed before antiresorptive medication administration or as early as possible after institution of treatment. If possible, institution of antiresorptive therapy should be delayed for approximately 4 to 6 weeks after invasive procedures, such as dental extractions, to give the bone a chance to recover.[81]

Dental prophylaxis, caries control, and conservative restorative dentistry are critical to maintaining functionally sound teeth. This level of care must be continued indefinitely. Patients with full or partial dentures should be examined for areas of mucosal trauma, especially along the lingual flange region. It is critical that patients be educated as to the importance of dental hygiene and regular dental evaluations and specifically instructed to report any pain, swelling, or exposed bone that would predict or characterize MRONJ.

Dental Care for Patients Taking Antiresorptive Medications

The treatment of patients receiving oral or intravenous antiresorptives is principally preventive. The dentist should contact the patient's physician to find out why the patient is taking the bisphosphonate, the type of bisphosphonate the patient is taking, and the expected duration of treatment. It is recommended that dentists follow existing guidelines for a dental consultation for the prevention of oral complications of cancer therapy (chemotherapy, radiation therapy). Elimination of all potential sites of infection must be the primary objective of this consultation. Restorative dentistry should be performed to eliminate caries and defective restorations. Crowns and more extensive fixed prosthodontic work may not be appropriate for some patients. Prosthodontic appliances should be evaluated for fit, stability, and occlusion, and necessary adjustments should be made. Extraction of teeth should be avoided, when possible. The goal of therapy should be to attain a state of good oral health to prevent the need for invasive dental procedures in the future. Prophylaxis should be performed and oral hygiene instructions given. The patient should also be given information about MRONJ and be made aware of the early signs of development of this condition. Once the active dental treatment is over, frequent periodic follow-up visits should be scheduled to reinforce the importance of oral hygiene maintenance and to conduct a new oral examination.



• **Fig. 19.8** A progressive case of bisphosphonate-related osteonecrosis of the mandible. At initial presentation, areas of bone exposure occurred along the anterior teeth (A) and along the mylohyoid ridges bilaterally (B–C). Minor debridements were performed, but an infection of the right mandible developed, with spontaneous breakdown of the skin in the submental region (D).

Role of Orally Administered Alendronate

It is unclear whether patients taking alendronate and having MRONJ had other systemic or local comorbid factors.[62,63,80,81] Because of the vast numbers of patients taking alendronate (Fosamax) for osteoporosis (approximately 22 million), a frequently asked question is whether such individuals can safely have invasive procedures such as dental extraction and dental implantation.[86] The risk of developing MRONJ after dental extraction, dental implantation, and periodontal and other surgical procedures for patients taking oral bisphosphonates such as alendronate is unknown. The duration of the physiologic effect of these drugs is variable. Evidence shows that severe suppression of bone remodeling may occur during long-term alendronate therapy and that bone resorption and formation markers may remain suppressed for the time during which the patient is taking the medication.[67,68,74] At this time it appears that the incidence of MRONJ manifesting in patients taking alendronate orally for osteoporosis is 1 : 1000 to 1 : 25,000.[87–90] However, the longer a patient takes this medication, the higher the risk for MRONJ.

One thing that can be done when one is contemplating an invasive procedure in a patient taking an oral bisphosphonate is withdrawing the medication for a time (drug holiday). This possibility can be discussed with the patient's physician because it may be possible to use alternative medication. Studies have shown that 6 to 12 months after cessation of an oral bisphosphonate, the development of MRONJ after invasive procedures is reduced.[91]

Dental Care for Patients With MRONJ

For patients with established MRONJ lesions, the goal is to get the patient comfortable, because it is likely the patient will have to live with the exposed bone. Treatment should be directed at eliminating or controlling pain and preventing progression of the exposed bone. If the exposed bone has sharp edges that are irritating adjacent soft tissue, the sharp edges of bone may be eliminated with a rotating diamond burr. This is particularly important when the lingual aspect of the posterior mandibular arch is involved. However, superficial debridement should be performed only as a last resort. Attempts to cover the exposed bone with flaps may cause more bone exposure and worsening of symptoms, with a risk of pathologic fracture. Several treatment modalities for MRONJ are reported in the literature and include minor debridement under local anesthesia, major surgical sequestrectomies, marginal and segmental mandibular resections, partial and complete maxillectomies, and HBO therapy. Unfortunately none of these therapeutic modalities have proved routinely successful. Despite the appearance of vascularized bone at the surgical margins, healing may not occur because the entire bone is affected, making it impossible to debride to normal bone.[63,85] Many cases have a very poor outcome in spite

of therapy, progressing to extensive dehiscence and exposure of bone.[63,81,85]

Patients should be closely monitored so as to reevaluate the affected areas and ensure that they have not become suppurative. If the area around the exposed bone exhibits painful erythema, suppuration, and/or sinus tracts, the patient should be treated with antibiotics until the areas heal. Use of chlorhexidine mouth rinse three or four times a day is also recommended to reduce bacterial load and colonization.

The dentist should discuss the patient's care with the patient's oncologist. Because of the extremely long half-life of bisphosphonates (years), it is not reasonable to discontinue the medication in an attempt to facilitate healing of the MRONJ. Further, patients taking bisphosphonates for metastatic cancer need their medication. However, if no cancer-related indication exists for continued bisphosphonate therapy or the original indication has resolved, it might be reasonable to discontinue the medication, although the drug will be present in the patient's bones for a long time. Discontinuation of oral bisphosphonate therapy in patients with MRONJ has been associated with a gradual improvement in clinical disease.[91] Discontinuation of oral bisphosphonates for 6 to 12 months may result in either spontaneous sequestration or resolution following debridement surgery.

Routine restorative care may be provided to patients with MRONJ. Local anesthetic may be used as necessary. Scaling and prophylaxis should be done as atraumatically as possible, with gentle soft tissue management. If the tooth is nonrestorable because of caries, root canal treatment and amputation of the crown may be a better option than removing the tooth unless it is very loose. Dental extractions should be avoided if possible; if necessary, they should be performed as atraumatically as possible. Patients should be monitored closely for the first several weeks thereafter and then monthly until the sockets are completely closed and healed. If any indication for antibiotic use exists, penicillin V, amoxicillin, or clindamycin may help reduce the incidence of local infection.

Any existing prosthetic appliances should be reevaluated to ensure that they fit well. Relining the denture with a soft liner to promote a better fit and to minimize soft tissue trauma and pressure points is recommended.

Odontogenic infections should be treated aggressively with systemic antibiotics. Although penicillin is the first-choice antibiotic in dentistry, amoxicillin, clindamycin, or both provide better bone penetration and a wider spectrum of coverage. If debridement, resection, or a combination of both seems necessary, these patients would best be managed by referral to an oral-maxillofacial surgeon.

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Odontogenic Diseases of the Maxillary Sinus

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CHAPTER OUTLINE

Embryology and Anatomy

The maxillary sinuses are air-containing spaces that occupy maxillary bone bilaterally. They are the first of the paranasal sinuses (e.g., maxillary, ethmoid, frontal, and sphenoid) to develop embryonically and begin in the third month of fetal development as mucosal invaginations or pouching of the ethmoid infundibula. The initial maxillary sinus development, also termed *primary pneumatization*, progresses as the invagination expands into the cartilaginous nasal capsule.[1] Secondary pneumatization begins in the fifth month of fetal development as the initial invaginations expand into the developing maxillary bone.

After birth, the maxillary sinus expands by pneumatization into the developing alveolar process and extends anteriorly and inferiorly from the base of the skull, closely matching the growth rate of the maxilla and the development of the dentition. As the dentition develops, portions of the alveolar process of the maxilla, vacated by the eruption of teeth, become pneumatized.[2] By the time a child reaches age 12 or 13 years, the sinus will have expanded to the point at which its floor will be on the same horizontal level as the floor of the nasal cavity. In adults, the apices of teeth may extend into the sinus cavity and can be identified in anatomic specimens or through computed tomography imaging.[3] Expansion of the sinus normally ceases after the eruption of permanent teeth, but on occasion the sinus will pneumatize further, after the removal of one or more posterior maxillary teeth, to occupy the residual alveolar process. In many of the cases, the sinus often extends virtually to the crest of the edentulous ridge. The maxillary sinus is significantly larger in adult patients who are edentulous in the posterior maxilla compared with patients with complete posterior dentition.[4]

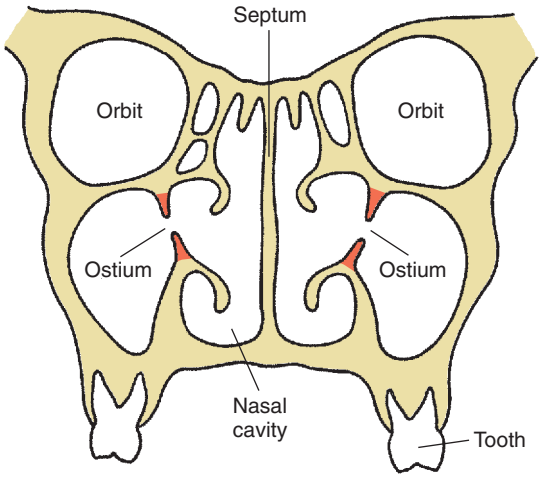
The maxillary sinus is the largest of the paranasal sinuses. It is also known as the antrum or the antrum of Highmore. The term *antrum* is derived from the Greek word meaning "cave." Nathaniel Highmore, an English physician in the 1600s, described a sinus infection associated with a maxillary tooth, and his name has long been associated with sinus nomenclature.

The maxillary sinus is described as a four-sided pyramid, with the base lying vertically on the medial surface and forming the lateral nasal wall. The apex extends laterally into the zygomatic process of the maxilla. The upper wall, or roof, of the sinus is also the floor of the orbit. The posterior wall extends the length of the maxilla and dips into the maxillary tuberosity. Anteriorly and laterally, the sinus extends to the region of the first bicuspid or cuspid teeth. The floor of the sinus forms the base of the alveolar process (Figs. 20.1 and 20.2). The adult maxillary sinus averages 34 mm in the anteroposterior direction, 33 mm in height, and 23 mm in width. The volume of the sinus is approximately 15 to 20 mL.

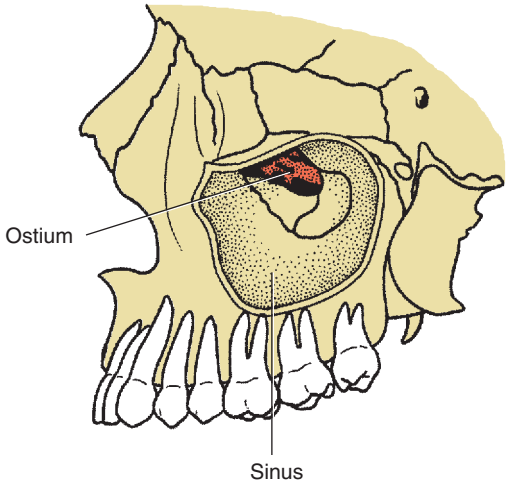
The sinuses are primarily lined by respiratory epithelium, a mucus-secreting pseudostratified and ciliated columnar epithelium. The cilia and mucus are necessary for the drainage of the sinus because the sinus opening, or ostium, is not in a dependent (inferior) position but lies two-thirds the distance up the medial wall and drains into the nasal cavity (see Figs. 20.1 and 20.2). The maxillary sinus opens into the posterior or inferior end of the semilunar hiatus, which lies in the middle meatus of the nasal cavity between the inferior and middle nasal conchae. Beating of the cilia moves the mucus produced by the lining epithelium and any foreign material contained within the sinus toward the ostium, from which it drains into the nasal cavity. The cilia beat at a rate of up to 1000 strokes per minute and can move mucus a distance of 6 mm/min.[5] The environment within the sinus is a constantly moving thin layer of mucus that is transported along the walls of the sinus through the ostium and into the nasopharynx.

Clinical Examination of the Maxillary Sinus

Clinical evaluation of a patient with suspected maxillary sinusitis should begin with a careful visual examination of the patient's face



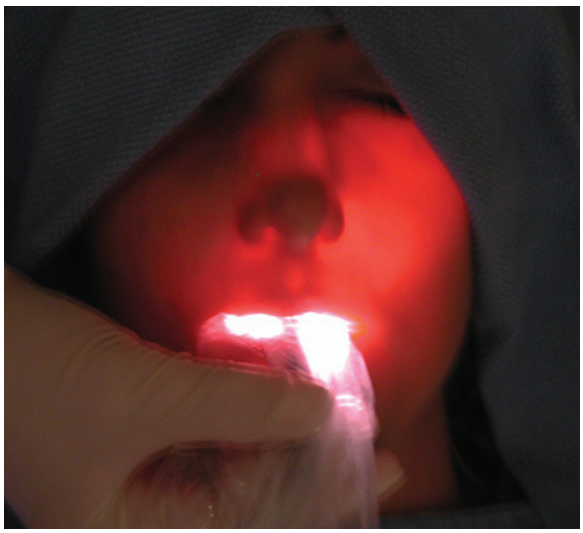
• **Fig. 20.1** Frontal diagram of midface at the ostium or opening of maxillary sinuses into the middle meatus of the nasal cavity. The ostium is in the upper third of the sinus cavity.



• **Fig. 20.2** Lateral diagram of left maxillary sinus with zygoma removed. The medial sinus wall (i.e., lateral nasal wall) is seen in the depth of the sinus, as is the ostium. The maxillary sinus is pyramidal, with its apex directed into the base of the zygoma.

and intraoral vestibule for swelling or redness. Nasal discharge may be evident during the initial evaluation. Examination of the patient with suspected maxillary sinus disease should also include tapping of the lateral walls of the sinus externally over the prominence of the cheekbones and palpation intraorally on the lateral surface of the maxilla between the canine fossa and the zygomatic buttress. The affected sinus may be very tender to gentle tapping or palpation. In some cases, the lateral wall of the sinus (lateral maxillary wall) may be eroded and have a palpable defect. Patients with maxillary sinusitis frequently complain of dental pain, and pain to percussion of several maxillary posterior teeth is often indicative of an acute sinus infection.

Further examination may include transillumination of the maxillary sinuses. This is done by placing a bright fiberoptic light against the mucosa on the palatal or facial surfaces of the sinus and observing, in a darkened room, the transmission of light through the sinus (Fig. 20.3). In unilateral disease, a sinus may be compared with the one on the opposite side. The involved sinus shows decreased transmission of light because of the accumulation of



• **Fig. 20.3** Transillumination of the maxillary sinus with a fiberoptic light source. The left maxillary sinus is normal and is transilluminated by the fiberoptic light source in the palate. The right maxillary sinus is filled with fluid or pus from infection and has decreased transillumination.

fluid, debris, or pus and the thickening of the sinus mucosa. These simple tests may help distinguish sinus disease, which may cause pain in the upper teeth from abscess or other pain of dental origin associated with molar and premolar teeth. Nasal and sinus endoscopy can be performed to obtain additional information regarding anatomic factors that may be contributing to sinus disease as well as the overall health of the mucosa.

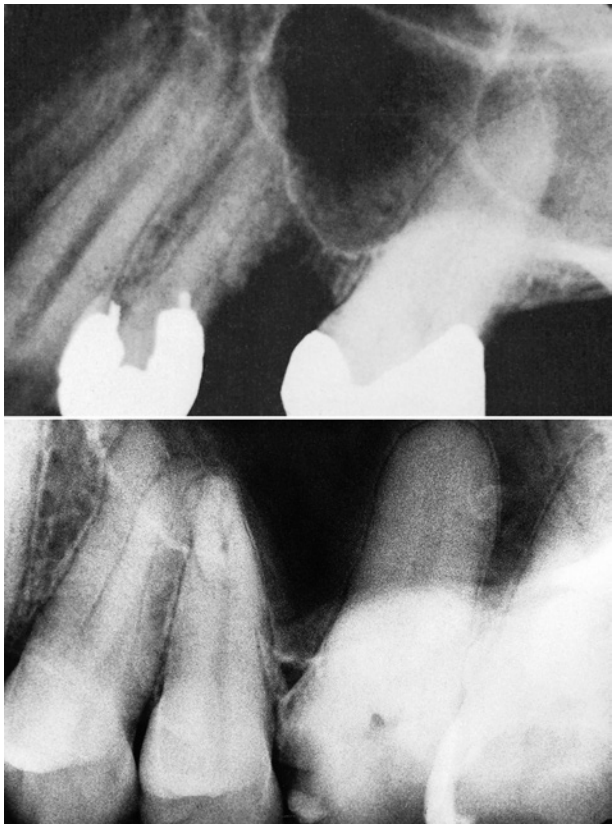
Radiographic Examination of the Maxillary Sinus

Radiographic examination of the maxillary sinus may be accomplished with a wide variety of exposures readily available in the dental office or radiology clinic. Standard dental radiographs that may be useful in evaluating the maxillary sinus include periapical, occlusal, and panoramic views. A periapical radiograph is limited in that only a small portion of the inferior aspect of the sinus can be visualized. In some cases, the apices of the roots of posterior maxillary teeth may be seen to project into the sinus floor (Fig. 20.4). Panoramic radiographs may provide a "screening" view of the maxillary sinuses (Fig. 20.5). This projection is the best radiograph that can be obtained in most dental offices to provide a view of both maxillary sinuses for comparison. Because a panoramic radiograph provides a focused image within a limited focal trough, structures outside of this area may not be clearly delineated.

Periapical, occlusal, and occasionally panoramic radiographs are of value in locating and retrieving foreign bodies within the sinus—particularly teeth, root tips, or osseous fragments—that have been displaced by trauma or during tooth removal (Fig. 20.6). These radiographs should also be used for the careful planning of surgical removal of teeth adjacent to the sinus.

If additional radiographic information is required, the Waters and lateral views, two plain film radiographs, are frequently useful.[6] The Waters view is taken with the head tipped 37 degrees to the central beam (Fig. 20.7). This projection places the maxillary sinus area above the petrous portion of temporal bones, allowing for a

clearer view of the sinuses than a standard posteroanterior view of the skull. The lateral view can be obtained in a standard cephalometric machine with the patient's head tipped slightly toward the cassette (Fig. 20.8). Tipping of the patient's head avoids superimposition of the walls of the sinus.

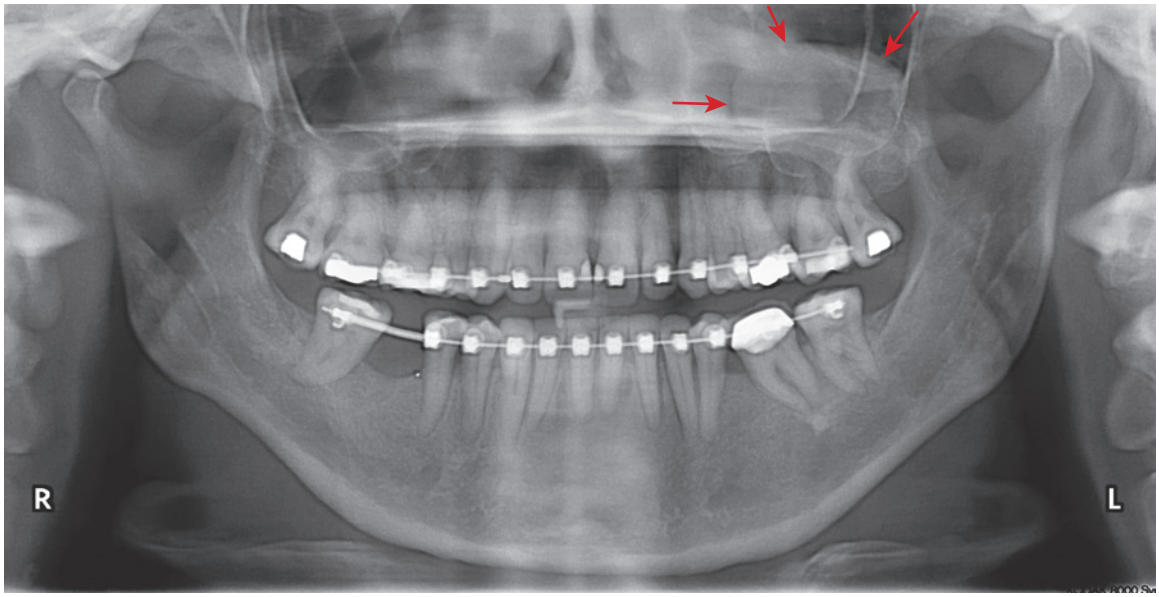


• **Fig. 20.4** Periapical radiographs showing the inferior portion of a pneumatized maxillary sinus. Molar roots appear to be protruding into the sinus because the sinus has pneumatized around the roots.

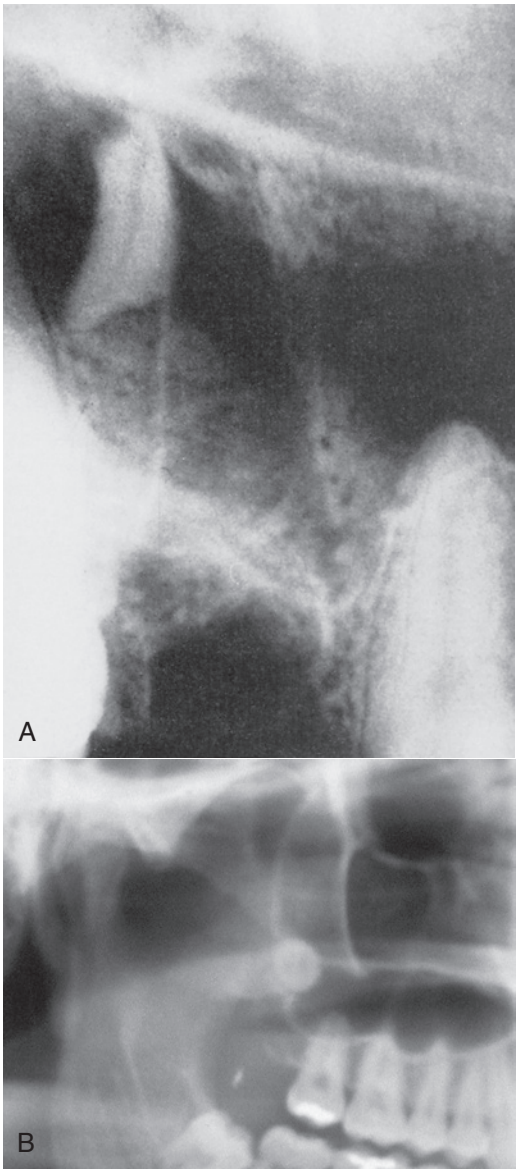
Computed tomography is a useful technique for imaging of the maxillary sinuses and other facial bony structures.[7] Lower cost and better accessibility combined with clear, easily visualized images have made computed tomography scans increasingly popular for evaluating all types of pathologic conditions of facial bone, including abnormalities of the maxillary sinus (Fig. 20.9).

Interpretation of the radiographs of the maxillary sinus is not difficult. The findings in the normal antrum are those to be expected of a rather large, air-filled cavity surrounded by bone and dental structures. The body of the sinus should appear radiolucent and be outlined in all peripheral areas by a well-demarcated layer of cortical bone. Comparison of one side with the other is helpful in examining radiographs. Thickened mucosa on the bony walls, air-fluid levels (caused by the accumulation of mucus, pus, or blood), or foreign bodies lying free should not be present. Partial or complete opacification of the maxillary sinus may be caused by the mucosal hypertrophy and fluid accumulation of sinusitis, by blood filling the sinus following trauma, or by neoplasia. Radiographic changes are to be expected with acute maxillary sinusitis. Mucosal thickening caused by infections may obstruct the ostium of the sinus and allow the accumulation of mucus, which will become infected and produce pus. The characteristic radiographic changes may include an air-fluid level in the sinus (see Fig. 20.7), thickened mucosa on any or all of the sinus walls (Fig. 20.10), or complete opacification of the sinus cavity. Radiographic changes indicative of chronic maxillary sinusitis include mucosal thickening, sinus opacification, and nasal or antral polyps. Air-fluid levels in the sinuses are more characteristic of acute sinus disease but may be seen in chronic sinusitis during periods of acute exacerbation.

Disruption of the cortical outline may be a result of trauma, tumor formation, an infectious process with abscess and fistula formation (Fig. 20.11), or a surgical procedure that violates the sinus walls. Expansion of the bony walls may also be apparent (Fig. 20.12). Dental pathologic conditions such as cysts or granulomas may produce radiolucent lesions that extend into the sinus cavity. These conditions may be distinguished from normal sinus anatomy by their association with the tooth apex, the clinical



• **Fig. 20.5** Panoramic radiograph showing a mucous retention phenomenon on the floor of the right maxillary sinus *(arrows)*.

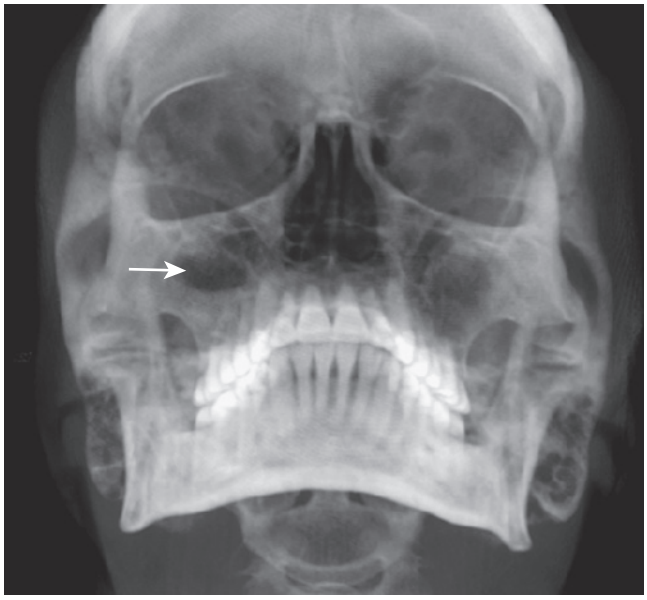


• **Fig. 20.6** (A) Periapical radiograph showing the apical third of the palatal root of the maxillary first molar, which was displaced into the maxillary sinus during removal of the tooth. (B) Close-up panoramic view of the right maxillary sinus with the third molar displaced superiorly and lying against the posterior wall of the sinus.

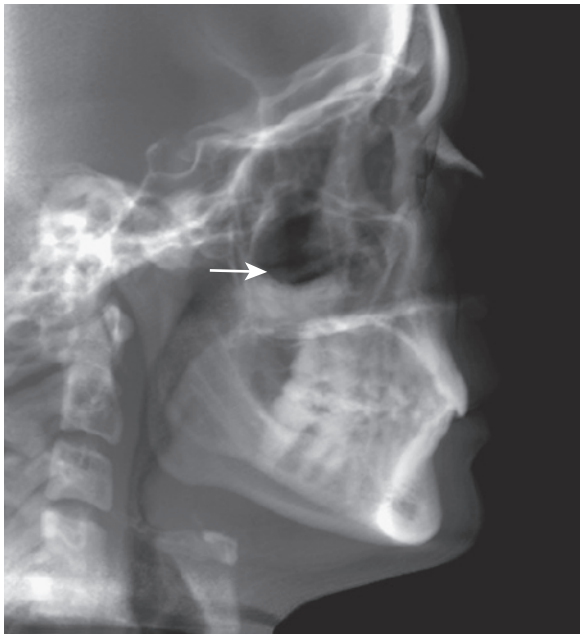
correlation with the dental examination, and the presence of a cortical osseous margin on the radiograph, which generally separates the area in question from the sinus itself.

Nonodontogenic Infections of the Maxillary Sinus

Historically the consensus has been that the maxillary sinus is usually not colonized by any bacteria and is essentially sterile.[8] More recent studies using updated techniques have occasionally shown that some bacteria may be cultured from a healthy paranasal sinus.[9] Even though some microorganisms may be present in the normal sinus, this appears to be minimal, and the dynamic nature of the sinus with active epithelium and a constantly moving mucus layer prevents any significant colonization.



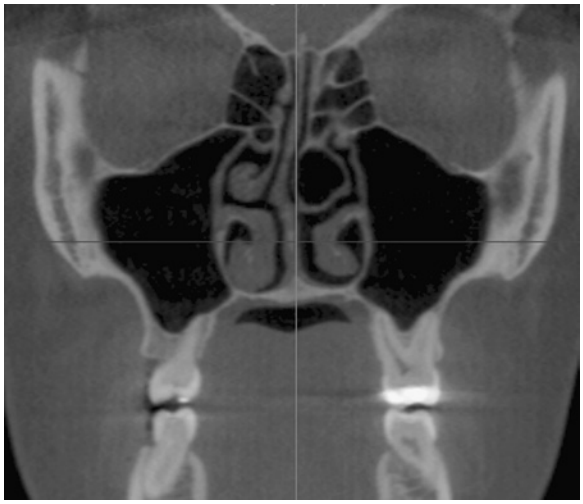
• **Fig. 20.7** Waters view radiograph demonstrating the right maxillary sinus with an air-fluid level *(arrow)* and increased opacity of the left sinus because of fluid, significant thickening of the mucosa, or both.



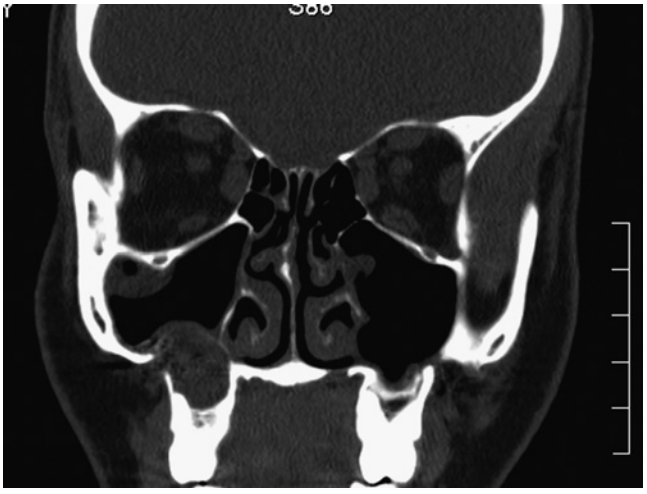
• **Fig. 20.8** Lateral radiograph demonstrates air-fluid levels in the maxillary sinus *(arrow)*.

The mucosa of the sinus is susceptible to infectious, allergic, and neoplastic diseases. Inflammatory diseases of the sinus, such as infection or allergic reactions, cause hyperplasia and hypertrophy of the mucosa and may cause obstruction of the ostium. If the ostium becomes obstructed, the mucus produced by the secretory cells lining the sinus collects over a long period. Bacterial overgrowth may then produce an infection, which results in the signs and symptoms of sinusitis as well as the radiographic changes seen with these conditions.

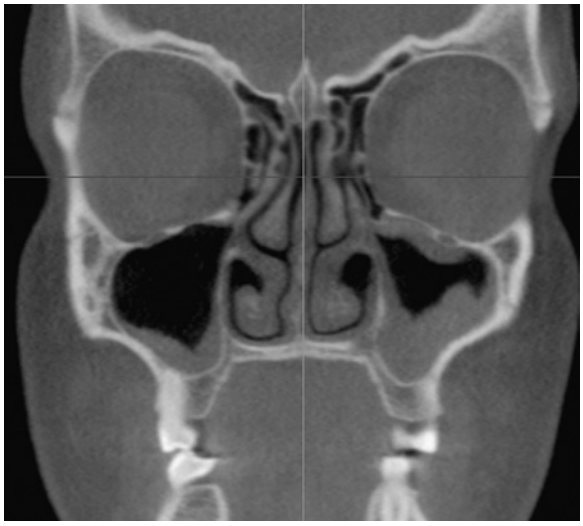
When inflammation develops in any of the paranasal sinuses, whether caused by infection or allergy, the condition is termed



• **Fig. 20.9** Computed tomography scan, coronal view, showing normal maxillary sinus anatomy with thin bony walls and without any thickening of the mucosal lining, masses, or fluid.



• **Fig. 20.11** Perforation of the lateral wall of the right sinus as a result of an odontogenic infection associated with a molar tooth. The abscess has expanded into the floor of the sinus and eroded its lateral wall.

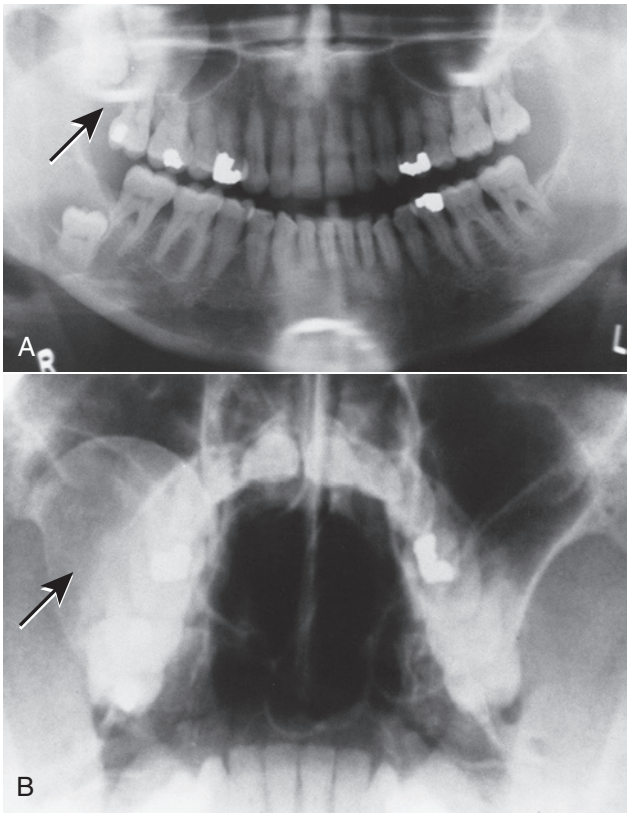


• **Fig. 20.10** Computed tomography scan showing a right maxillary sinus with thickened mucosa at the inferior portion of the sinus. The patient's left side has significant mucosal thickening along the entire lining of the sinus.

sinusitis. Inflammation of most or all of the paranasal sinuses simultaneously is known as *pansinusitis* and is usually caused by infection. Similar conditions of individual sinuses are known as *maxillary sinusitis* or *frontal sinusitis*.

Acute maxillary sinusitis may occur at any age. The onset is usually described by the patient as a rapidly developing sense of pressure, pain, fullness, or all of these in the vicinity of the affected sinus. The discomfort rapidly increases in intensity and may be accompanied by facial swelling and erythema, malaise, fever, and drainage of foul-smelling mucopurulent material into the nasal cavity and nasopharynx.

Chronic maxillary sinusitis is usually a result of bacterial or fungal infections that are low-grade and recurrent, obstructive nasal disease, or allergy. Chronic maxillary sinusitis is characterized by episodes of sinus disease that respond initially to treatment, only to return, or that remain symptomatic in spite of treatment.



• **Fig. 20.12** (A) Panoramic radiograph showing a large odontogenic keratocyst associated with an impacted right maxillary third molar *(arrow)*. As it has expanded, the cyst has impinged on the right maxillary sinus. The sinus cavity is almost totally obstructed by the lesion. Another odontogenic keratocyst is seen associated with the impacted right mandibular third molar. (B) A Waters view radiograph demonstrates the odontogenic keratocyst (seen in A). The lesion is also seen to have expanded the lateral wall of the right maxillary sinus *(arrow)*.

Aerobic, anaerobic, or mixed bacteria may cause infections of the maxillary sinuses. The organisms usually associated with maxillary sinusitis of nonodontogenic origin include those usually found within the nasal cavity. Mucostasis that occurs within the sinus allows for colonization of these organisms. The causative bacteria are primarily aerobic, and a few are anaerobes. The important aerobes are *Streptococcus pneumoniae, Haemophilus influenzae,* and *Branhamella catarrhalis*. Anaerobes include *Streptococcus viridans, Staphylococcus aureus,* Enterobacteriaceae, *Porphyromonas, Prevotella, Peptostreptococcus, Veillonella, Propionibacterium, Eubacterium*, and *Fusobacterium*.

Odontogenic Infections of the Maxillary Sinus

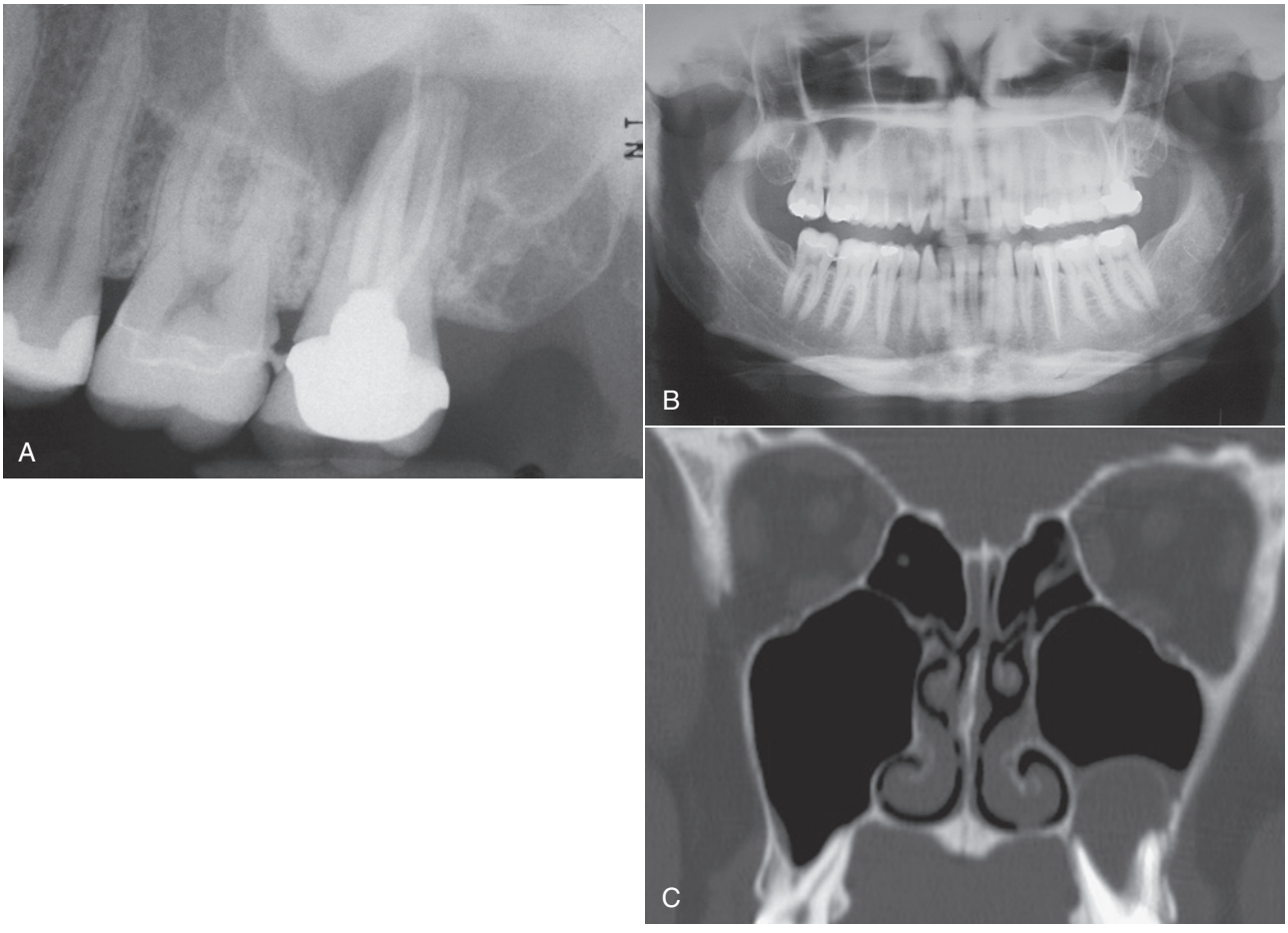
Maxillary sinusitis is occasionally a result of odontogenic sources because of the anatomic juxtaposition of teeth and the maxillary sinus (Fig. 20.13). Odontogenic sources account for approximately 10% to 12% of all maxillary sinusitis cases.[10] This condition may readily spread to involve the other paranasal sinuses if left untreated or inadequately treated. In rare cases, these infections become life threatening and can include orbital cellulitis, cavernous sinus thrombosis, meningitis, osteomyelitis, intracranial abscess, and death.

Sources of odontogenic infections that involve the maxillary sinus include acute and chronic periapical diseases and periodontal diseases. Infection and sinusitis may also result from trauma to the dentition or from surgery in the posterior maxilla, including removal of teeth, alveolectomy, tuberosity reduction, sinus lift grafting and implant placement, or other procedures that create an area of communication between the oral cavity and the maxillary sinus.

Maxillary sinus infections of odontogenic origin are more likely to be caused by anaerobic bacteria, as is the usual odontogenic infection. Rarely does *H. influenzae* or *S. aureus* cause odontogenic sinusitis. The predominant organisms are aerobic and anaerobic streptococci and anaerobic *Bacteroides*, Enterobacteriaceae, *Peptococcus, Peptostreptococcus, Porphyromonas, Prevotella,* and *Eubacterium*.

Treatment of Maxillary Sinusitis

Early treatment of maxillary sinusitis consists of humidification of inspired air to loosen and aid in the removal of dried secretions from the nasal passage and the sinus ostium. Systemically administered decongestants (e.g., pseudoephedrine [Sudafed]) and nasal



• **Fig. 20.13** (A) Periapical radiograph showing an endodontically treated molar tooth. The tooth has a periapical abscess affecting the maxillary sinus, not seen well on this radiograph but more apparent on the panoramic radiograph and computed tomography scan. (B) Panoramic radiograph showing significant opacification of the inferior portion of the left maxillary sinus. (C) Computed tomography scan clearly shows a fluid-filled mass associated with the roots of the second molar.

spray containing vasoconstrictors (e.g., 2% ephedrine or 0.25% phenylephrine) decrease nasal and sinus congestion and help facilitate normal drainage. Patients with sinus infections often experience moderate to severe pain, hence prescribing a nonsteroidal or narcotic analgesic may be appropriate.[11]

Many cases of sinusitis are caused by allergies that result in congestion and altered natural drainage of the sinus. Allergic sinusitis often responds to the measures described earlier. However, when sinusitis is a result of an infectious process, the use of antibiotics is indicated. Knowledge of the bacteria most likely to be isolated in sinusitis is important in selecting an antibiotic. In cases of nonodontogenic sinusitis, the most likely organisms are *H. influenza, S. aureus*, *S. pneumoniae*, and a variety of anaerobic streptococci. Antibiotic choices for treatment of nonodontogenic maxillary sinusitis include amoxicillin, trimethoprim-sulfamethoxazole, amoxicillin-clavulanate, azithromycin, and cefuroxime.

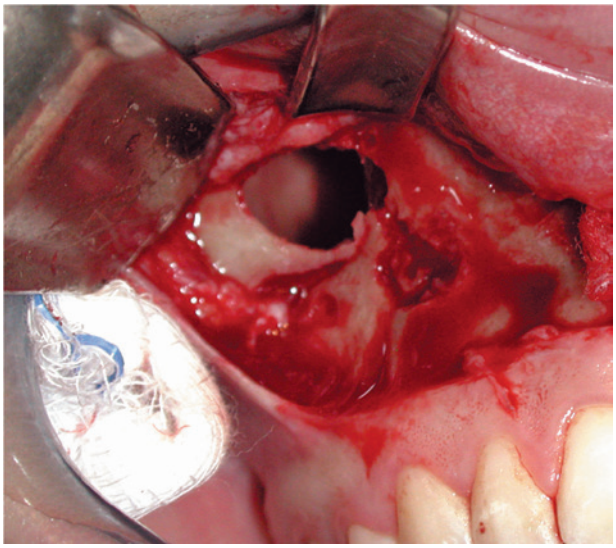
Odontogenic sinusitis usually involves organisms that are associated with common odontogenic infections, including aerobic and anaerobic streptococci and anaerobes such as *Bacteroides* and Enterobacteriaceae. Therefore antibiotics such as penicillin, clindamycin, and metronidazole, which are generally effective against odontogenic infections, are also effective against sinusitis of odontogenic origin.

Because of the wide variety of microorganisms that can contribute to infections of the maxillary sinus, it is important to obtain purulent material for culture and sensitivity testing whenever possible. Sensitivity testing may suggest a change to another antibiotic if resistant organisms are cultured from the sinus and if the infection is failing to respond to appropriate initial treatment.

If the patient fails to respond to this initial treatment regimen within 72 hours, it is necessary to reassess the treatment and the antibiotic. If the cause of the problem has not been identified and eliminated, it must be carefully reevaluated. The results of the culture and sensitivity tests should be evaluated, and changes should be made if indicated. As many as 25% of the organisms cultured from acute sinus infections are β-lactamase producers, and many may be anaerobic, especially if the infection is odontogenic.[11] If the organism(s) causing the infection are β-lactamase producers, another antibiotic such as the combination agent trimethoprim-sulfamethoxazole (Bactrim, Septra) may be effective. Cefaclor or a combination of amoxicillin and clavulanate potassium (Augmentin) has also been shown to be effective.

Acute maxillary sinusitis is a painful, potentially serious condition that requires immediate attention and aggressive medical and surgical care. Patients suspected of having maxillary sinusitis should be referred to an oral-maxillofacial surgeon or another specialist such as an otolaryngologist. The referring clinician should send radiographs, the results of clinical procedures, and the results of culture and sensitivity tests of purulent drainage and any other pertinent diagnostic information to the surgeon.

The diagnosis and treatment of chronic maxillary sinusitis is difficult and may include allergy testing, nasal or septal surgery, and surgical debridement of the sinuses. The goal of sinus surgery is to remove abnormal tissue from within the sinus cavity and restore normal drainage through the ostium. Traditionally this was accomplished with an open approach to the sinus known as the *Caldwell-Luc procedure* (Fig. 20.14).[12] In this technique, the anterior wall of the sinus is accessed in the area of the canine fossa through a vestibular approach. The sinus is opened and abnormal tissue or foreign bodies are removed. The ostiomeatal area is evaluated and opened, or a new opening for more dependent drainage into the nose (termed an *antrostomy*) may be created near the floor of the sinus. Newer techniques permit the exploration and surgical treatment of the sinus with less invasive endoscopic approaches (Fig. 20.15).[12,13]



• **Fig. 20.14** Caldwell-Luc exposure of the maxillary sinus through a vestibular incision and bone window created in the anterior maxillary wall.

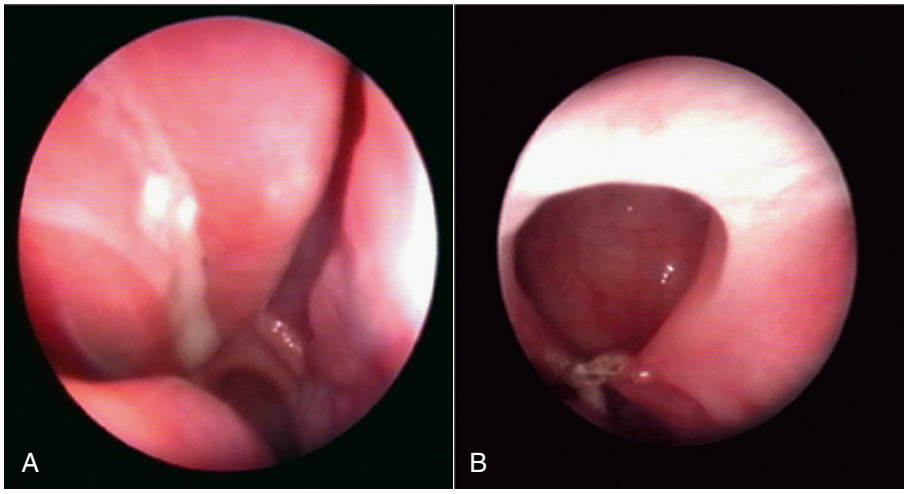
Sinus lift procedures, done primarily as preprosthetic surgical procedures to improve the posterior maxillary alveolar base for secondary or simultaneous endosseous implant placement, occasionally contribute to sinus infections. In most cases careful elevation of the Schneiderian (i.e., sinus) membrane creates a space into which particulate grafts of autologous bone, allogeneic bone, alloplastic materials, or combinations of these can be placed. If the procedure is done carefully, complications from sinus lift operations are rare. Complications become more frequent in at least two instances: (1) when the sinus membrane is severely lacerated or avulsed or (2) when the sinus is overfilled.

Significant disruption of the sinus membrane allows exposure of the graft material to the open sinus and possible contamination by nasal bacteria. Disruption also allows particulate material from the sinus grafts or implants to become free foreign bodies within the sinus, which can cause foreign-body rejection responses from the sinus mucosa or outright infection. Lacerated sinus membranes may also interfere with normal nasal epithelial ciliary motility and thereby impede physiologic sinus drainage. Finally, fragments of sinus mucosa or graft material may obstruct the sinus ostium, further preventing normal sinus drainage.

When these situations occur, treatment consists of infection control and the removal of contaminated or devitalized graft materials. This treatment also includes removal of foreign-body free segments and debulking of overly extended grafts. These procedures are usually accomplished through the Caldwell-Luc lateral sinus wall surgical approach or, rarely, with nasal access endoscopic sinus surgery. Antibiotic therapy alone may temporarily improve the acute problem, but the ultimate treatment will require sinus exploration and debridement.

Antral Pseudocysts

Pseudocysts, mucoceles, and retention cysts are benign accumulations of fluid underneath or surrounded by sinus epithelium. The



• **Fig. 20.15** (A) Ostium and surrounding inflamed mucosa as seen through the endoscope. (B) Ostium and surrounding healthy sinus mucosa. (From Costa F, Emanuelli E, Robiony M, et al. Endoscopic surgical treatment of chronic maxillary sinusitis of dental origin. *J Oral Maxillofac Surg.* 2007;65:225–226.)

term *mucocele* has often been used to describe any type of localized fluid accumulation, but this is not accurate.[14] Although each of these may appear as a round, faint radiopacity within the sinus, the cause of each is different, as is the histology.

The antral pseudocyst is seen in 2% to 10% of panoramic radiographs. This pseudocyst is a result of the accumulation of serum (not sinus mucus) under the sinus mucosa. The cause of these accumulations is not clear but may be related to inflammation of the sinus lining. These lesions are of no clinical consequence, require no treatment, and often disappear over time.

Sinus mucoceles are actually cystic lesions in that they are lined by epithelium. One of the most common causes of true mucoceles is surgery on the sinus, which results in separation of a portion of the sinus lining from the main portion of the sinus. This area can then become filled with mucus and be walled off, forming a separate cystic lesion. These lesions are termed *surgical ciliated cysts* or *postoperative maxillary cysts*. They can become expansile and may expand or erode the walls of the sinus and must be differentiated, usually through removal and biopsy, from more aggressive and even malignant lesions of the sinus.

Retention cysts in the maxillary sinus result from blockage of ducts within the mucus-secreting glands of the sinus. The accumulated mucin becomes surrounded by epithelium, forming a true cystic lesion. These lesions are usually so small that they are not visible on radiographic images.

Complications of Oral Surgery Involving the Maxillary Sinus

The most common dental complications of oral surgical procedures that subsequently involve the maxillary sinus include the displacement of teeth, roots, or instrument fragments into the sinus or the creation of a communication between the oral cavity and the sinus during surgery of the posterior maxilla. Retrieval of a tooth, root fragment, or broken instrument can be accomplished in several ways. In many cases, the opening created during initial displacement can be enlarged slightly and the tooth or other object can be visualized and retrieved with small forceps or the use of suction. Irrigating or flooding the sinus followed by suction can often accomplish retrieval or can position the object close to the opening for easy recovery. In some cases, however, the sinus must be opened through the Caldwell-Luc approach and the object retrieved.

A sinus perforation resulting from a tooth extraction most commonly occurs when a maxillary molar with widely divergent roots that is adjacent to edentulous spaces requires extraction. In this instance, the sinus is likely to have become pneumatized into the edentulous alveolar process surrounding the tooth, which weakens the entire alveolus and brings the tooth apices into a closer relationship with the sinus cavity. Other causes of perforation into the sinus include abnormally long roots, destruction of a portion of the sinus floor by periapical lesions, perforation of the floor and sinus membrane with injudicious use of instruments, forcing of a root or tooth into the sinus during attempted removal, and removal of large cystic lesions that encroach on the sinus cavity.

In many cases, the opening is small, and primary closure can easily be accomplished with adequate healing. In some cases, a larger perforation or communication is apparent, and routine closure is not possible or is not adequate to cover the opening.

The treatment of oroantral communications is accomplished immediately, when the opening is created, or later, as in the instance of a long-standing fistula or failure of an attempted primary closure.

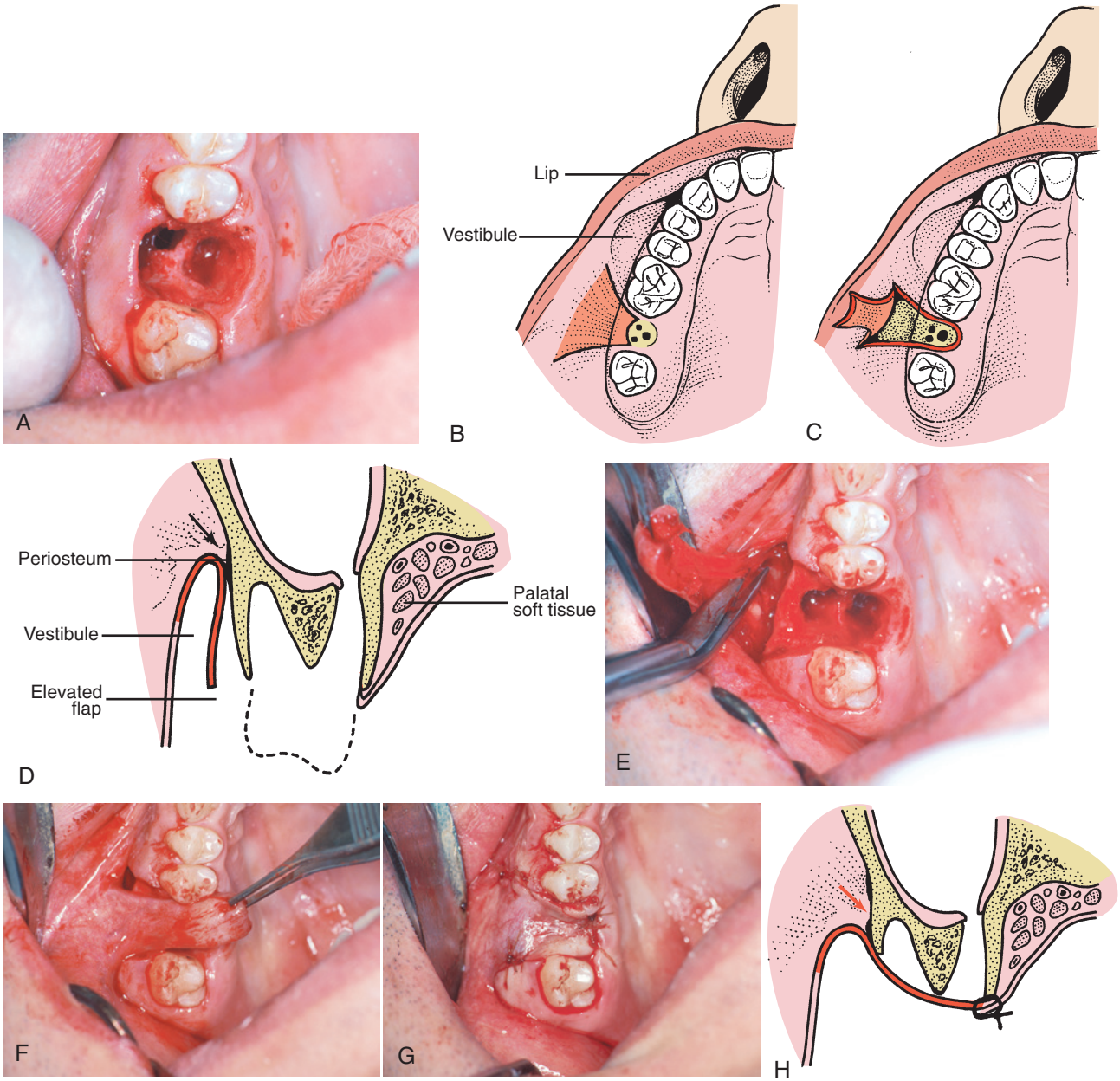
Oroantral Communications: Immediate Treatment

The best treatment of a potential sinus exposure is avoiding the problem through careful observation and treatment planning. Evaluation of high-quality radiographs before surgery usually reveals the presence or absence of an excessively pneumatized sinus or widely divergent or dilacerated roots, which have the potential of having a communication with the sinus or causing fractures in the bony floor of the antrum during removal. If this is observed, surgery may be altered to section the tooth and remove it one root at a time (see Chapter 8).

When exposure and perforation of the sinus result, the least invasive therapy is indicated initially. If the opening to the sinus is small and the sinus is disease free, efforts should be made to establish a blood clot in the extraction site and preserve it in place. Additional soft tissue flap elevation is not required. Sutures are placed to reposition soft tissue, and a gauze pack is placed over the surgical site for 1 to 2 hours. The patient is instructed to use

nasal precautions for 10 to 14 days. These include opening the mouth while sneezing, not sucking on a straw or cigarettes, and avoiding nose blowing and any other situation that may produce pressure changes between the nasal passages and oral cavity. The patient is placed on an antibiotic, usually a penicillin, an antihistamine, and a systemic decongestant for 7 to 10 days to prevent infection, shrink mucous membranes, and lessen nasal and sinus secretions. The patient is seen postoperatively at 48- to 72-hour intervals and is instructed to return if an oroantral communication becomes evident as leakage of air into the mouth or fluid into the nose or if symptoms of maxillary sinusitis appear.

Most patients treated in this manner heal uneventfully in the absence of evidence of preexisting sinus disease. If larger perforations occur, it may be necessary to cover the extraction site with some type of flap advancement to provide primary closure in an attempt to cover the sinus opening. The most commonly used flap procedure involves elevating a buccal flap, releasing the periosteum, and advancing the flap to cover the extraction site (Fig. 20.16). The



• **Fig. 20.16** Closure of large oroantral communication. (A) Clinical image of a large oroantral fistula in the molar region of the right maxilla. (B) Diagram of the flap design. (C) Illustration of the flap elevated to the depth of the vestibule. (D) Cross-sectional view of flap elevation. The periosteum must be incised at the height of the dissection *(arrow)* in the vestibule, releasing the flap attachment in this area to allow the tissue flap to be positioned without tension across the extraction site. (E) Clinical image showing elevation and flap. Scissors are used to incise the periosteum at the height of the dissection. (F) Passive repositioning of the flap across the extraction site. (G) Flap sutured in position. Note that the flap margins extend well beyond the extraction site and the communication defect. (H) Cross-section of closure. In some cases a small amount of bone reduction may be necessary over the facial aspect to facilitate flap closure.

most important aspects of flap advancement for closure include elevating a broad-based flap with adequate width to cover the communication with margins of the flap positioned over bone rather than directly over the defect or area of communication. The flap must be free of any tension. To accomplish this, the periosteum must usually be incised and released at the height of the dissection. After closure, the patient is instructed to follow the sinus precautions as described previously.

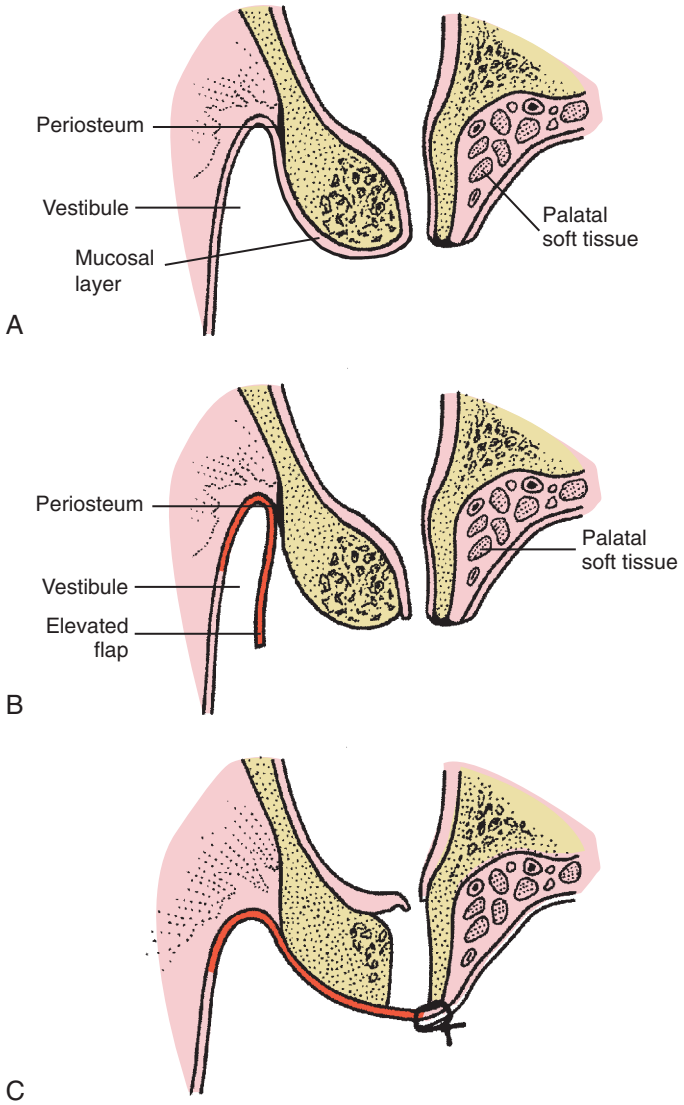
Oroantral Fistulae: Delayed Treatment

Successful treatment and closure of the oroantral fistula requires more extensive medical and surgical treatment. Before closure of an oroantral fistula, it is imperative to eliminate any acute or chronic infection within the sinus. This may require frequent irrigation of the fistula and sinus combined with the use of antibiotics and decongestants. It may also be helpful to construct a temporary appliance to cover the fistula to prevent food and other oral contaminants from getting into the sinus. If sinus disease persists, it may be necessary to remove diseased tissues from the sinus using the Caldwell-Luc procedure through the lateral maxillary wall above the apices of the remaining teeth.

Adjacent teeth must be carefully evaluated for possible involvement. If the fistula has developed in approximation to the root of an adjacent tooth, closure is further complicated; to be successful, removal of the tooth may be necessary.

Methods of closing oroantral fistulae include buccal flap advancement (Fig. 20.17), palatal flap advancement (Fig. 20.18), and advancement of palatal and facial flaps over a membrane of alloplastic material (Fig. 20.19). The buccal flap procedure is performed in a manner similar to the buccal advancement described previously for immediate closure of an oroantral communication.[15] In the case of a chronic fistula, however, the fistulous tract will be lined with epithelium that must be excised or elevated from the bony walls of the fistula, sutured together if possible, and inverted into the sinus cavity (see Fig. 20.17). This should be accomplished before elevating the buccal flap so that the actual size of the bony defect can be inspected and the size of the flap designed appropriately to allow the flap to cover the entire defect with the margins lying over bone. The flap is elevated, the periosteum is released, and the flap is then extended over the defect and carefully sutured in place. In a similar technique, a larger buccal flap is elevated, but then the defect is covered directly by using a pedicled portion of the buccal fat pad with partial closure of the mucoperiosteal flap.[16] Regardless of the technique used, one must remember that the osseous defect surrounding the fistula is always much larger than the clinically apparent soft tissue deformity.[17] Surgical planning of the closure technique must be adjusted accordingly.

Rotation of a palatal flap is often used to close an oroantral fistula.[18] The advantages of using a full-thickness palatal flap are that (1) a large amount of tissue can be elevated with sufficient blood supply from the palatal vessels and that (2) the thickness and keratinized nature of palatal tissue more closely resemble crestal ridge tissue than the thinner, less keratinized tissue in the buccal vestibule. The disadvantage of this flap is the large area of exposed bone resulting from elevation of the flap. The size of the flap must allow for passive rotation of the flap to cover the entire defect with flap margins extending past the bony margins of the defect. Once the fistula has been excised and the flap elevated, rotated, and sutured in place, the palatal defect will eventually heal with granulation and secondary epithelialization (see Fig. 20.18). In some cases, the defect can be covered with a temporary obturator with some

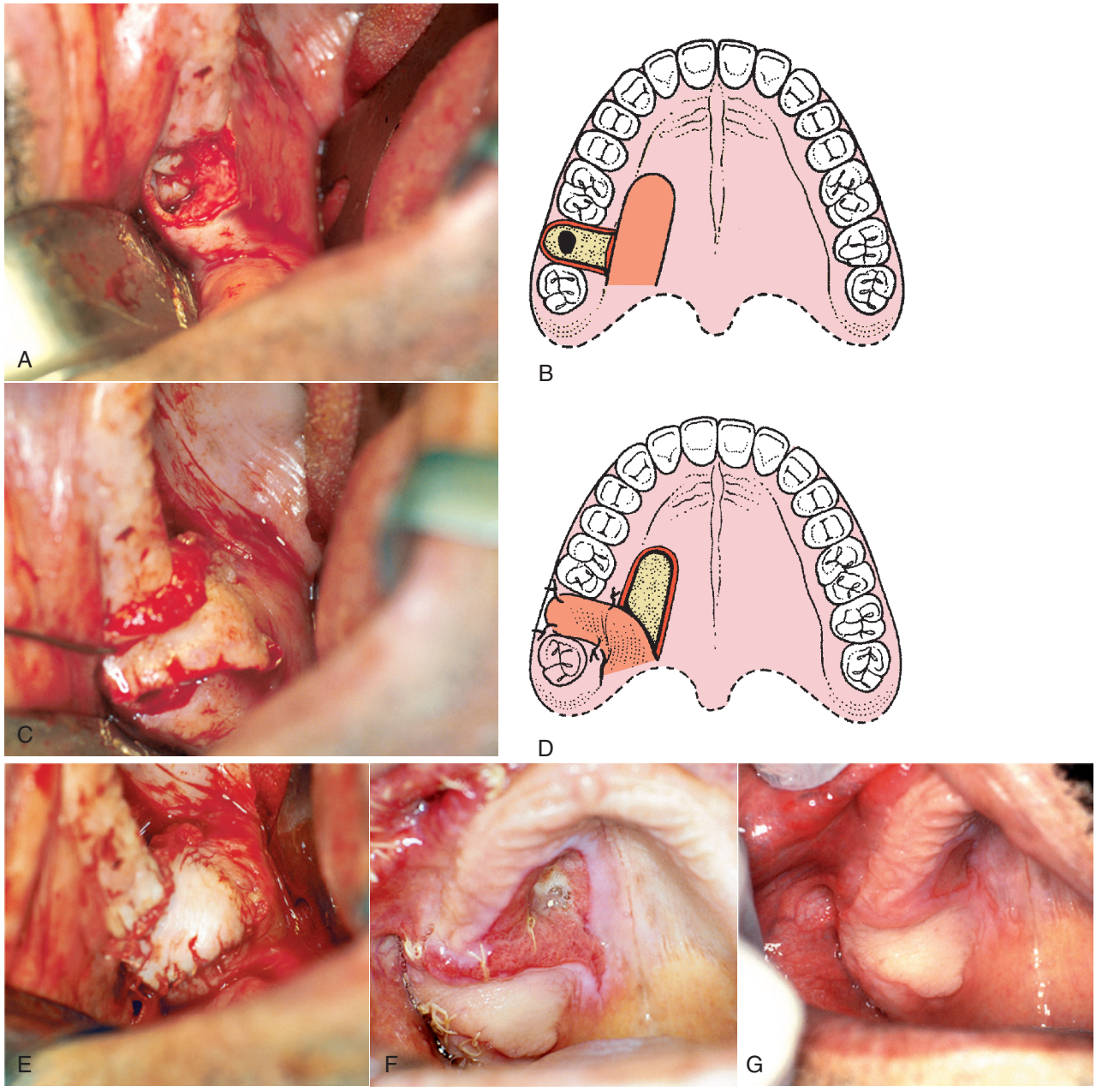


• **Fig. 20.17** Buccal flap closure of oroantral fistula. (A) Cross-section of oroantral fistula in the molar region. (B) The buccal flap has been elevated. (C) The epithelium lining the fistula has been excised, the periosteum has been released at the vestibular height of the dissection, and the tension-free flap has been closed across the defect, with the margins of the flap resting over bone.

type of soft tissue–conditioning liner; however, it is important that no pressure be applied over the flap area because this can decrease the blood supply and cause tissue necrosis.

Another technique for fistula closure uses excision of the fistula, elevation of flaps on the facial and palatal aspects of the defect, covering of the defect with some type of alloplastic material, and approximating the flaps as closely as possible over the alloplast. Thin metallic foil such as gold foil or thin titanium has been used for this purpose and must be closely adapted to the contour of the bony surface.[19] The sinus lining and, in some cases, crestal bone heal over the superior surface of the metal. In some cases, the foil remains permanently, but more frequently a small portion of the metal eventually becomes exposed and the material is gradually exfoliated. An identical closure technique may also be performed using material such as a collagen membrane that is eventually resorbed.[20,21]

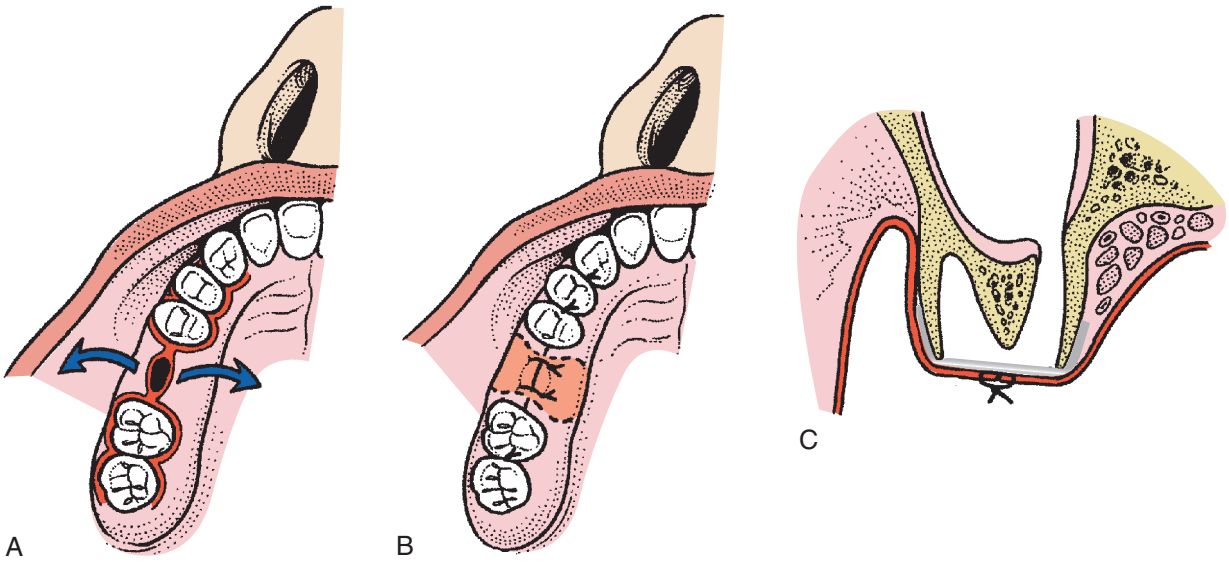
Combined intraoral and endoscopic approaches may increase the chances of long-term success. Successful management of an



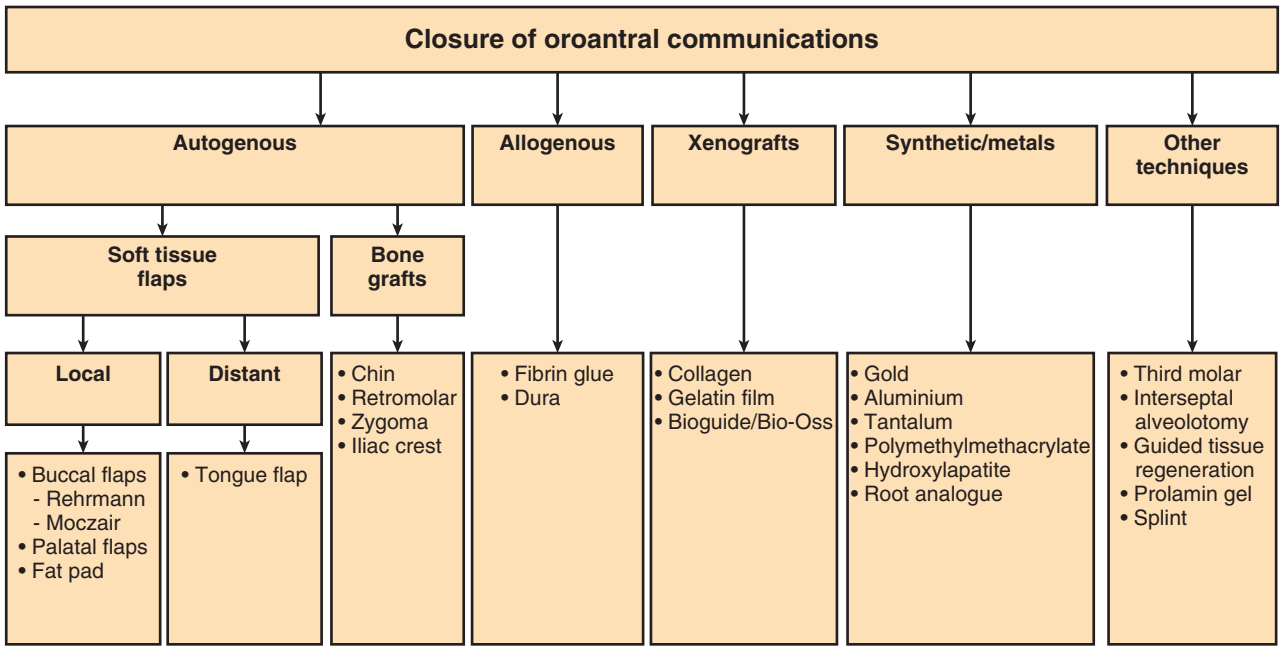
• **Fig. 20.18** Palatal flap closure of oroantral fistula. (A) Clinical image of a fistula resulting from removal of a long-standing molar in the posterior maxilla, where the sinus was pneumatized. (B) Soft tissue surrounding the oroantral opening is excised, exposing underlying alveolar bone around the osseous defect. The full-thickness palatal flap is outlined, incised, and elevated from anterior to posterior. The flap should be the full thickness of the mucoperiosteum, have a broad posterior base, and include the palatine artery. The flap width should be sufficient to cover the entire defect around the oroantral opening, and its length must be adequate to allow rotation of the flap and repositioning over the defect without placing undue tension on the flap. (C) The flap is rotated to ensure that there will be no tension on the flap when it is positioned to cover the osseous defect. (D) Flap rotation and closure. (E) Clinical photograph of closure. (F) Healing at 1 week after surgery. (G) Three weeks after surgery.

oroantral fistula often requires the management of both the infectious process within the maxillary sinus and the physical communication. Functional endoscopic sinus surgery is a minimally invasive approach that allows for transnasal management of chronic sinusitis and optimization of drainage from the maxillary sinus. This may involve the dislocation of the middle turbinate, complete uncinectomy, and maxillary antrostomy.

In rare cases, larger defects, particularly those resulting from surgical removal of pathologic lesions, may require larger flaps to accomplish closure and may include the use of pedicle flaps from the tongue or the temporalis muscle. Multiple treatment modalities exist for the management of an oroantral fistula. Understanding the size and specific needs of the patient's anatomy as well as managing concomitant sinus disease are crucial factors (Fig. 20.20).



• **Fig. 20.19** Membrane-assisted closure of oroantral communications. (A) Diagrammatic illustration of an oroantral fistula in the right maxillary alveolar process in the region of the missing first molar, which is to be closed with subperiosteal placement of alloplastic material such as gold or titanium foil or a resorbable collagen membrane. Facial and palatal mucoperiosteal flaps are developed. Extension of the flaps along the gingival sulcus one or two teeth anterior and posterior allows some stretching of the flap to facilitate advancement for closure over the defect. The fistulous tract is excised. Osseous margins must be exposed 360 degrees around the bony defect to allow placement of the membrane beneath the muco-periosteal flaps. The flap is supported on all sides by underlying bone. (B) Diagram of closure. Ideally, the flaps can be approximated over the defect. In some cases, a small gap between the flaps will heal over the membrane by secondary intention. Even if the intraoral mucosa does not heal primarily, the sinus lining usually heals and closes, and the membrane is then exfoliated or resorbed, and mucosal healing progresses. (C) Cross-sectional diagram of membrane closure technique. Buccal and palatal mucoperi-osteal flaps are elevated to expose osseous defect and large area of underlying alveolar bone around the oroantral communication. The membrane overlaps all the margins of the defect, and the facial and palatal flaps are sutured over the membrane.



• **Fig. 20.20** Possible modalities in the management of oroantral fistulas. (From Visscher SH, van Minnen B, Bos RR. Closure of oroantral communications: a review of the literature. *J Oral Maxillofac Surg*. 2010;68[6]:1384–1391.)

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21

Diagnosis and Management of Salivary Gland Disorders

MICHAEL MILORO AND ANTONIA KOLOKYTHAS

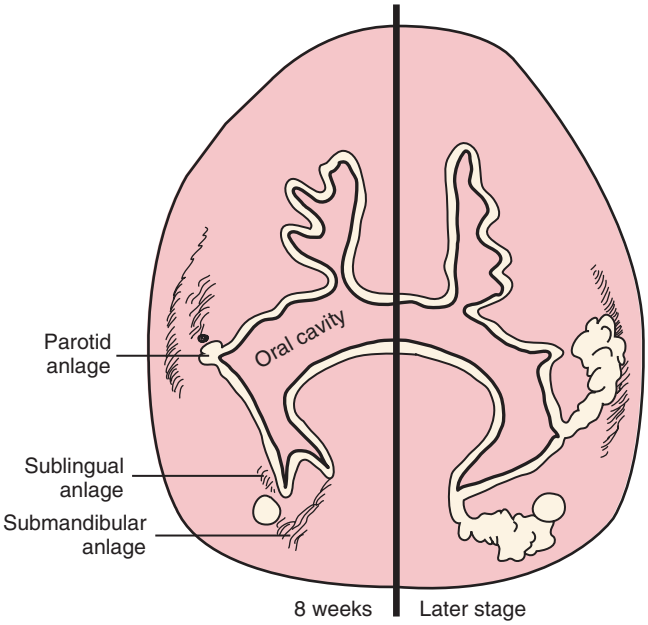
CHAPTER OUTLINE

As experts in the oral and maxillofacial region, the practicing dentist and dental specialist may be required to perform the necessary assessment, diagnosis, and management of a variety of salivary gland disorders ranging from minor, self-limiting disease processes to more significant disorders of the major and minor salivary glands; thus a thorough practical knowledge of the incidence, demographics, embryology, anatomy, and pathophysiology is necessary to manage these patients in the most appropriate manner. This chapter reviews the anatomy and physiology of salivary glands, as well as the etiologies, diagnostic methods, contemporary radiographic evaluation, and medical and surgical management of a variety of salivary gland disorders, including sialolithiasis and obstructive phenomena (e.g., mucocele and ranula), acute and chronic salivary gland infections, traumatic salivary gland disorders, Sjögren syndrome, necrotizing sialometaplasia, and benign and malignant salivary gland tumors.

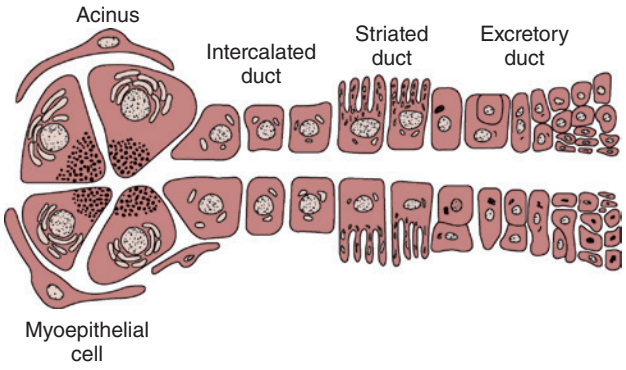
Embryology, Anatomy, and Physiology

The salivary glands are divided into two groups: (1) the *major glands* and (2) the *minor glands*. All salivary glands develop from the embryonic oral cavity as buds of epithelium that extend into the underlying mesenchymal tissues. These epithelial ingrowths, or anlages, are apparent anatomically at 8 weeks' gestation (Fig. 21.1) and then branch to form a primitive ductal system that eventually becomes canalized to provide the basic salivary gland unit for the production and drainage of salivary secretions (Fig. 21.2). This unit consists of an *acinus* (or secretory unit), which is a cluster of cells including *myoepithelial cells* and *acinar (secretory) cells* with secretory granules that coalesce into the collecting ducts that include the *intercalated duct*, followed by the *striated duct*, and finally the *excretory duct*; each ductal unit consists of unique acinar cells with branching ducts. The minor salivary glands begin to develop around the fortieth day in utero, whereas the larger major glands begin to develop slightly earlier, at about the thirty-fifth day in utero. At around the seventh or eighth month in utero, secretory cells called *acini* begin to develop around the ductal system. The acinar cells of the salivary glands are classified either as *serous cells*, which produce a thin, watery serous secretion, or *mucous cells*, which produce a thicker, more viscous mucous secretion. The minor salivary glands are well developed and functional in the newborn infant. The acini of the minor salivary glands produce primarily mucous secretions, although some are composed of serous cells as well; this results in the classification of these minor glands as *mixed*. Between 800 and 1000 minor salivary glands are present throughout the portions of the oral cavity that are covered by mucous membranes, with a few exceptions, such as the anterior third of the hard palate, the attached gingiva, and the dorsal surface of the anterior third of the tongue. The well-established locations of the minor salivary glands are referred to as *labial*, *buccal*, *palatine*, *tonsillar* (Weber glands), *retromolar* (Carmalt glands), and *lingual glands*. The lingual glands are divided into three groups of glands: (1) *inferior apical glands* (of Blandin and Nuhn), (2) *taste buds* (Ebner glands), and (3) *posterior lubricating glands* (Table 21.1).

The major salivary glands are paired structures and include the *parotid*, *submandibular*, *and sublingual glands*. The parotid glands contain primarily serous acini with few mucous cells. Serous cells



• **Fig. 21.1** Embryologic development of the major salivary glands.



• **Fig. 21.2** Basic salivary gland unit.

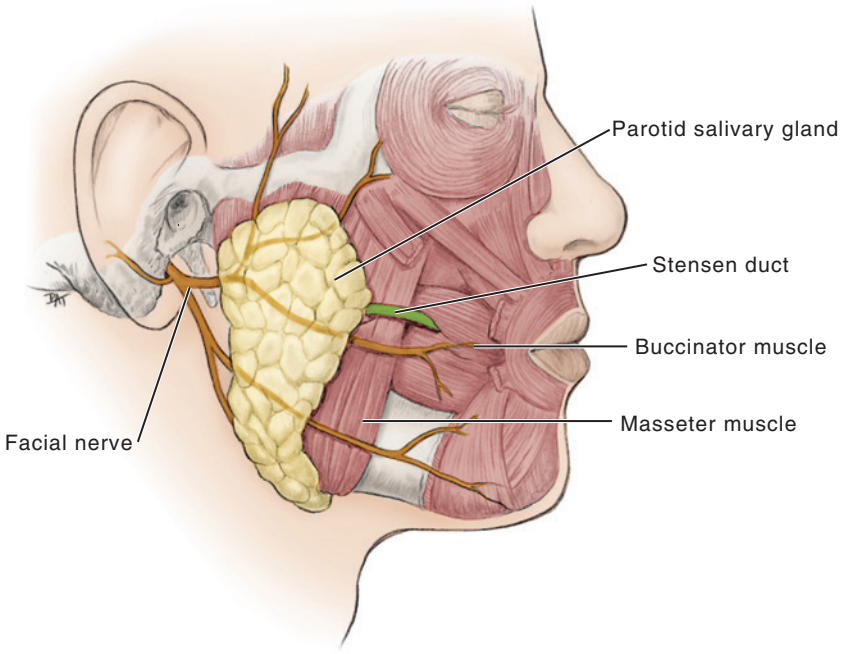
TABLE 21.1 Salivary Gland Embryology and Anatomy

	Minor Salivary Glands	Major Salivary Glands
In utero development	Day 40	Day 35
Number of glands	800–1000 minor glands	6 (3 paired glands)
Types of glands	Labial Buccal Palatine Tonsillar (Weber glands) Retromolar (Carmalt glands) Lingual 1. Inferior apical glands (of Blandin and Nuhn) 2. Taste buds (Ebner glands) 3. Posterior lubricating glands	Parotid Submandibular Sublingual

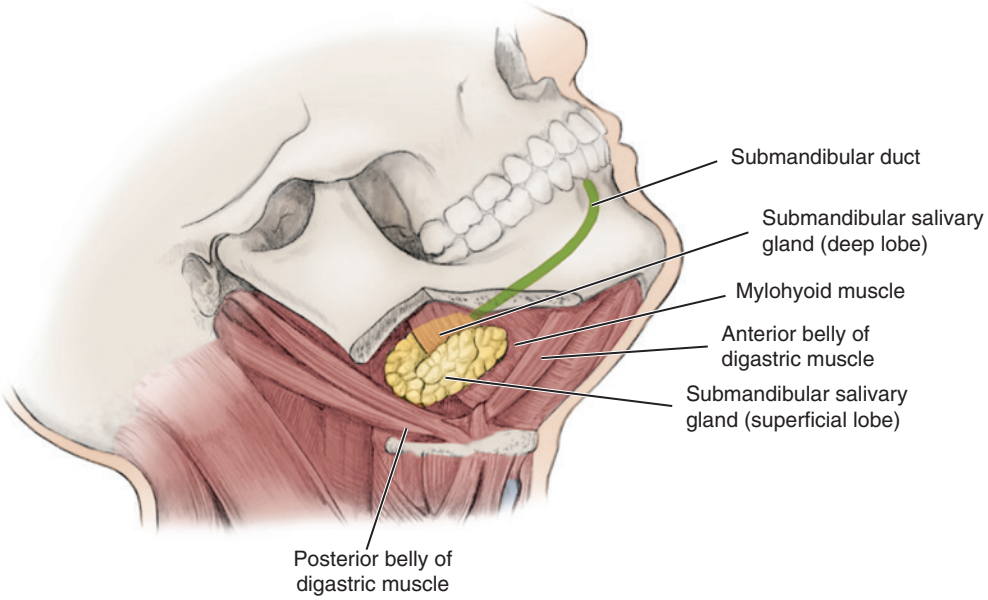
are cuboidal cells with eosinophilic secretory granules and produce thin, watery secretions with a low viscosity (1.5 Pa • s). Conversely, the sublingual glands are, for the most part, composed of mucous cells, which are clear low columnar cells with nuclei polarized away from the lumen of the acini, and produce a thick secretion with high viscosity (13.4 Pa • s). The submandibular glands are mixed glands, made up of approximately equal numbers of serous and mucous acini and thus produce a secretion with an intermediate viscosity of 3.4 Pa • s.

The *parotid glands*, the largest salivary glands, lie superficial to the posterior aspect of the masseter muscles and the ascending rami of the mandible, in an "inverted triangular" shape below the zygomatic arch. Peripheral portions of the parotid glands may extend to the mastoid process, along the anterior aspect of the sternocleidomastoid muscle, and around the posterior border of the mandible into the pterygomandibular space (Fig. 21.3). The major branches of the seventh cranial (facial, VII) nerve roughly divide the parotid gland into a superficial lobe and a deep lobe and course anteriorly from the exit of the nerve from the stylomastoid foramen to innervate the muscles of facial expression. Since the parotid gland contains the terminal branches of the facial nerve, this may explain why a mandibular block local anesthetic injection may result in transient facial paralysis if the anesthetic solution is deposited into the parotid gland as it extends around the posterior border of the mandible into the pterygomandibular space. Small ducts from various regions of the parotid gland coalesce at the anterosuperior aspect of the parotid gland to form the *Stensen duct*, which is the major duct of the parotid gland. The Stensen duct is about 1 to 3 mm in diameter and 6 cm in length. Occasionally a normal anatomic variation occurs in which an accessory parotid duct may aid the Stensen duct in the drainage of salivary secretions. In addition, an accessory portion of the parotid gland may be present anywhere along the course of the Stensen duct. The duct traverses anteriorly from the parotid gland hilum and courses in a position superficial to the masseter muscle. At the location of the anterior edge of the masseter muscle, the Stensen duct turns sharply in a medial direction and pierces through the fibers of the buccinator muscle. The Stensen duct opens into the oral cavity through the buccal mucosa as a punctum in the maxillary posterior buccal vestibule, usually adjacent to the maxillary first or second molar. The parotid gland receives neural innervation from the ninth cranial (glossopharyngeal) nerve via the auriculotemporal nerve from the otic ganglion (see Fig. 21.7).

The *submandibular glands* are located in the "submandibular triangle" of the neck, which is a triangle formed by (1) the anterior belly of the digastric muscle, (2) the posterior belly of the digastric muscle, and (3) the inferior border of the mandible (Fig. 21.4). The posterosuperior portion of the gland curves upward around and above the posterior border of the mylohyoid muscle and gives rise at the hilum to the major duct of the submandibular gland known as the *Wharton duct*. This duct passes forward along the superior surface of the mylohyoid muscle in the sublingual space, adjacent to the lingual nerve. The anatomic relationship in this area is such that the lingual nerve loops under the Wharton duct, from lateral to medial, in the posterior floor of the mouth; the lingual nerve then branches to provide sensory input to the anterior two-thirds of the tongue on each side of the tongue. Of course the glossopharyngeal nerve provides sensation to the posterior one-third of each side of the tongue, and the chorda tympani branch of the facial nerve provides taste sensation to the anterior two-thirds of the tongue. The Wharton duct continues forward in a straight line, and the lingual nerve traverses under the duct

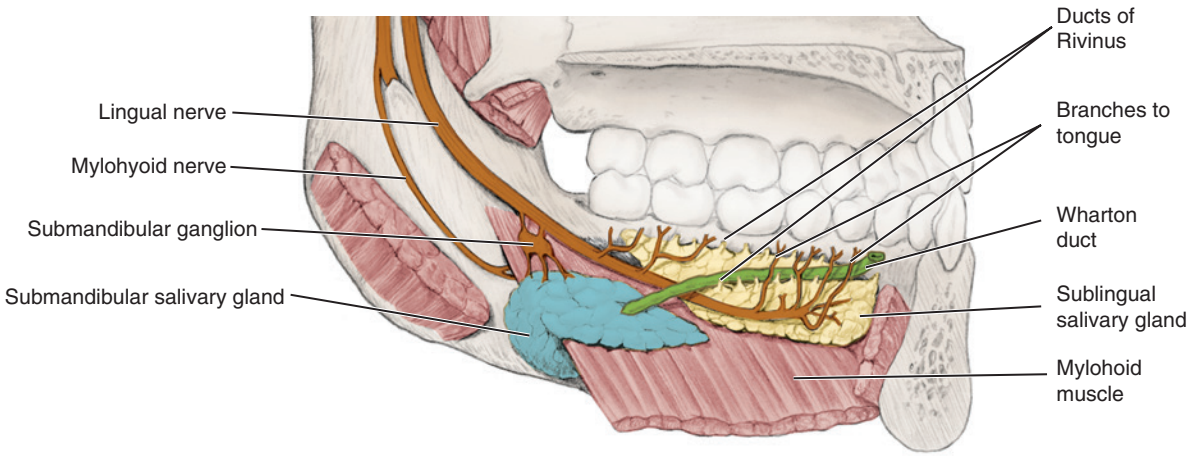


• **Fig. 21.3** Parotid gland anatomy. The facial nerve branches divide the gland into superficial and deep lobes. The Stensen duct courses superficial to the masseter muscle then curves sharply to pierce the buccinator muscle and enter the oral cavity.



• **Fig. 21.4** Submandibular gland anatomy. The submandibular triangle is formed by the anterior and posterior bellies of the digastric muscles and inferior border of the mandible. A portion of the gland may extend above the mylohyoid muscle. The Wharton duct courses superiorly and anteriorly to exit in the anterior floor of the mouth.

from a lateral position (beginning in the pterygomandibular space after separating from the inferior alveolar nerve) to a medial position. In a medial position, the Wharton duct is vulnerable to injury in the third molar region during third molar extraction surgery because it lies in a position close to the medial surface of the internal oblique ridge of the posterior mandible. Subsequently, as mentioned, the nerve turns in a medial direction to branch extensively into the tongue musculature bilaterally. The Wharton duct is about 5 cm in length, and the duct lumen is 2 to 4 mm in diameter. The Wharton duct opens into the floor of the mouth via a muscular punctum located close to the mandibular incisors at the most anterior aspect of the junction of the lingual frenum and the floor of the mouth. The punctum is a constricted portion of the duct, and it functions to limit retrograde flow of bacteria-laden oral fluids into the ductal system. This is particularly important since this punctum limits retrograde entry of those bacteria that tend



• **Fig. 21.5** Sublingual gland anatomy. Note the relationship of the Wharton duct and the lingual nerve.

TABLE 21.2 Composition of Normal Adult Saliva

	Parotid Gland	Submandibular Gland
Amino acids	1.5 mg/dL	<1 mg/dL
Ammonia	0.3 mg/dL	0.2 mg/dL
Bicarbonate	20 mEq/L	18 mEq/L
Calcium	2 mEq/L	3.6 mEq/L
Chloride	23 mEq/L	20 mEq/L
Cholesterol	<1 mg/dL	<1 mg/dL
Fatty acids	1 mg/dL	<1 mg/dL
Glucose	<1 mg/dL	<1 mg/dL
Magnesium	0.2 mEq/L	0.3 mEq/L
Phosphate	6 mEq/L	4.5 mEq/L
Potassium	20 mEq/L	17 mEq/L
Proteins	250 mg/dL	<150 mg/dL
Sodium	23 mEq/L	21 mEq/L
Urea	15 mg/dL	7 mg/dL
Uric acid	3 mg/dL	2 mg/dL

TABLE 21.3 Daily Saliva Production by Salivary Gland

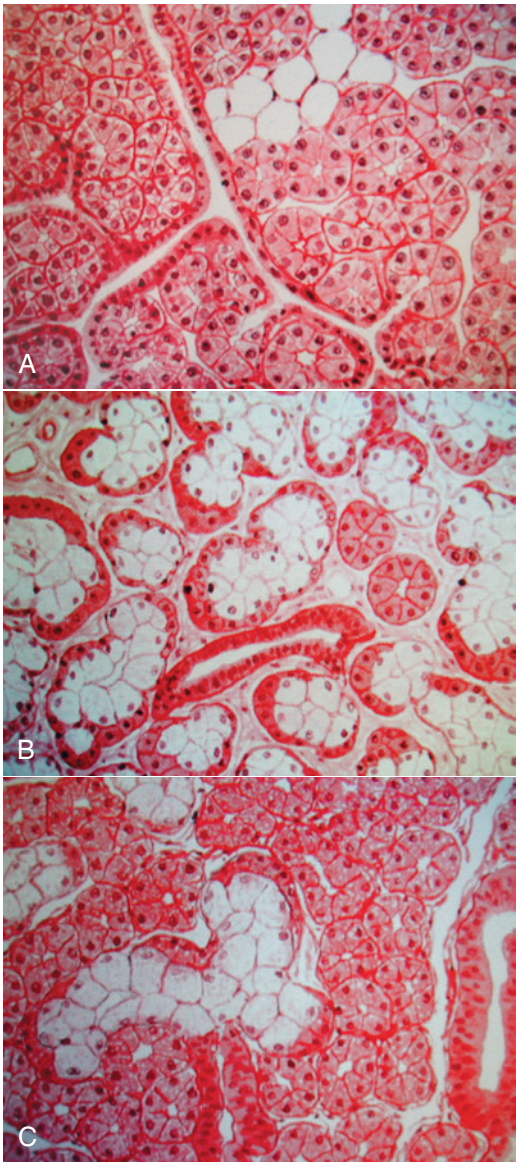
Gland	Production
Submandibular gland	70%
Parotid gland	25%
Sublingual gland	3%–4%
Minor glands	Trace

to colonize around the ductal orifices, such as *Staphylococcus aureus* and *Streptococcus* species.

The *sublingual glands* are located on the superior surface of the mylohyoid muscle, in the sublingual space, and are separated from the oral cavity by a thin layer of oral mucosa in the anterior floor of the mouth (Fig. 21.5). The main acinar ducts throughout the sublingual glands are called *Bartholin ducts* and in most instances coalesce to form 8 to 20 ducts of Rivinus. These Rivinus ducts are short and small in diameter, and they open individually, directly into the anterior floor of the mouth on a crest of mucosa known as the *plica sublingualis*; or, alternatively, they may open indirectly through connections to the submandibular duct and then into the oral cavity via the *Wharton duct*. The sublingual and submandibular glands are innervated by the facial (VII) nerve through the submandibular ganglion via the chorda tympani nerve (see Fig. 21.8).

The functions of saliva are to provide lubrication for speech and mastication, produce enzymes for digestion, and produce compounds with antibacterial properties (Table 21.2). The salivary glands produce approximately 1000 to 1500 mL of saliva per day, with the highest flow rates occurring during meal times. The relative contributions of each salivary gland to the total daily production vary, with the submandibular gland providing 70%, the parotid gland 25%, the sublingual gland 3% to 4%, and the minor salivary glands contributing only trace amounts of saliva (Table 21.3). The electrolyte composition of saliva also varies between the major salivary glands, with the parotid gland concentrations generally higher than the submandibular gland, except for submandibular gland calcium concentration, which is approximately twice the concentration of parotid calcium levels. The relative viscosities of saliva vary according to the specific gland involved and correspond to the relative percentages of mucous and serous cells in the gland; thus the highest viscosity saliva is found in the sublingual gland secretions composed of mostly mucous cells, followed by the submandibular gland secretions (mixed mucous and serous cells), and lastly, the parotid gland secretions with the lowest viscosity, which are composed mainly of serous cells (Fig. 21.6). Of note, the daily production of saliva begins to decrease gradually after the age of 20 years because of increased intraparenchymal fibrosis as well as decreased neural secretory stimulation.

The neurosecretory control of salivary production is derived from sympathetic and parasympathetic stimulation. The sympathetic innervation originates from the superior cervical ganglion nerve supply to the salivary glands via the vast arterial vascular plexus of the face. Parasympathetic control is different for each of the major salivary glands. The parasympathetic innervation to the parotid gland originates from the tympanic branch of the glossopharyngeal nerve (IX), which then travels via the lesser petrosal nerve to the otic ganglion. Postganglionic parasympathetic nerves then travel via the auriculotemporal nerve to the parotid gland (Fig. 21.7). The parasympathetic control of the submandibular



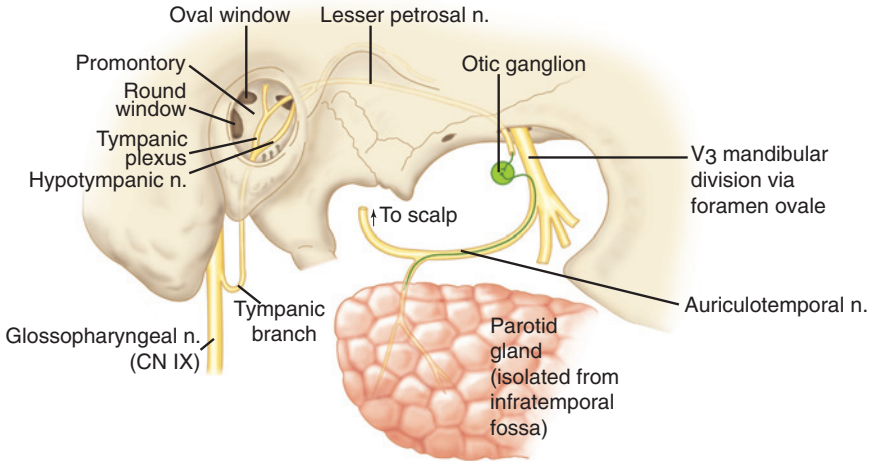
• **Fig. 21.6** (A) Parotid gland histology (serous cells). (B) Sublingual gland (mucous cells). (C) Submandibular gland (mixed mucous and serous cells). Note that some of the mucous cells (lighter color) have associated surrounding serous demilunes (darker color).

and sublingual glands originates in the superior salivatory nucleus, which travels via the facial nerve (chorda tympani branch) to the submandibular ganglion. Postganglionic parasympathetic nerves then travel directly to the submandibular gland or with the lingual nerve to the sublingual gland (Fig. 21.8).

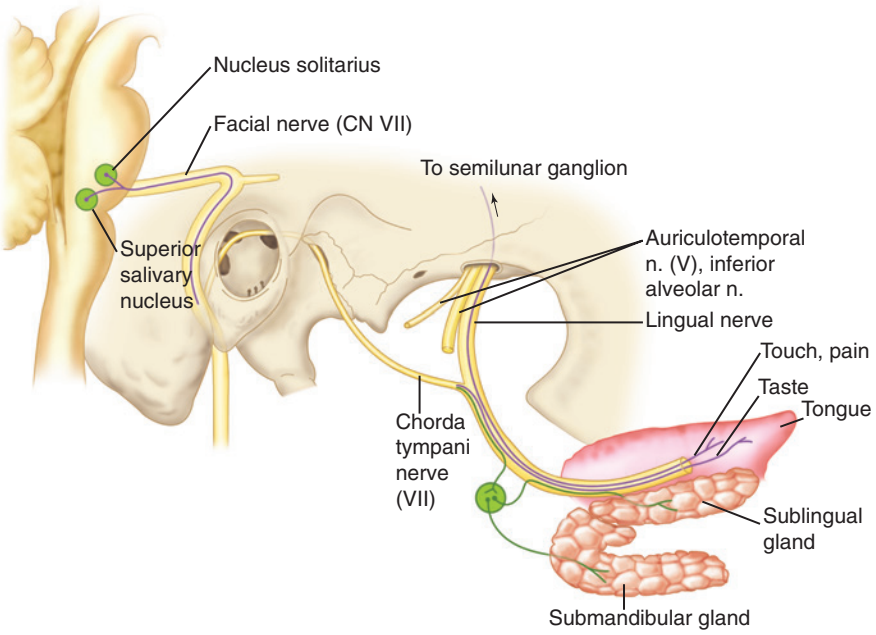
Diagnostic Modalities

History and Clinical Examination

The most important components of diagnosis in salivary gland disorders, as with other disease processes, are the patient history and clinical examination. In most cases, the patient will guide the doctor to the diagnosis merely by relating the events that have occurred in association with the presenting chief complaint. Specific questions should focus on the specific nature of the complaint(s), and whether the symptoms are exacerbated during mealtimes, which may indicate an obstructive phenomenon, or whether inadequate hydration has resulted in decreased salivary flow, if comorbidities may have contributed to the salivary gland complaints (e.g., autoimmune disease), or whether trauma has occurred (e.g., lip biting resulting in a mucocele). The astute clinician must perform a thorough clinical evaluation, and in many instances, the diagnosis can be determined without the need for further diagnostic testing. The clinical examination should include inspection and a bimanual palpation of the specific salivary gland with a determination of adequacy and normalcy of salivary flow, which may be accomplished through "milking" of the main duct of the gland to encourage drainage to assess the quantity and quality of the saliva produced. On occasion a lacrimal probe may be required to obturate the punctum of the gland duct (generally for the Stensen and Wharton ducts) to clear a mucous plug, salivary "sludge," or a small calculus so that a patent ductal system and normal salivary flow can be restored. At the very least, the clinician may be able to develop a differential diagnosis and categorize the problem as reactive, obstructive, inflammatory, infectious, metabolic, neoplastic, developmental, or traumatic, and this designation will guide further appropriate diagnostic testing. Occasionally the clinician may find it necessary to use any of several diagnostic modalities, including serum or salivary fluid electrolytes, salivary gland imaging studies, functional salivary studies, endoscopic salivary procedures, and salivary biopsy procedures to assist in establishing a diagnosis in salivary gland disease.



• **Fig. 21.7** Parotid gland innervation. *CN,* Cranial nerve.



• **Fig. 21.8** Submandibular and sublingual gland innervation. *CN,* Cranial nerve.

TABLE 21.4 Incidence of Radiopaque (vs. Radiolucent) Stones

Location	Incidence
Submandibular gland	80% radiopaque
Parotid gland	40% radiopaque
Sublingual gland	20% radiopaque
Minor glands	Rare

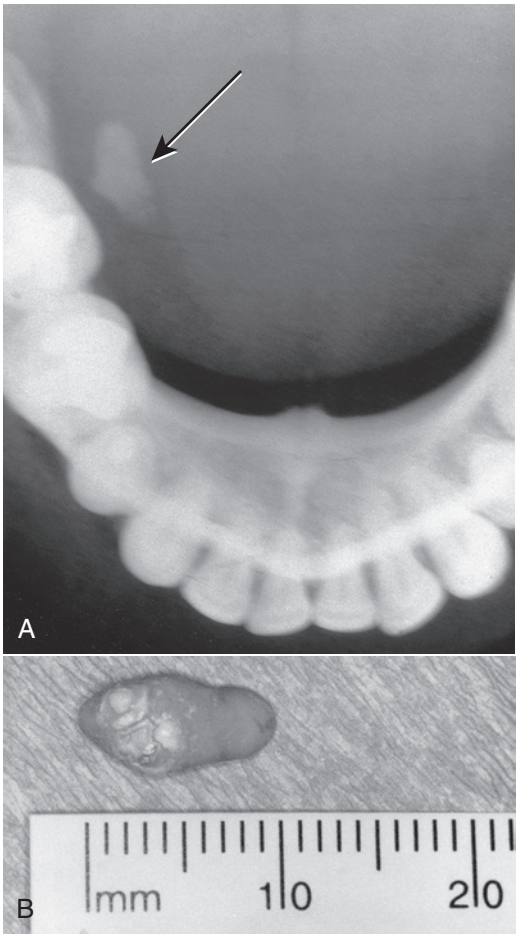
Salivary Gland Radiology

Plain-Film Radiographs

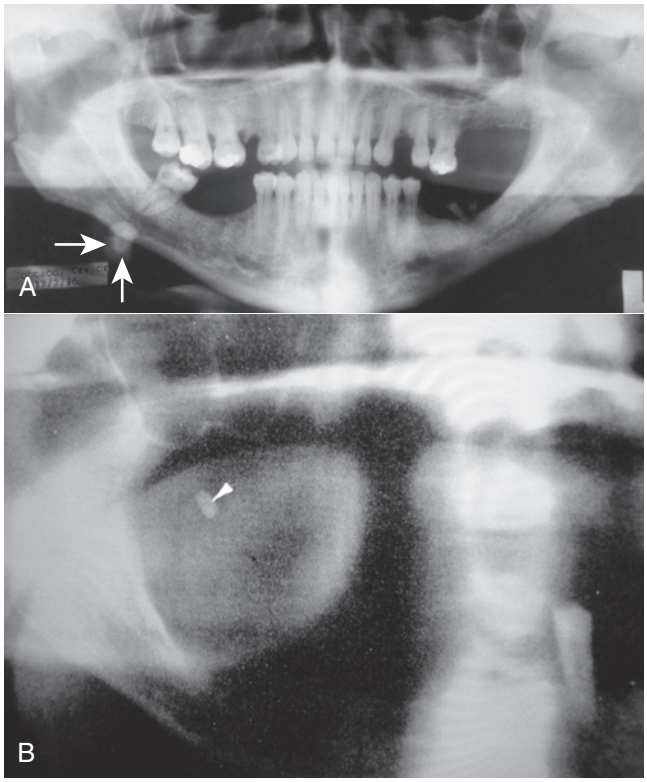
The primary purpose of *plain films*, or two-dimensional radiographs, in the assessment of salivary gland disease is to identify salivary stones (calculi), although only 80% to 85% of all stones are radiopaque and therefore visible radiographically. The incidence of radiopaque stones varies, depending on the specific gland involved, compared with the parotid glands having less radiopaque stones than the submandibular gland (Table 21.4). A *mandibular occlusal radiograph* is most useful for detecting sublingual and submandibular gland calculi in the anterior floor of the mouth (Fig. 21.9), although a high false-negative rate for detecting radiolucent stones or mucous plugs as the cause of obstruction does exist. In addition, a mandibular occlusal film may miss a posteriorly located stone. *Periapical radiographs* can show calculi in each salivary gland or duct, including minor salivary glands, depending on film placement. In most instances, when the stone is visible radiographically, the radiographic image corresponds in size and shape to the actual stone morphology. *Panoramic radiographs* can reveal stones in the parotid gland and may identify posteriorly located submandibular stones (Fig. 21.10).

Sialography

The gold standard in diagnostic salivary gland radiology is *sialography*, although this diagnostic study is performed less commonly



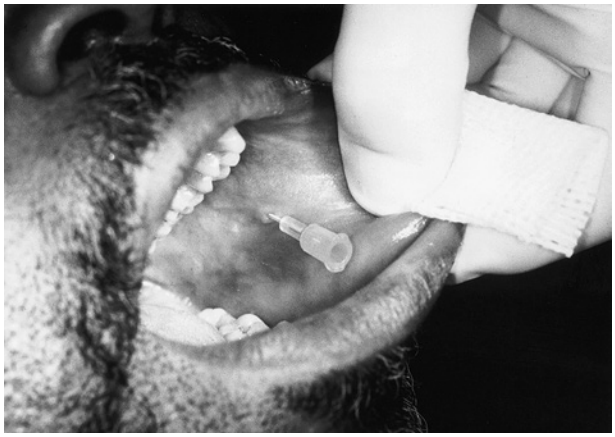
• **Fig. 21.9** (A) Mandibular occlusal radiograph showing a radiopaque sialolith *(arrow)*. (B) Submandibular sialolith (1 cm) after intraoral removal.



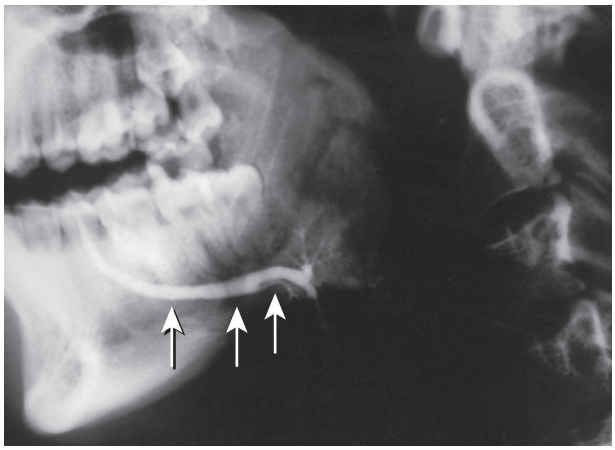
• **Fig. 21.10** (A) Panoramic radiograph demonstrates a right submandibular sialolith *(arrows)*. (B) Panoramic radiograph showing right parotid stone in Stensen duct *(arrowhead)*.

today with fewer radiologists having the necessary expertise to perform sialography. Sialography is indicated as an aid in the detection of radiopaque and radiolucent (15% to 20%) stones, as well as mucous plugs, because it can identify obstruction within the ductal system. In addition, sialography is also useful in the assessment of the extent of destruction of the salivary duct or gland parenchyma or both as a result of obstructive, inflammatory, traumatic, and neoplastic diseases. Also, sialography may be used as a therapeutic maneuver because the ductal system is dilated during the study, and small mucous plugs or necrotic debris (or "sludge") may be cleared during the injection of contrast medium into the ductal system.

The sialography technique can be easily performed under local anesthesia and includes the following steps: (1) *cannulation* of the salivary duct (Stensen or Wharton duct) with a plastic or metal catheter (Fig. 21.11), (2) *injection* of a radiographic contrast medium into the ductal system and the substance of the gland, and (3) *acquisition* of a series of radiographic images at various time points during this process. Approximately 0.5 to 1 mL of contrast material may be injected into the duct and gland before the patient begins to experience pain from ductal distension and retrograde filling of the gland parenchyma. The two types of contrast media available for sialographic studies are water-soluble solutions and oil-based solutions. Both types of contrast material contain relatively high concentrations (25% to 40%) of iodine. Most clinicians prefer to use water-soluble media, which are more miscible with salivary secretions, more easily injected, disseminated into the finer portions of the ductal system, and, after the study is completed, more readily eliminated from the gland by drainage through the duct or systemic absorption from the gland and excretion through the



• **Fig. 21.11** Cannulation of the Stensen duct with a plastic catheter and traction on the cheek to straighten the ductal curvature in this area.



• **Fig. 21.12** Ductal phase of a submandibular sialogram. Contrast medium is contained only within the main salivary ducts *(arrows)*.

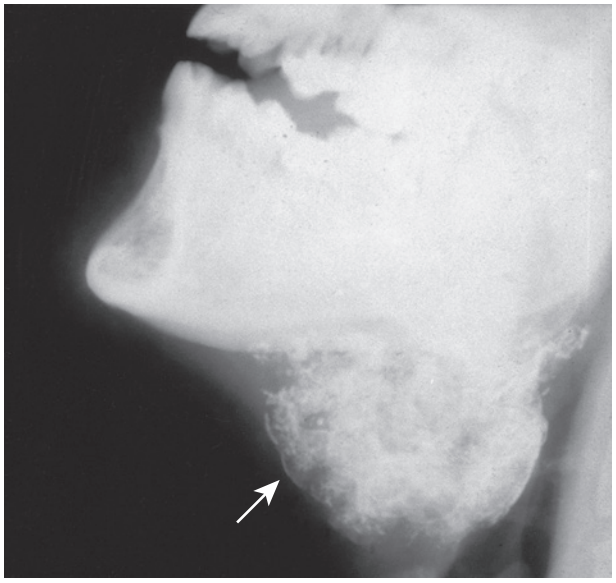
kidneys. Oil-based media are more viscous and require a higher injection pressure to visualize the smaller ductules compared with water-soluble media. As a result, oil-based media usually produce more discomfort to the patient during the injection process. Oil-based media are poorly eliminated from the ductal system and may cause persistent iatrogenic ductal obstruction following the sialogram. Also, any residual oil-based contrast medium not absorbed by the gland may produce severe foreign-body reactions and glandular necrosis following the sialogram. In addition, if the patient has ductal disruption resulting from chronic inflammatory changes, the extravasation of oil-based media into soft tissue around the gland may cause significantly more soft tissue damage compared with the water-soluble material.

Sialography provides the preliminary step in outlining the ductal morphology and localizing an obstruction, if present, thus providing a route map for therapeutic intervention. Important information that may be obtained during the sialogram study includes the size, number, position, and mobility of a stone(s), as well as the diameter of the distal duct and presence of stenosis within the ductal system. A complete sialogram consists of three distinct phases, depending on the time at which the radiograph is obtained after injection of the contrast material:

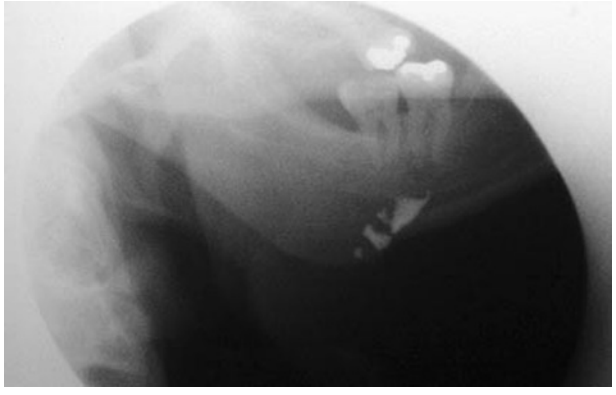
1. *Ductal phase* (Fig. 21.12), which occurs almost immediately after injection of contrast material and allows visualization of the major ducts

2. *Acinar phase* (Fig. 21.13), which begins within minutes after the ductal system has become fully opacified with contrast medium and the gland parenchyma becomes subsequently filled with contrast material
3. *Evacuation phase* (Fig. 21.14), which assesses normal secretory clearance and elimination function of the gland to determine whether any evidence remains of retention of contrast medium in the gland or ductal system during a period greater than 5 minutes after the contrast has been injected into the ductal system

Digital subtraction sialography has been shown to provide superior images of the ductal system, particularly images of the area where the path of the duct overlies, or is obstructed by, bony structures or the dentition. A normal ductal phase of a sialogram shows a large primary duct branching gradually and smoothly into secondary and terminal ductules, like the branches of a tree. In the acinar phase of the sialogram, the even distribution of contrast medium throughout the gland results in opacification of the entire acinoparenchyma that outlines the gland and its lobules. When a stone or mucous plug obstructs a salivary duct, continued functional secretion by the gland produces distention of the ductal system proximal to the obstruction (seen during the ductal phase of the sialogram) and finally leads to pressure atrophy of the parenchyma of the gland (seen during the acinar phase of the sialogram; Fig. 21.15). For the evacuation phase of the study, the retention of any contrast medium in the gland or ductal system beyond 5 minutes is considered abnormal, and the contrast should be eliminated completely out of the gland and ducts as seen on the final postevacuation radiograph.



• **Fig. 21.13** Acinar phase of a submandibular sialogram. Normal arborization of the entire ductal system of the gland *(arrow)*.



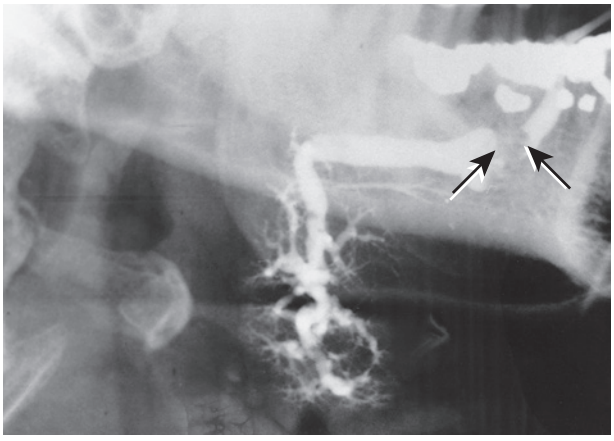
• **Fig. 21.14** Evacuation phase of a submandibular sialogram with some abnormal retention of contrast medium in the ductal system after 5 minutes.

Sialodochitis is a dilation of the salivary duct resulting from epithelial atrophy as a result of repeated inflammatory or infectious processes, with irregular narrowing caused by reparative fibrosis (i.e., "sausage link" pattern; Fig. 21.16). *Sialadenitis* represents inflammation mainly involving the acinoparenchyma of the gland. Patients with sialadenitis experience saccular dilation of the acini of the gland resulting from acinar atrophy and infection, which results in "pruning" of the normal arborization of the small ductal system of the gland (Fig. 21.17). Centrally located lesions or *tumors* that occupy a part of the gland or impinge on its surface will displace the normal ductal anatomy. On sialographic images, the ducts adjacent to the lesion are draped and stretched in a curvilinear fashion around the mass, producing a characteristic "ball-in-hand" appearance (Fig. 21.18).

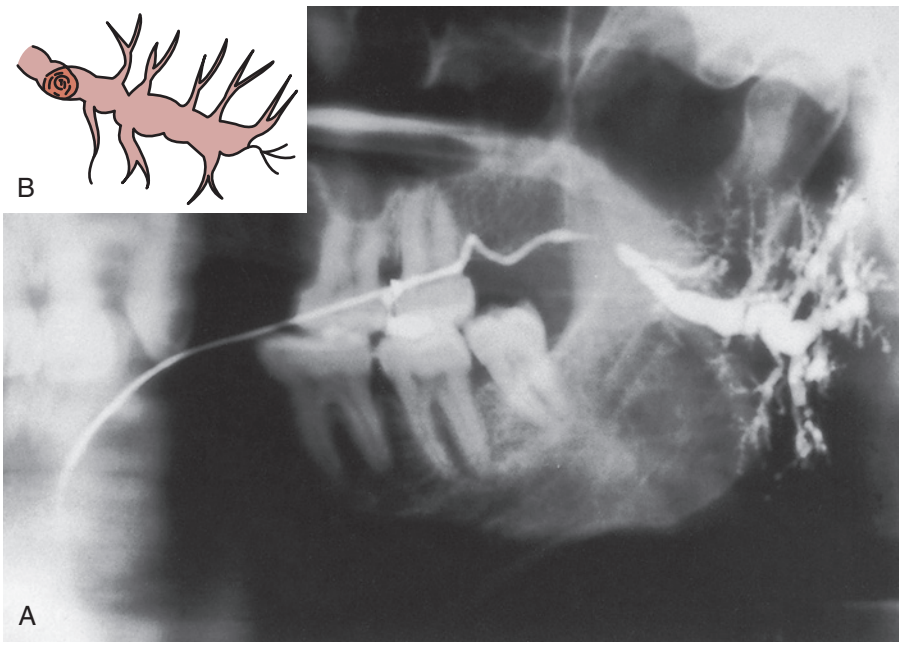
Sialograms are specialized radiologic studies performed by oral-maxillofacial surgeons and some interventional radiologists trained in the technique, although this is performed less commonly today than in the past. Those inexperienced in the performance of, or proper interpretation of, the sialogram should not attempt this examination. The three contraindications to sialography are (1) *acute salivary gland infections*, because a disrupted ductal epithelium may allow extravasation of contrast medium into the soft tissues and cause severe pain and possibly a foreign-body reaction; (2) patients with a *history of iodine sensitivity*, especially a severe allergic reaction after a previous radiologic examination using contrast medium; and (3) *preceding a thyroid gland study*, because retained iodine in the salivary gland or ductal system may interfere with interpretation of the thyroid gland scan.

Computed Tomography, Magnetic Resonance Imaging, Ultrasonography, and Positron Emission Tomography

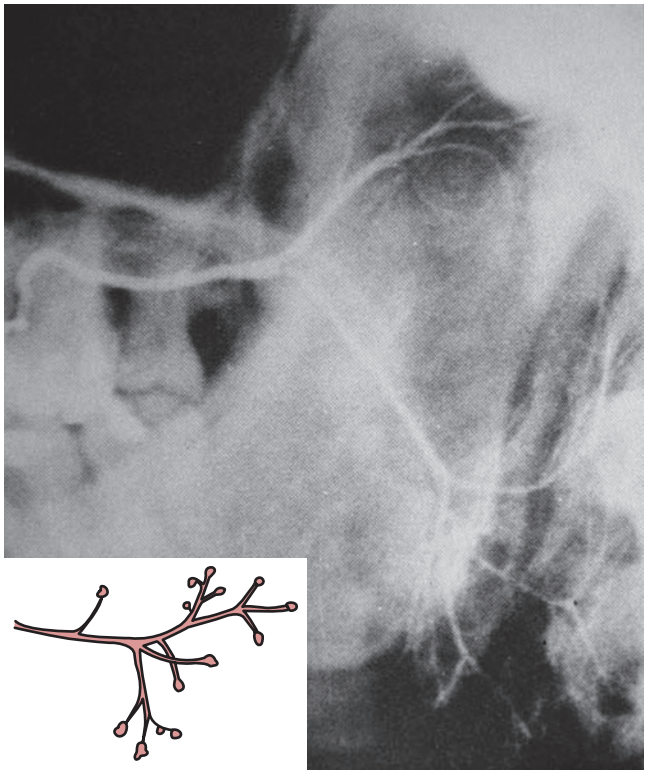
The use of *computed tomography* (CT) has been generally reserved for the assessment of mass lesions of the salivary glands. Although



• **Fig. 21.15** Sialogram of right submandibular gland. Obstruction of duct by a radiolucent sialolith *(arrows)* has caused inflammatory dilation of the proximal duct (sialodochitis) and loss of normal parenchyma of the gland (sialadenitis).

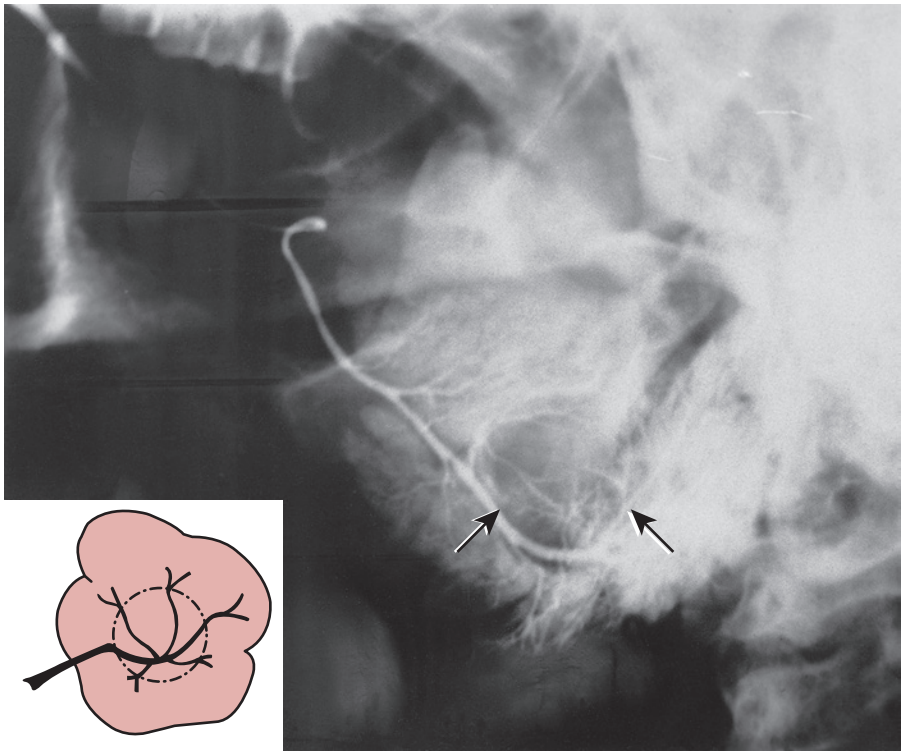


• **Fig. 21.16** (A) Sialogram of left parotid gland. The characteristic "sausage link" appearance of the duct indicates ductal damage from obstructive disease with irregular narrowing of duct caused by reparative fibrosis (sialodochitis). (B) Diagram inset of obstruction with proximal dilation of the ductal system.



• **Fig. 21.17** Parotid sialadenitis with acinar destruction from chronic disease. *Inset* shows "pruning of the tree" caused by acinar destruction.

CT scanning results in radiation exposure to patients, it is less invasive than sialography and does not require the use of contrast material or operator expertise in the sialography procedure. In addition, CT scanning can demonstrate salivary gland calculi, especially submandibular stones that are located posteriorly in the duct, at the hilum of the gland, or in the substance of the gland itself (Fig. 21.19). *Three-dimensional CT* imaging can allow much better resolution and delineation of the stone and of the ductal system in a noninvasive fashion (Fig. 21.20). The office-based *cone-beam computed tomography* (CBCT) technology has been evaluated with regard to the diagnosis of sialolithiasis in the major salivary glands, and, compared with ultrasonography, it was found



• **Fig. 21.18** Sialogram of left parotid gland illustrates the "ball-in-hand" phenomenon *(arrows)*. The filling defect indicates a tumor of the gland with displacement of normal surrounding ductal anatomy. *Inset* shows "ball-in-hand" phenomenon caused by tumor displacement of the gland.

to have high sensitivity and specificity. While dental artifacts and patient movement that result in poor image quality may limit its diagnostic value, the availability, low cost, and lower radiation doses of CBCT, compared with medical-grade CT imaging, makes it a valuable alternative for a noninvasive diagnosis of sialolithiasis.

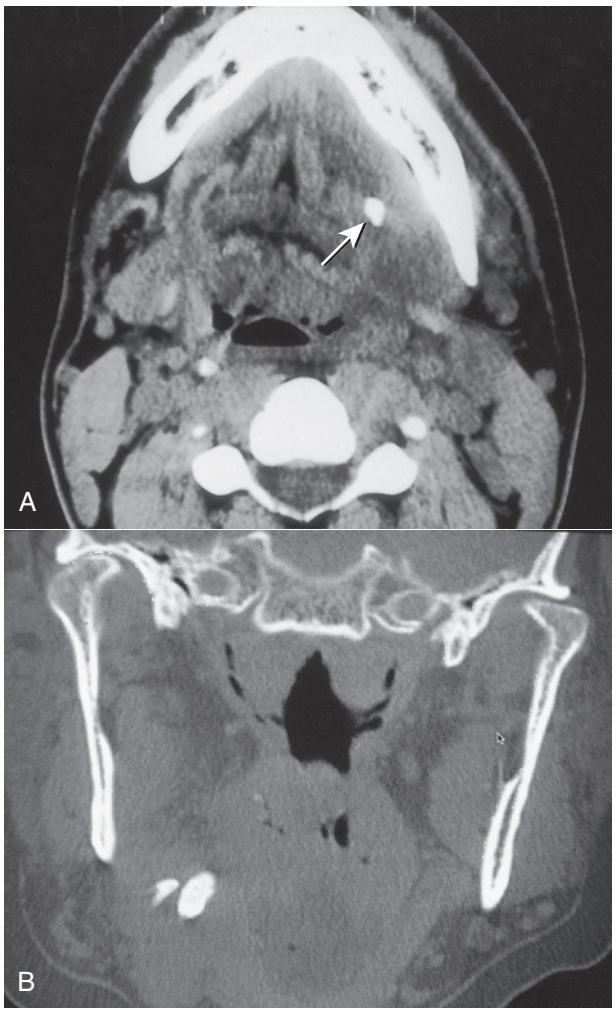
Magnetic resonance imaging (MRI) is superior to CT in delineating soft tissue details of salivary gland lesions, specifically tumors or other mass lesions, with no radiation exposure to the patient or the necessity of contrast enhancement. Three-dimensional MRI reconstruction and MRI virtual endoscopy of the ductal system have shown promising results in the visualization of abnormalities in conditions such as Sjögren syndrome, sialolithiasis, cysts, tumors, and inflammatory conditions. These advances in MRI may prove beneficial in evaluating and understanding the relationship of the ductal system to surrounding tissues as well as the endoluminal conditions of the ducts.

Current advances in *ultrasonography* technology have made this imaging modality extremely valuable in diagnosis of salivary gland pathology. Ultrasonography can provide high-resolution images, is noninvasive, has a low cost, and is an easily performed procedure that allows for accurate evaluation of the parotid and submandibular glands. In salivary gland tumor evaluation, important information regarding vascularization can be obtained with *color Doppler* ultrasonographic examination, which may aid in the differentiation of benign and malignant disease processes. Ultrasonography represents the most common examination method for nodular lesions and is useful to guide biopsies for diagnostic purposes (e.g., *fine-needle aspiration [FNA] biopsy*), especially when the clinical examination is limited because of a small size or difficult access location of the nodule. Finally, ultrasonography, with intraductal injection of contrast material, has been proposed as a complementary method for evaluation of obstructive salivary gland disease. In addition to the examination of the ductal system of the gland, parenchymal evaluation is possible with this ultrasound technique.

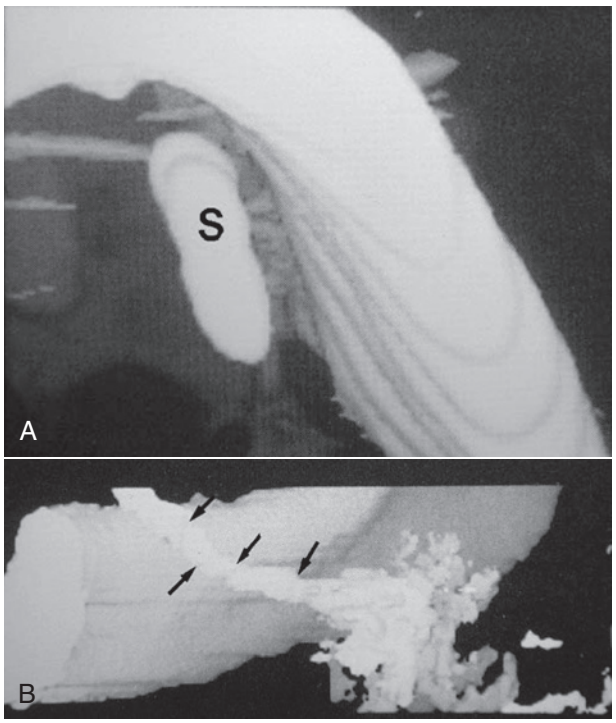
The role of *fluorodeoxyglucose positron emission tomography* (FDG-PET) scanning has been examined in the assessment and workup of salivary gland malignancies for diagnostic and treatment planning purposes. Initial reports have found FDG-PET to be of low value in distinguishing between benign and malignant lesions, as well as in the management of salivary gland malignancies. More recent studies though have demonstrated that the diagnostic accuracy of FDG-PET for the prediction of pathologic tumor extent and nodal involvement was superior to conventional CT for high-grade malignancies. Furthermore, FDG-PET was found to be clinically useful in both the initial tumor staging, as well as in the accurate evaluation of nodal involvement by cervical lymph node level and posttreatment evaluation and monitoring for recurrences (Fig. 21.21).

Salivary Scintigraphy (Radioactive Isotope Scanning)

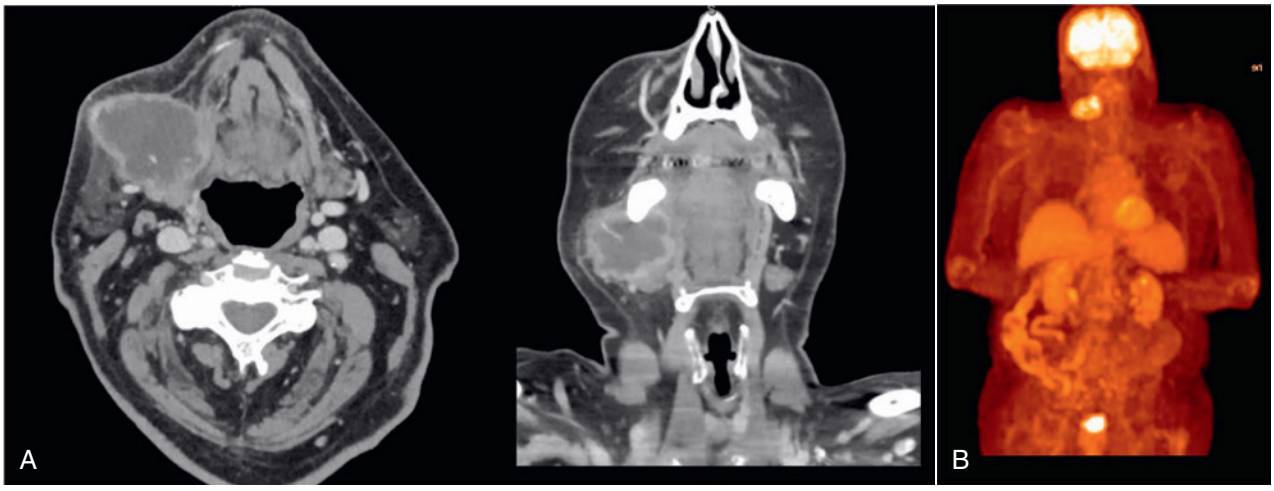
The use of nuclear imaging in the form of radioactive isotope scanning, or salivary scintigraphy *(sialoscintigraphy)*, allows a thorough evaluation of the salivary gland parenchyma with regard to the presence of mass lesions, as well as the function of the gland itself. This study uses a radioactive isotope, usually technetium-99m injected intravenously, which becomes distributed throughout the body and is taken up preferentially by a variety of tissues with an active rate of biological turnover, including the salivary glands. The major limitation of this study, other than radiation exposure, is the poor resolution of the images obtained. Salivary gland scintigraphy may demonstrate increased uptake of radioactive



• **Fig. 21.19** (A) Axial computed tomography (CT) scan of the mandible and floor of mouth shows a posterior submandibular sialolith *(arrow)*. (B) Coronal CT scan showing a two stones in the submandibular duct near the gland hilum.



• **Fig. 21.20** (A) Three-dimensional computed tomography (3D-CT) scan showing a large submandibular stone *(S)*. (B) 3D-CT scan showing irregular narrowing and destruction of the submandibular duct from chronic inflammation *(arrows)*.



• **Fig. 21.21** (A) Computed tomography scan of malignant neoplasm of right submandibular gland. (B) Corresponding fluorodeoxyglucose positron emission tomography scan showing the same malignant neoplasm of right submandibular gland.

isotope in an acutely inflamed gland or decreased uptake in a chronically inflamed gland, as well as the presence of a mass lesion, either benign or malignant in nature. Perhaps the most valuable application of sialoscintigraphy is in the diagnosis, therapeutic decision-making, and follow-up of patients with Sjögren syndrome. The American-European Consensus Group in 2002 established the scintigraphy scoring system (0 to 12 scale) and, based upon this scoring system, an abnormal scintigraphy study is an established criterion used in the diagnosis of Sjögren syndrome.

Salivary Gland Endoscopy (Sialoendoscopy)

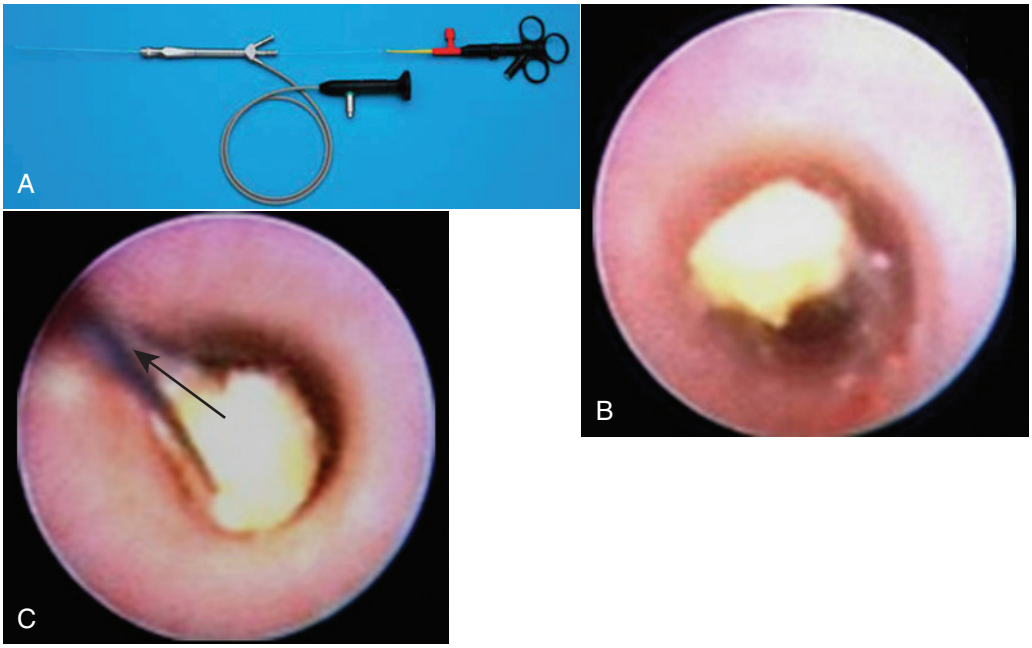
Minimally invasive modalities have been applied recently to the diagnosis and treatment of conditions related to the major salivary glands. Salivary gland endoscopy *(sialoendoscopy)* is a specialized procedure that uses a small video camera (endoscope) with a light at the end of a flexible cannula, that is introduced into the ductal orifice following dilation of the orifice. The endoscope can be used both diagnostically and therapeutically. Salivary gland endoscopy can demonstrate strictures and kinks in the ductal system, as well as mucous plugs and calcifications under indirect visualization on a video monitor. The endoscope may be used to dilate small strictures and flush small mucous plugs from the salivary gland ductal system. In addition, salivary gland stones located near the hilum, which are usually inaccessible from a transoral surgical approach, may be removed with flexible endoscopes and baskets, thereby avoiding removal of the gland, which is typically necessary with most posteriorly located or intrahilar stones. Since the initial introduction of endoscopy, advances have been made in the development of mini-endoscopes (diameter = 1.1 mm) with several ports for visualization, irrigation, and instrumentation of the ductal system. Specialized devices such as small balloon catheters (similar to those used for coronary angioplasty procedures) can be used to dilate sites of ductal constriction; also, small metal baskets or mini-forceps or graspers may be introduced into the duct for direct stone retrieval (Fig. 21.22). In addition, a small laser or lithotripsy device may be used through the endoscope to induce fragmentation of a large stone into smaller stones, thereby making them amenable to basket retrieval or spontaneous evacuation from the duct with fluid irrigation of the ductal system following lithotripsy.

Sialochemistry

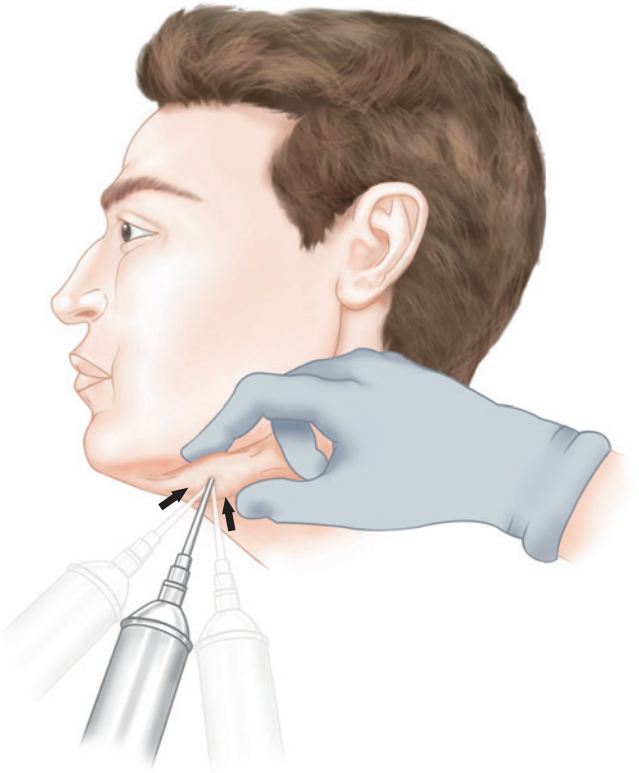
An examination of the electrolyte composition of the saliva (see Table 21.2) of each major salivary gland may indicate a variety of salivary gland disorders and systemic disease processes. The clinical importance of salivary chemical determinations *(sialochemistry)* has become more widespread, and some of these applications include endocrine functional assessment, drug concentration monitoring, antibody–antigen measurements, and dynamic diagnostic testing. Principally the concentrations of sodium and potassium, which normally change with changes in salivary flow rate, are measured. Certain changes in the relative concentrations of these electrolytes are seen in specific salivary gland diseases. For example, an elevated sodium (Na) concentration with a decreased potassium (K) concentration may indicate an inflammatory sialadenitis. Most recently, in the area of head and neck oncology, tremendous interest and advances have been made in salivary proteomics for molecular markers to assist in the detection and diagnosis of oral squamous cell carcinoma.

Fine-Needle Aspiration Biopsy

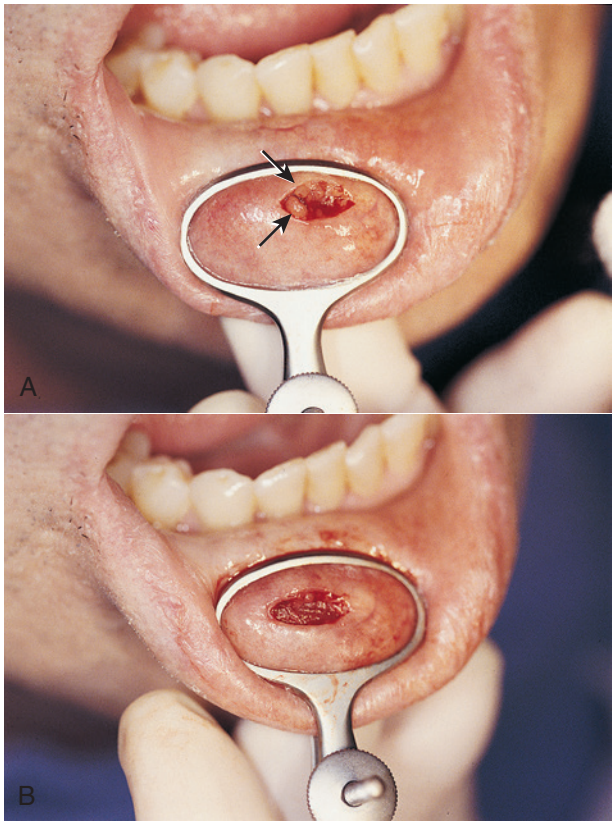
The use of *FNA biopsy* in the diagnosis of salivary gland tumors has been well documented. This procedure has a high accuracy rate for differentiating benign versus malignant lesions in superficial locations throughout the head and neck region. FNA biopsy is performed using a syringe with a 20-gauge or smaller needle. After regional local anesthetic administration, the needle is advanced into the mass lesion, the plunger is activated to create a vacuum



• **Fig. 21.22** (A) Salivary gland endoscope with ports for visualization, illumination, irrigation, and instrumentation. (B) Endoscopic view of a stone on the ductal system. (C) Endoscopic retrieval of a stone with a mini-forceps grasper technique *(arrow)*.



• **Fig. 21.23** Fine-needle aspiration biopsy technique of a submandibular gland mass lesion with multiple redirectional passes of the needle in the lesion.



• **Fig. 21.24** (A) Labial salivary gland biopsy. The lower lip is everted with a chalazion clamp. An incision through mucosa permits visualization of the minor salivary glands *(arrows)*. (B) The minor salivary glands (5 to 10) have been removed (note orbicularis oris muscle) and submitted for histologic assessment.

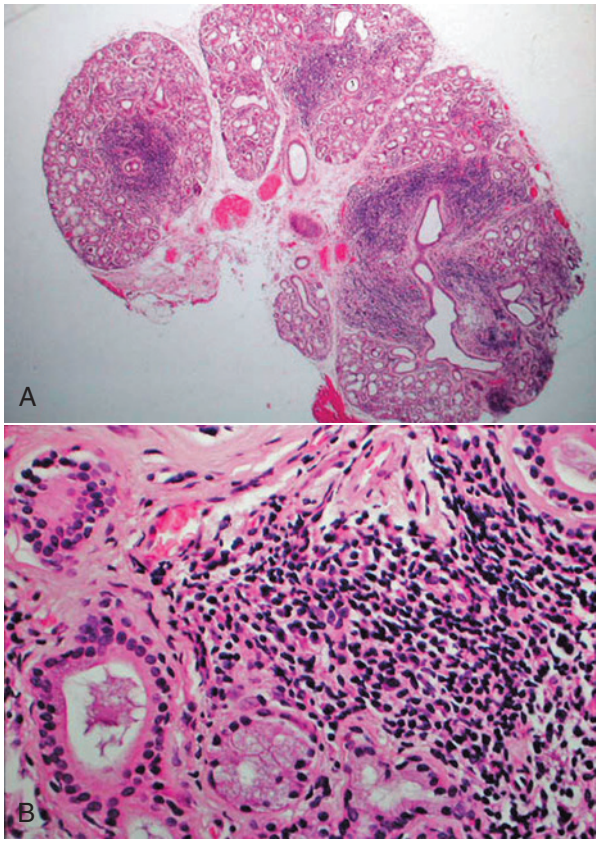
in the syringe, and the needle is advanced back and forth throughout the mass, with pressure maintained on the plunger (Fig. 21.23). The pressure is then released, the needle is withdrawn, and the cellular material and fluid are expelled onto a slide and prepared and fixed for histologic examination. This allows an immediate determination of benign versus malignant disease; this FNA examination also offers the possibility of providing a precise and accurate tissue diagnosis, especially if the oral and maxillofacial surgeon and oral and maxillofacial pathologist have excellent communication during the process and are experienced in performing and interpreting the results of this examination.

Salivary Gland Biopsy

A *salivary gland biopsy*, incisional or excisional, may be used to diagnose a lesion of one of the major or minor salivary glands, but it is also commonly performed as an aid in the diagnosis of Sjögren syndrome. The lower lip labial salivary gland biopsy has been shown to demonstrate certain characteristic histopathologic changes that are seen in the major glands in patients with Sjögren syndrome, thereby avoiding the need for an open biopsy of the parotid gland with increased morbidity to establish the diagnosis. The procedure is performed using regional local anesthesia. A circular chalazion clamp is useful to isolate the area and to aid in hemostasis. Approximately 5 to 10 minor salivary glands are removed for histologic examination, and the mucosa is closed with resorbable suture (Fig. 21.24). The labial minor salivary glands are then examined histologically, and they are assigned a *focus score*. A "focus" represents an aggregate of 50 or more lymphocytes, histiocytes, and plasma cells per 4 mm^2 of salivary gland tissue at high power (Fig. 21.25). The diagnosis of Sjögren syndrome is supported by a focus score greater than one, indicating the presence of one or more foci in the minor salivary gland tissue.

Obstructive Salivary Gland Disease: Sialolithiasis

The formation of stones, or calculi, may occur throughout the body, including the gallbladder, the biliary system, the urinary tract, as well as the salivary glands. The occurrence of salivary gland stones *(sialolithiasis)* is twice as common in men, with a peak incidence between 30 and 50 years of age. Multiple stone formation occurs in approximately 25% of patients with salivary calculi. Traditional etiopathogenic factors associated with stone formation are obstruction, reduced salivary flow rate, dehydration, change in salivary pH associated with oropharyngeal sepsis, and impaired crystalloid solubility. Physiologically, *microliths* (small sialoliths) can be detected following precipitation in a supersaturated solution of mucous plugs or membrane phospholipids within redundant secretory vesicles. These microliths may become symptomatic and act as a nidus on which successive layers of organic and inorganic substances are deposited to create a larger concretion or sialolith that will eventually obstruct the ductal system. Most recently, a retrograde theory of lithogenesis has been proposed; in this theory, a retrograde migration of food, bacteria, foreign bodies, and debris from the oral cavity enter the ductal system. These



• **Fig. 21.25** (A) Labial salivary gland biopsy specimen in a patient with Sjögren syndrome (note the presence of three foci of lymphocytes in the three gland lobules at low power). (B) A high-power view showing one focus (>50 lymphocytes) and normal adjacent acinar tissue.

TABLE 21.5 Incidence of Sialolithiasis (by Gland)

Location	Incidence
Submandibular gland	85%
Parotid gland	10%
Sublingual gland	5%
Minor glands	Rare

small particles then act as the nidus that leads to stone formation, and this process is facilitated by the sphincter actions of the ductal orifices that act to maintain the debris within the ductal system, preventing the normal self-flushing action of the gland.

The incidence of stone formation varies, depending on the specific gland involved (Table 21.5). The submandibular gland is involved in 85% of cases, which is more common than all other glands combined. A variety of factors contribute to the higher incidence of submandibular calculi. Salivary gland secretions contain water, electrolytes, urea, ammonia, glucose, fats, proteins, and other substances. Although parotid secretions are more concentrated than those of the other salivary glands, the main exception is the concentration of calcium, which is about twice as abundant in submandibular saliva as in parotid saliva (see Table 21.2). In addition, the alkaline pH of submandibular saliva may further support stone formation. In addition to salivary composition, several

• BOX 21.1 Sialolithiasis for the General Dentist

Signs and Symptoms

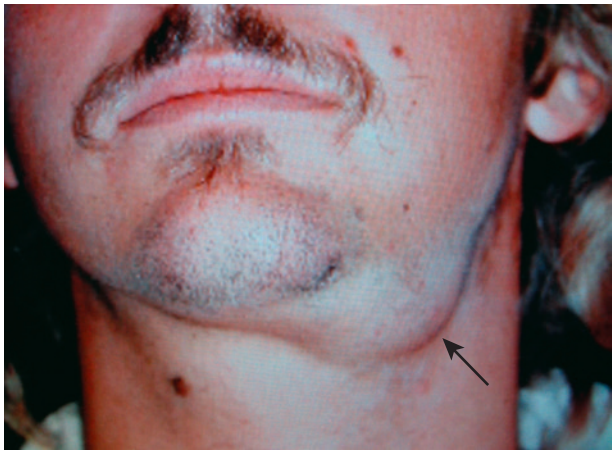
- Pain and swelling of the submandibular gland at mealtimes
- Tenderness to palpation of submandibular gland
- Cervical lymphadenopathy
- Constitutional symptoms (e.g., fever, malaise)
- Reduced salivary flow, or purulence, from Wharton duct
- Palpable stone at orifice of Wharton or Stensen duct
- Occlusal film, Panorex, or cone-beam computed tomography may show stone in duct

Treatment

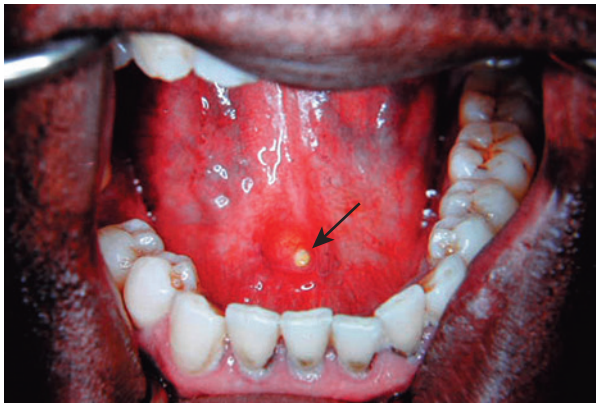
- Anterior Wharton duct stone
  - "Milk" gland with bimanual palpation to express stone
  - Dilate Wharton duct with lacrimal probes
  - Do not to displace stone posteriorly
  - If successful, prescribe salivary stimulants
- Posterior stone, or no stone visualized
  - Refer to oral/maxillofacial surgeon

anatomic factors of the submandibular gland and duct are important in the pathogenesis of stone formation. The Wharton duct is the longest salivary duct; therefore saliva has a greater distance to travel before evacuation into the oral cavity. In addition, the duct of the submandibular gland has two sharp curves in its course: (1) one at the posterior border of the mylohyoid muscle near the hilum of the gland and (2) one near the ductal opening in the anterior floor of the mouth. Finally, the punctum of the submandibular duct is smaller than the opening of the Stensen duct and may contribute to the reduction in salivary flow elimination from the Wharton duct. These features contribute to a slowed salivary flow and provide potential areas of stasis of salivary flow, or obstruction, which are not commonly found in the parotid or sublingual ductal systems. Precipitated material, mucous, and cellular debris are more easily trapped in the tortuous and lengthy submandibular duct, especially when its small orifice is its most elevated location, and its flow, therefore, occurs against the force of gravity throughout the entire course from the gland to the ductal opening. The precipitated material then forms the nidus for mucous plugs and sialoliths (radiopaque or radiolucent, depending on the calcium concentration and degree of stone maturation), and these may eventually enlarge to the point of partial or complete obstruction of the flow of saliva from the gland into the oral cavity.

The clinical manifestations of the presence of submandibular stones become apparent when acute ductal obstruction occurs at mealtime, when saliva production is at its maximum and salivary flow is stimulated. The resultant swelling is sudden and usually very painful (Box 21.1; Fig. 21.26). Gradual reduction of the edema follows, but swelling recurs repeatedly whenever salivary flow is stimulated against a fixed obstruction. This process may continue until complete obstruction, infection, or a combination of both occurs. Obstruction, with or without infection, may cause atrophy of the secretory cells of the involved gland. Infection of the gland manifests with swelling in the floor of the mouth, erythema, and an associated cervical lymphadenopathy. Bimanual palpation of the gland extraorally in the submandibular triangle and intraorally at the posterior floor of the mouth with "milking" of the gland and duct to stimulate salivary flow may reveal a complete absence of salivary flow or the presence of purulent discharge through the ductal orifice.



• **Fig. 21.26** Left submandibular edema *(arrow)* caused by obstruction from a submandibular sialolith.

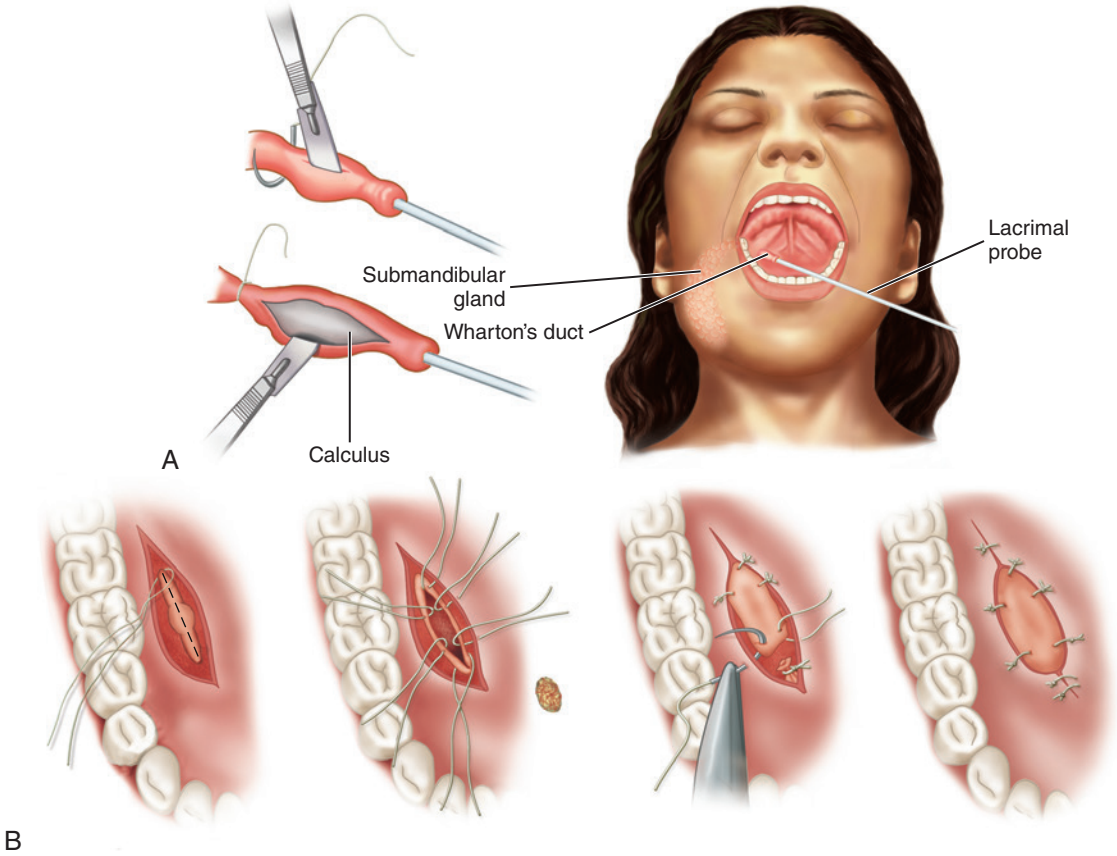


• **Fig. 21.27** Stone at the orifice of the Wharton duct that is amenable to intraoral removal *(arrow)*.

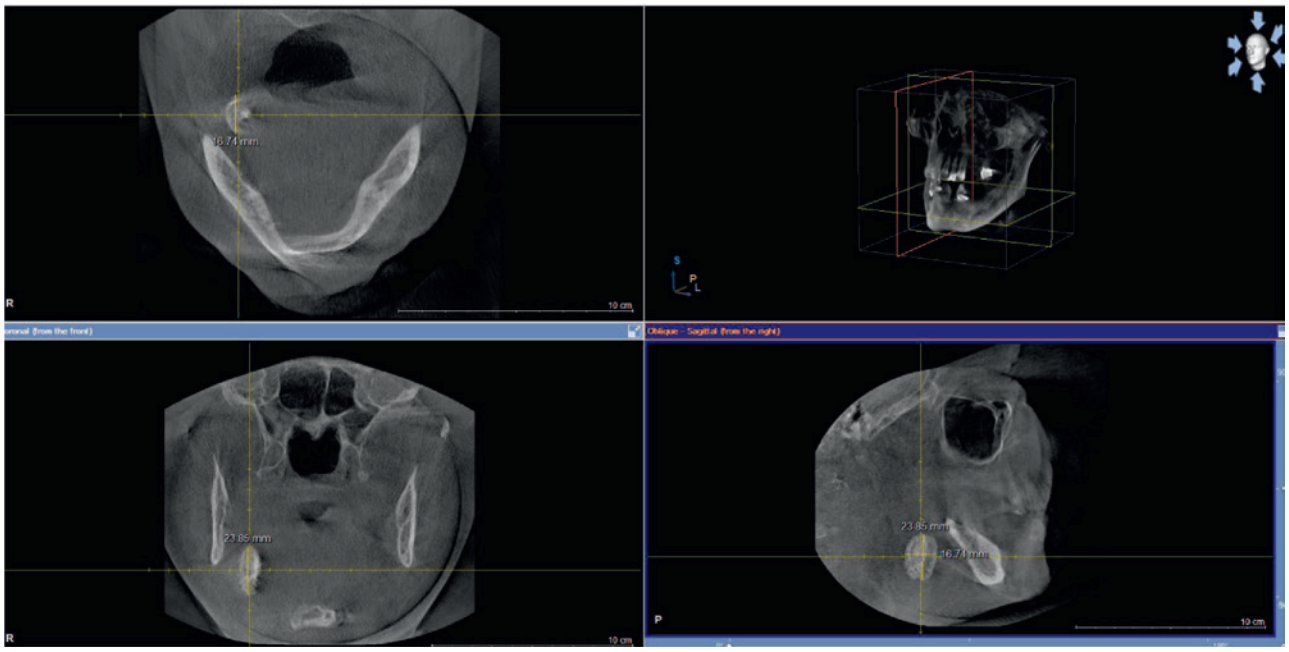
Sialolithiasis in children is rare, with only 3% of the cases reported in the pediatric population. Boys are more commonly affected compared with girls, and the left submandibular gland is most commonly affected. As discussed previously, the diagnosis may be made clinically and confirmed radiographically by plain films, ultrasonography, CT or CBCT, sialography, or sialoendoscopy.

The management of submandibular gland calculi depends on the duration of symptoms, the number of repeated episodes, the size of the stone, and, perhaps most importantly, the location of the stone. Submandibular stones are classified as *anterior* or *posterior* stones in relation to a transverse line drawn across the mandibular arch between the mandibular first molars. Stones that occur anterior to this line are generally well-visualized on a mandibular occlusal radiograph and may be amenable to intraoral removal. Small anteriorly located stones may be retrieved through the ductal opening after dilation of the orifice (Fig. 21.27). Occasionally it becomes necessary to remove submandibular stones via an incision made in the floor of the mouth to expose the duct and the stone (*sialodochotomy*; Fig. 21.28A). A suture is passed around the duct proximal to the stone to prevent propagation of the stone further toward the hilum of the gland. A lacrimal probe may be used to locate the ductal orifice and to estimate the direction of the duct in the floor of the mouth. Following exposure of the Wharton duct, a longitudinal incision is made in the duct directly over the palpable stone, the stone is retrieved, and the ductal lining is sutured to the mucosa of the floor of the mouth (see Fig. 21.28B). The duct is not repaired directly, since this might lead to scarring and stricture following healing that might lead to recurrence of the obstruction. With the duct edges sutured to the floor of mouth mucosa, saliva will flow out of the revised ductal opening and not through the original ductal orifice anteriorly. This procedure, known as a *sialodochoplasty* (i.e., revision of the salivary duct), eliminates many of the factors that contributed to formation of the stone: the entire length of the duct is decreased, the revised opening created is now larger, the punctum is eliminated, and the influence of gravity leading to salivary stasis is lessened. On occasion, a cannula may be left in the new ductal opening to prevent scarring and stricture, but regardless of the specific procedure performed, patients are encouraged to maintain ample salivary flow by using salivary stimulants such as citrus fruits, flavored candies, or at least glycerin swabs during the first few weeks following the procedure. Posterior stones occur in up to 50% of cases and may be located at the hilum of the gland or within the substance of the gland itself, making intraoral removal difficult because of limited access. A routine mandibular occlusal film will likely not demonstrate the stone because of its posterior position, thus a panoramic radiograph, a CT, or a CBCT scan may be necessary to localize the stone (Fig. 21.29). In cases of posterior stones that cannot be palpated intraorally, and in many instances of repeated chronic stone formation with classic signs and symptoms, an extraoral approach for removal of the gland *(sialoadenectomy)* and the associated stone(s) may be required (Fig. 21.30). Recently, however, this concept has been challenged, since it has been demonstrated that functional restoration of the gland after stone removal was found in 78% of the cases using scintigraphy, whereas 50% of the glands removed were normal on histopathologic examination. *Shock wave lithotripsy* may represent a better alternative to sialoadenectomy for treatment of sialolithiasis, especially in the era of minimally invasive gland-sparing procedures. Lithotripsy may be extracorporeal with piezoelectric or electromagnetic techniques or intracorporeal using electrohydraulic, pneumatic, or laser endoscopic devices. Extracorporeal approaches have shown promising results in clinical trials, and specifically, extracorporeal shock wave lithotripsy is considered the treatment of choice for all parotid calculi and submandibular perihilar or intraparenchymal stones measuring less than 7 mm in greatest dimension, when the technology and expertise are available. Several of the intracorporeal methods, although reported to be successful in the urological literature, have not made it into clinical application in the head and neck region because of several risks identified via in vitro studies.

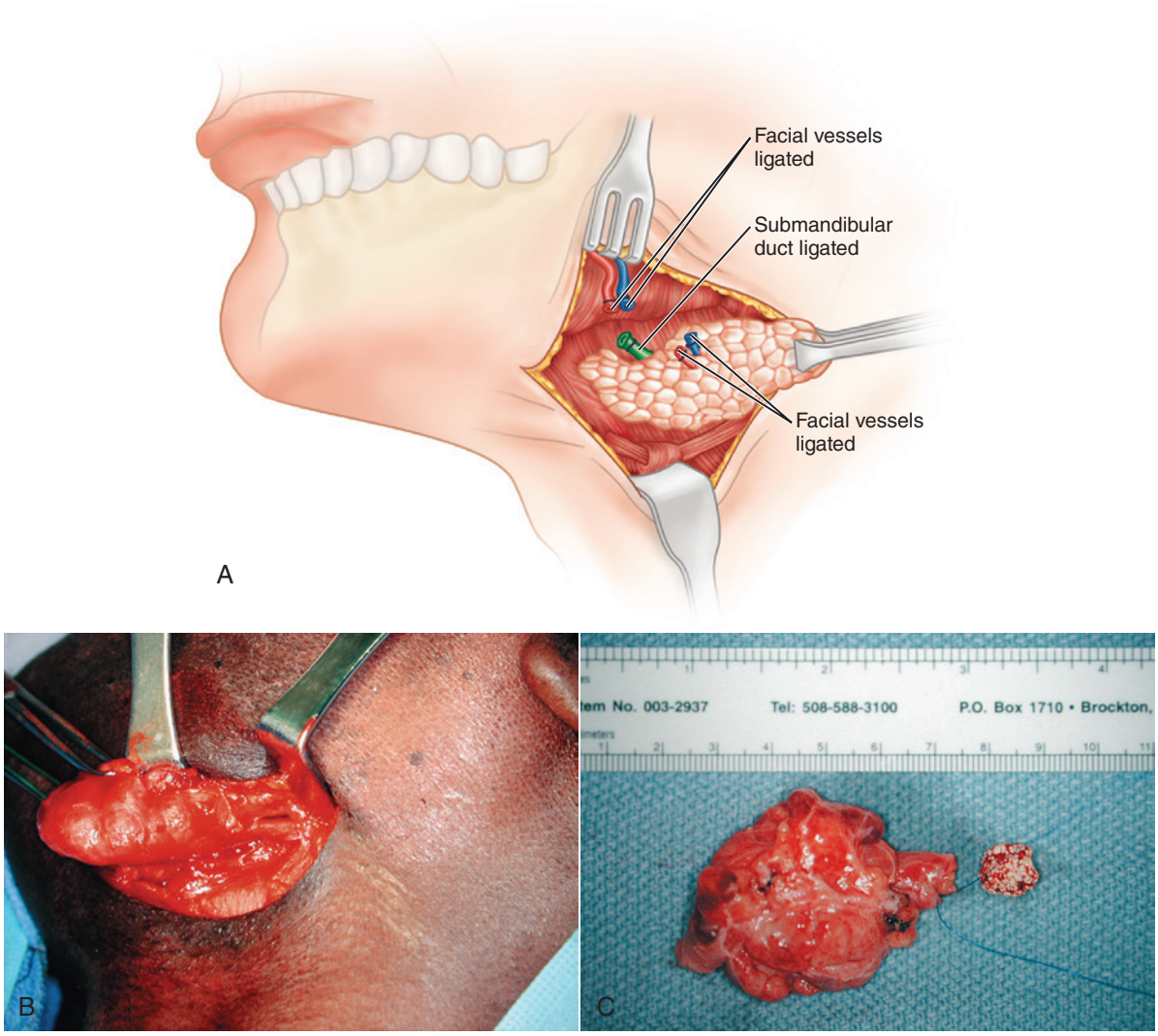
Salivary gland calculi occur much less commonly in the parotid gland. The parotid gland is examined by inspection and palpation of the gland extraorally over the ascending mandibular ramus. The Stensen duct and its orifice can be examined intraorally in the buccal mucosa adjacent to the maxillary first or second molar. Palpation of the gland and simultaneous observation of the duct allow observation of salivary flow or the production of other material such as purulence, from the punctum of the duct. Parotid sialoliths found in the distal third of the Stensen duct, which can be palpated intraorally, may be removed after dilation of the duct orifice or, if slightly more proximal, may require surgical exposure to gain access to the stone. On rare occasions, the presence of a parotid stone at the hilum of the gland or within the gland itself may necessitate an extraoral approach to remove the stone and possibly the superficial lobe of the parotid gland *(superficial parotidectomy)*.



• **Fig. 21.28** (A) Surgical opening of the submandibular duct (sialodochotomy) and removal of the stone (sialolithectomy). Note the lacrimal probe in the orifice of the Wharton duct and the suture passed proximal to stone to prevent displacement. (B) Duct revision occurs by suturing the duct to the floor of mouth mucosa (sialodochoplasty) and tying off the distal end of the duct.



• **Fig. 21.29** Con-beam computed tomography of right submandibular sialolith.



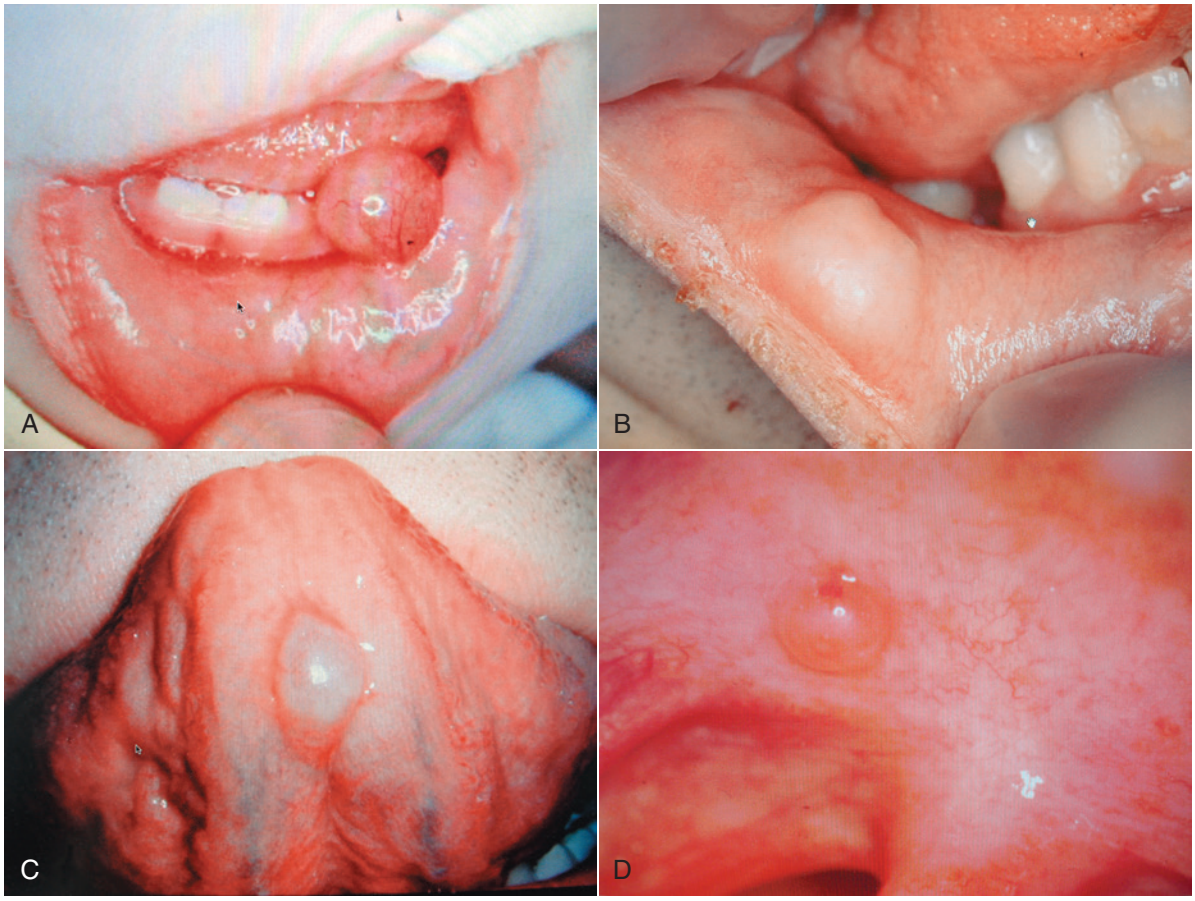
• **Fig. 21.30** (A) Diagram of extraoral cervical approach for removal of the submandibular gland. (B) Submandibular gland removal (sialoadenectomy). (C) Specimen of submandibular gland and associated stone.

Obstruction of the sublingual gland as a result of stone formation is unusual, but if it occurs, it is usually the result of obstruction of the Wharton duct on the same side of the oral cavity because of the intimate association between the ducts of Rivinus and Wharton ducts, as discussed previously. Although stone formation is rare in the sublingual and minor salivary glands, the treatment is simple excision of the sublingual gland *(sialoadenectomy)* and associated stone *(sialolithectomy)*. The sublingual gland is examined by observation and bimanual palpation of the submental region extraorally and the anterior third of the floor of the mouth intraorally.

Mucous Retention and Extravasation Phenomena

Mucocele

Salivary ducts, especially those of the minor salivary glands, are occasionally traumatized, commonly by lip biting, and are severed or disrupted beneath the surface mucosa. Subsequent saliva production may then extravasate beneath the surface mucosa into soft tissue. Over time, secretions accumulate within the tissue and may produce a pseudocyst (a cyst without a true epithelial lining) that contains thick, viscous saliva. These lesions are most common in the mucosa of the lower lip and are known as *mucoceles* (Fig. 21.31). The second most common site of mucocele formation is the buccal mucosa. Mucocele formation results in an elevated, thinned, and stretched overlying mucosa that appears as a vesicle filled with a clear or blue-gray fluid. The patient frequently relates a history of the lesion filling with fluid, rupture of the fluid collection, and refilling of the lesion. Some instances of mucocele formation regress spontaneously without surgery, while repeated trauma may induce the formation of a fibroma. For persistent or recurrent lesions, the preferred treatment consists of excision of the mucocele and the associated minor salivary glands that contributed to its formation to prevent recurrence in that same location (Fig. 21.32). For lower lip mucoceles, regional local anesthesia is administered via a mental nerve block, and an incision is made through the mucosa. Careful dissection around the mucocele may permit its complete removal; however, in many cases, the thin lining ruptures and decompresses the mucocele before removal. The associated minor salivary glands are removed as well and sent



• **Fig. 21.31** Mucoceles of (A) lower lip, (B) buccal mucosa (fibrotic appearance due to chronic trauma), (C) ventral tongue, and (D) soft palate.

for histopathologic evaluation. The recurrence rates of mucoceles may be as high as 15% to 30% after surgical removal, possibly caused by incomplete removal or repeat trauma to the residual minor salivary glands.

Ranula

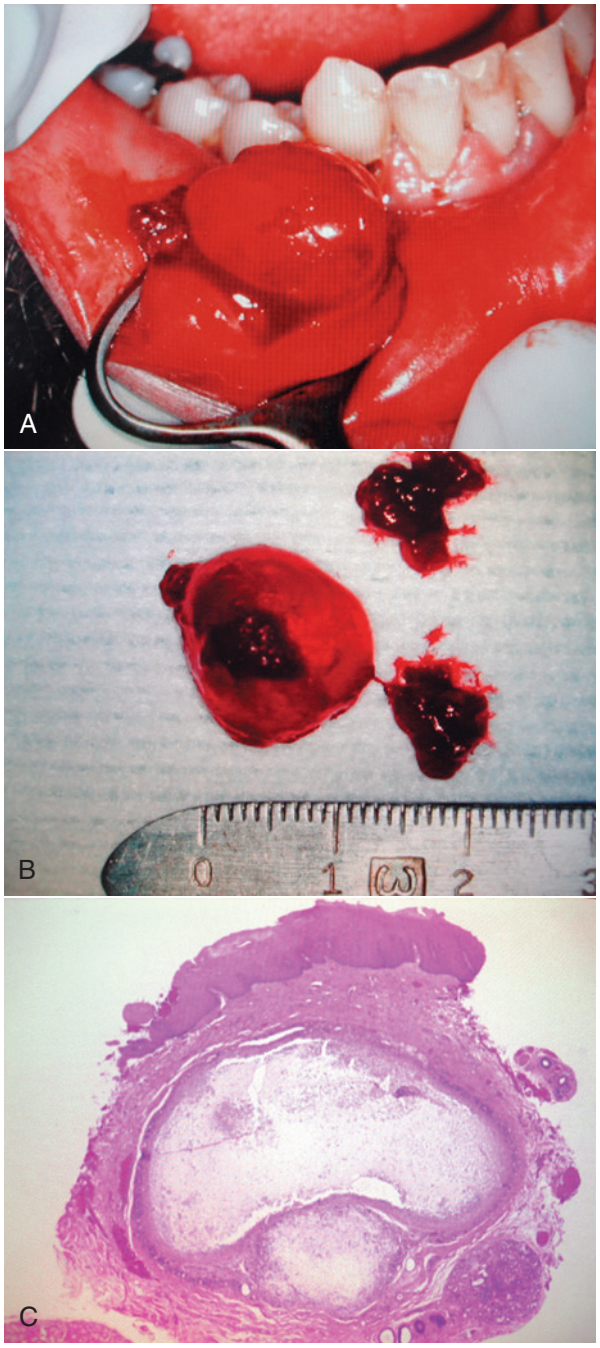
The most common lesion of the sublingual gland is the *ranula*, which may be considered a mucocele of the sublingual salivary gland. Ranulas result from mucous retention in the sublingual gland ductal system or mucous extravasation as a result of ductal disruption caused by inflammation or trauma. The two types of ranulas are the *simple ranula* and the *plunging ranula*. The simple ranula is confined to the area occupied by the sublingual gland in the sublingual space, superior to the mylohyoid muscle (Fig. 21.33). The progression of a simple ranula to a plunging ranula occurs when the lesion extends through and below the level of the mylohyoid muscle into the submandibular space (Fig. 21.34). Ranulas may reach a larger size than mucoceles because their overlying mucosa is thicker, and they occur less commonly because trauma that would cause their formation is less likely in the anterior floor of the mouth. As a result, a plunging ranula has the potential to extend through the mylohyoid muscle into the neck and compromise the airway, resulting in a medical emergency.

The differential diagnosis of a floor of mouth swelling includes ranula, lymphoepithelial cyst, epidermoid or dermoid cyst, salivary gland tumors (e.g., mucoepidermoid carcinoma), and mesenchymal tumors (e.g., lipoma, neurofibroma, or hemangioma). The differential diagnosis of a midline neck mass includes thyroid enlargement (i.e., goiter or tumor), thyroglossal duct cyst, dermoid cyst, and plunging ranula. The differential diagnosis of a lateral neck mass includes lymphadenopathy, epidermoid cyst, lipoma, infectious mononucleosis, metastatic carcinoma, lymphoma, salivary gland tumors (e.g., submandibular gland or tail of the parotid gland), submandibular gland sialadenitis, lymphoepithelial cyst, sarcoidosis, tuberculosis, cat-scratch disease, cystic hygroma, carotid body tumor, or plunging ranula.

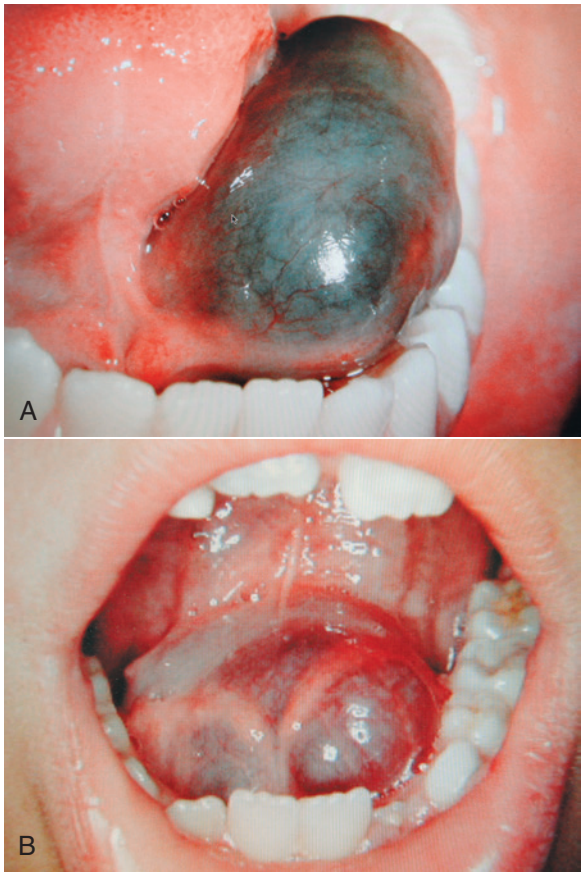
The usual treatment of a ranula is *marsupialization*, in which a portion of the oral mucosa of the floor of the mouth is excised, along with the superior wall of the ranula (Fig. 21.35). Subsequently the ranula wall is sutured to the oral mucosa of the floor of the mouth and allowed to heal by secondary intention with cicatrix (scar) formation and a decreased likelihood of recurrence. The preferred treatment for recurrent or persistent ranulas is excision of the ranula as well as the sublingual gland via an intraoral approach in the anterior floor of mouth (Fig. 21.36); several recent studies have indicated that this might be appropriate for initial therapy since the recurrence rate with marsupialization may be unacceptably high, especially in the pediatric patient population.

Salivary Gland Infections

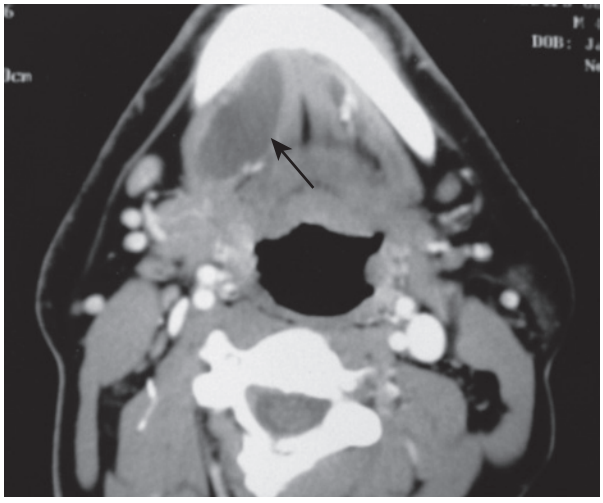
Infections of the major salivary glands can be acute or chronic and are commonly, but not always, related to obstructive disease,



• **Fig. 21.32** (A) Excision of mucocele of right lower lip using a chalazion clamp. (B) Gross specimen of intact mucocele and associated minor salivary glands. (C) Histologic specimen of a mucocele with epithelium (twelve o'clock position) and surrounding minor salivary glands (two o'clock and five o'clock positions).

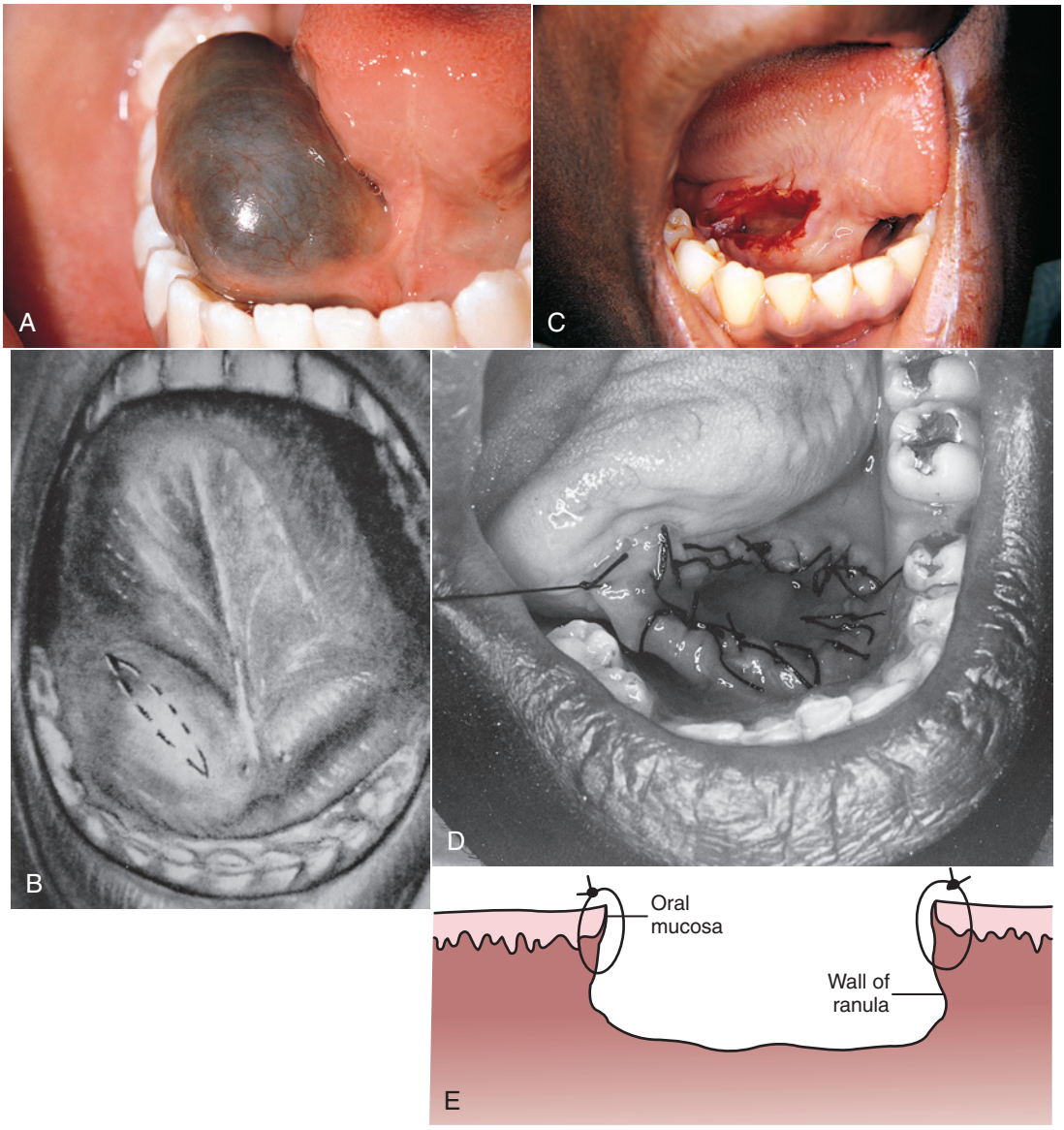


• **Fig. 21.33** (A) Left floor of mouth ranula. (B) Bilateral floor of mouth ranula. Note the bluish appearance of these ranulas from the high mucous (mucin) content.



• **Fig. 21.34** Right plunging ranula through the mylohyoid muscle seen on computed tomography scan *(arrow)*.

especially in the submandibular gland (where "obstruction leads to infection"). The cause of *acute suppurative sialadenitis* of the parotid gland usually involves a change in fluid balance that is likely to occur in older patients; those who are debilitated, malnourished, or dehydrated; or those with chronic illness or significant comorbidities. In these cases, most parotid gland infections are bilateral. The mean age of occurrence of salivary gland infections is 60 years, with a slight male predilection. Salivary gland infections may be caused by a variety of organisms, including aerobic and anaerobic bacteria, viruses, fungal organisms, and mycobacteria. In most cases, a mixed bacterial flora is responsible for *sialadenitis*, or inflammation or infection of the salivary glands. The single most common organism implicated in salivary gland infections is *S. aureus* because this organism normally colonizes around ductal orifices. In addition, during instances of decreased or slowed salivary flow (i.e., obstruction or dehydration), retrograde influx of *S. aureus*



• **Fig. 21.35** (A) Ranula in the right floor of mouth from accumulation of sublingual gland saliva in soft tissue due to ruptured salivary duct. (B) Elliptical marsupialization incisions. (C) Marsupialization of ranula, with excision of oral mucosa together with the superior wall of ranula. (D) Completion of marsupialization of left floor of mouth ranula with placement of circumferential sutures. (E) Completed marsupialization with ranula lining sutured to floor of mouth mucosa.

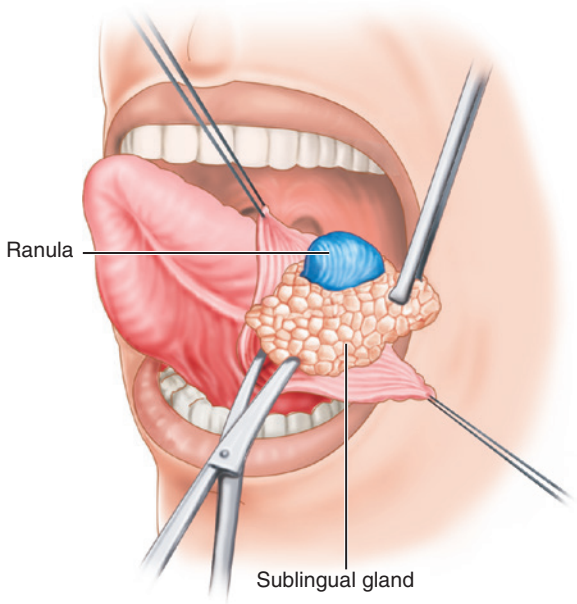
into the ductal system and gland occurs and may result in infection.

The clinical characteristics of acute bacterial salivary gland infections include rapid onset of swelling in the preauricular (parotid gland) or submandibular regions, with associated erythema and pain (Fig. 21.37). Palpation of the involved gland reveals no flow or elicits a thick, purulent discharge from the orifice of the duct (in this case, "infection leads to obstruction"; Fig. 21.38).

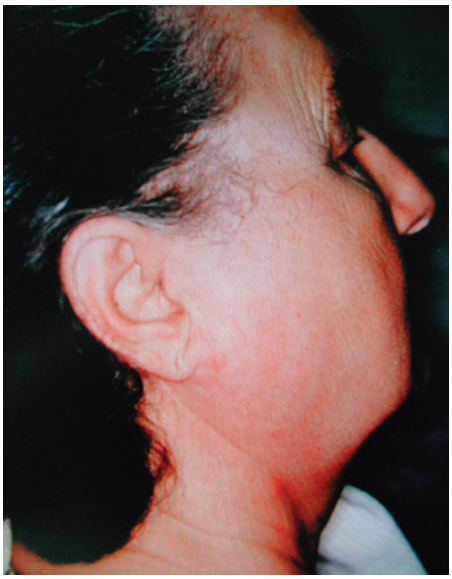
Treatment of bacterial salivary gland infections includes symptomatic and supportive care that includes intravenous fluid hydration, antibiotics, and analgesics. Initial empiric antibiotics should target the most likely causative organism, *S. aureus*, and should include a cephalosporin (first-generation) or antistaphylococcal semisynthetic penicillin (oxacillin or dicloxacillin). Culture and sensitivity studies of any purulent material should be obtained to aid in selecting the most appropriate antibiotic for each patient.

Antibiotics should be administered intravenously in high doses for the majority of these patients who ordinarily require hospitalization for intravenous hydration, pain control, and nutritional assessment. On most occasions, surgery, consisting of incision and drainage, becomes necessary in the management of salivary gland infections. Untreated infections may progress rapidly and can cause respiratory obstruction, septicemia, and eventually death. In some instances of recurrent salivary gland infection, the repeated insults result in irreversible impairment of gland function, in which case excision of the gland *(sialoadenectomy)* may be indicated.

Viral parotitis, or *mumps*, is an acute, nonsuppurative communicable disease. Prior to routine vaccination (e.g., measles, mumps, and rubella vaccine) against the disease, viral parotitis occurred in epidemics during the winter and spring seasons. The clinical differentiation of viral and bacterial salivary gland infections is important because viral infections are not the result of obstructive

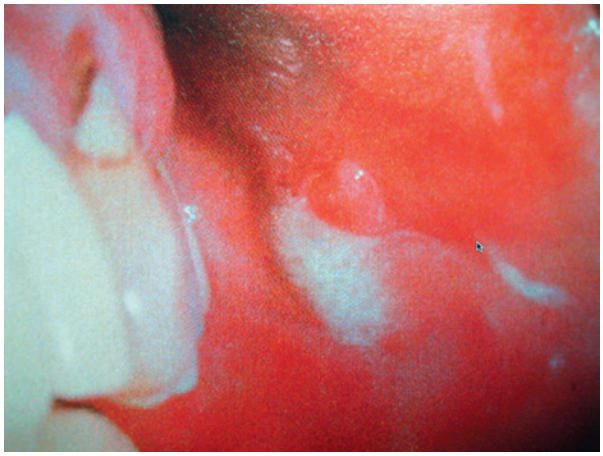


• **Fig. 21.36** Intraoral removal of sublingual gland and ranula.



• **Fig. 21.37** Patient profile view with right acute bacterial parotitis with significant edema and erythema.

disease and require different treatment, not including antibiotic therapy. Mumps is characterized by a painful, nonerythematous swelling of one or both parotid glands that begins 2 to 3 weeks after exposure to the virus (incubation period). This disease occurs most commonly in children between ages 6 and 8 years. The signs and symptoms of mumps include preauricular pain and swelling, fever, chills, and headache. Viral parotitis usually resolves in 5 to 12 days after its onset. Treatment includes supportive care for fever, headache, and malaise with antipyretics, analgesics, and adequate hydration. Complications of the disease include meningitis, pancreatitis, nephritis, orchitis, testicular atrophy, and sterility in approximately 20% of young males affected.



• **Fig. 21.38** Purulent discharge from the left Stensen duct in a patient with an infection involving the left parotid gland.

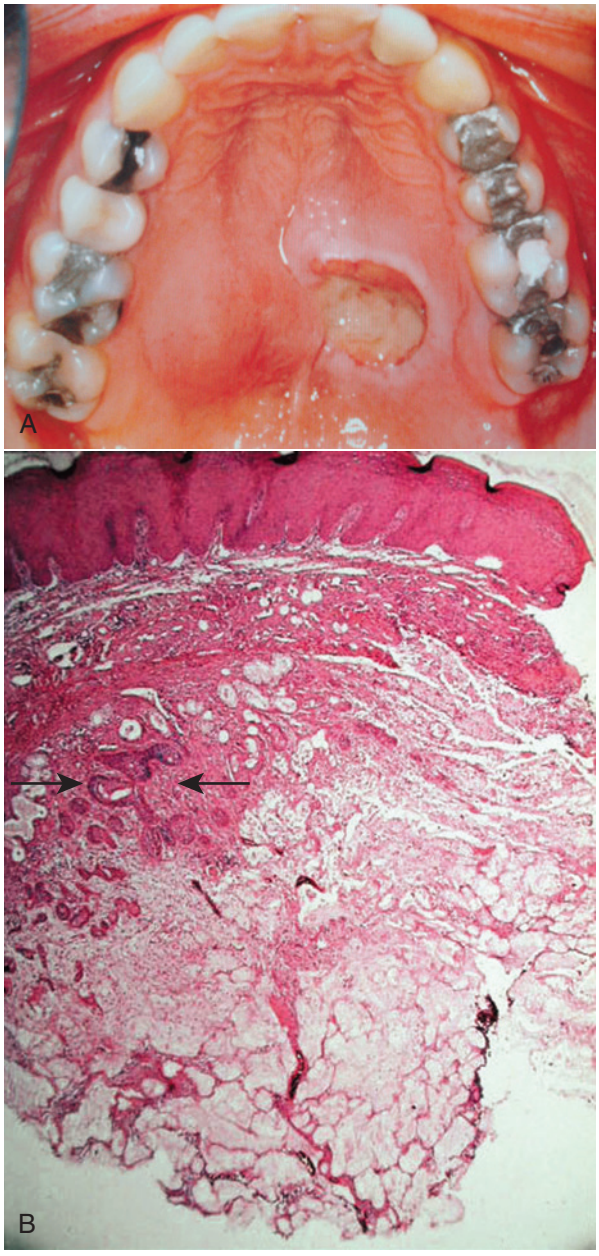
Necrotizing Sialometaplasia

Necrotizing sialometaplasia is a reactive, nonneoplastic inflammatory process that usually affects the minor salivary glands of the palate. However, it may involve minor salivary glands in any location. Necrotizing sialometaplasia is of unclear origin but is thought to result from vascular infarction of the salivary gland lobules. Potential causes of diminished blood flow to the affected area include trauma, local anesthetic injection, smoking, diabetes mellitus, vascular disease, and pressure from a denture prosthesis. The usual age range of affected patients is between 23 and 66 years. Lesions usually appear as large (1 to 4 cm), painless or painful, deeply ulcerated areas lateral to the palatal midline and near the junction of the hard and soft palates (Fig. 21.39A). Although lesions are usually unilateral, bilateral involvement may occur. Some patients may report a prodromal flu-like illness before the onset of the ulceration.

This condition is of considerable concern because, clinically and histologically (see Fig. 21.39B), it resembles a malignant carcinoma (squamous cell carcinoma or mucoepidermoid carcinoma). The appropriate diagnosis and management of this disease relies on evaluation by an oral and maxillofacial surgeon and an oral and maxillofacial pathologist who are both familiar with this entity because the result of a misdiagnosis may be extensive, unwarranted surgical resection for a benign, self-limiting disease process. The histopathologic appearance is that of *pseudoepitheliomatous hyperplasia*, which appears as epithelial infiltration into underlying tissue similar to a carcinoma. Helpful histologic criteria for distinguishing necrotizing sialometaplasia from a malignant process include the absence of cellular pleomorphism, maintenance of the overall salivary lobular morphology, generally nondysplastic appearance of the squamous islands or nests, and evidence of residual ductal lumina within the epithelial nests. The ulcerations of necrotizing sialometaplasia usually heal spontaneously within 6 to 10 weeks after onset and require no surgical management.

Sjögren Syndrome

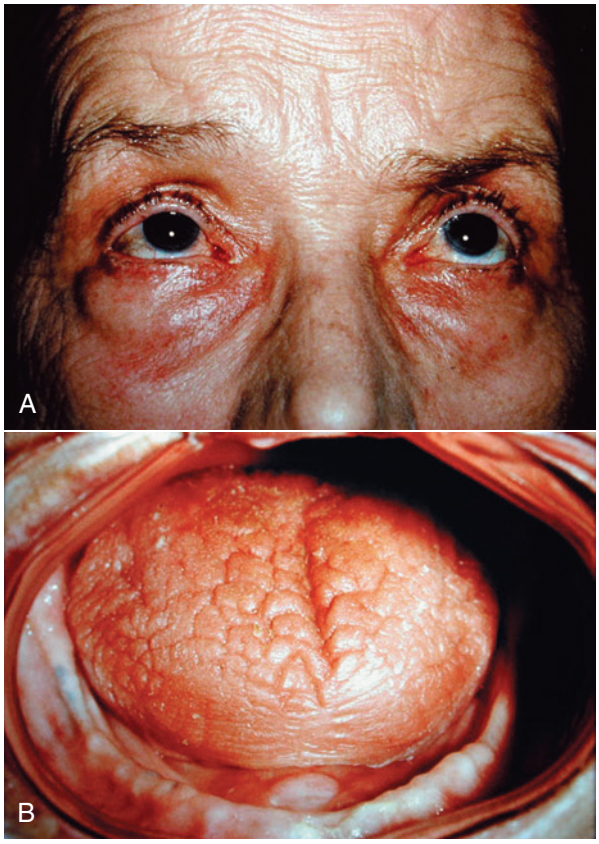
Sjögren syndrome is a multisystem disease process with a variable presentation. The two types of Sjögren syndrome are (1) *primary Sjögren syndrome*, or *sicca syndrome*, characterized by *xerostomia* (dry mouth) and *keratoconjunctivitis sicca* (dry eyes; Fig. 21.40) and (2) *secondary Sjögren syndrome*, which is composed of primary



• **Fig. 21.39** (A) Necrotizing sialometaplasia of posterior hard palate with ulceration. (B) Histopathologic examination of necrotizing sialometaplasia shows pseudoepitheliomatous hyperplasia *(arrows)*, which appears similar to epithelial infiltration of a carcinoma into the underlying connective tissue stroma.

Sjögren syndrome and an associated connective tissue disorder, most commonly rheumatoid arthritis. Although the cause of Sjögren syndrome is unknown, a strong autoimmune influence seems to be present. Sjögren syndrome shows a female predilection of 9:1, with more than 80% of affected individuals being female gender and with a mean age of 50 years.

In general, the first symptoms to appear are arthritic complaints, followed by ocular symptoms and, late in the disease process, salivary gland symptoms. The involvement of the salivary and lacrimal glands results from a lymphocytic replacement of the normal glandular elements. The xerostomia results from a decreased function of the major and minor salivary glands, with the parotid gland being the most sensitive. The diagnosis of Sjögren syndrome is suggested by



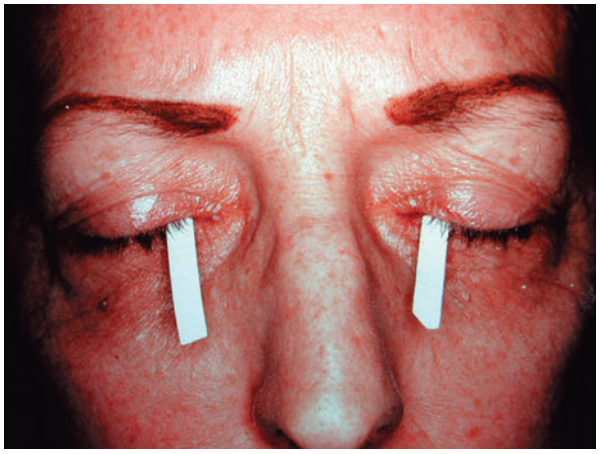
• **Fig. 21.40** Patient with Sjögren syndrome showing (A) dry eyes (keratoconjunctivitis sicca) and (B) dry mouth (xerostomia).

the patient's complaints and by a variety of abnormal immunologic laboratory tests. The oral component of Sjögren syndrome may be diagnosed by using salivary flow rate studies and sialograms that can show typical acinar destruction. The use of a labial minor salivary gland biopsy, as mentioned previously, is considered highly accurate in establishing the diagnosis of Sjögren syndrome, since the histopathologic changes seen in the minor glands are similar to those in the major glands (parotid). Keratoconjunctivitis sicca is suggested by the patient's complaints, and the *Schirmer test* for lacrimal flow can be performed to quantify the degree of lacrimal flow reduction (Fig. 21.41). The results of the Schirmer test are as follows: (1) normal: 15 mm or greater wetting of the paper after 5 minutes; (2) mild: 14 to 9 mm wetting of the paper after 5 minutes; (3) moderate: 8 to 4 mm wetting of the paper after 5 minutes; (4) severe: less than 4 mm wetting of the paper after 5 minutes. Usually patients with Sjögren syndrome who have keratoconjunctivitis sicca are in the severe category of the disease, with less than 4 mm of wetting of the paper strip after 5 minutes.

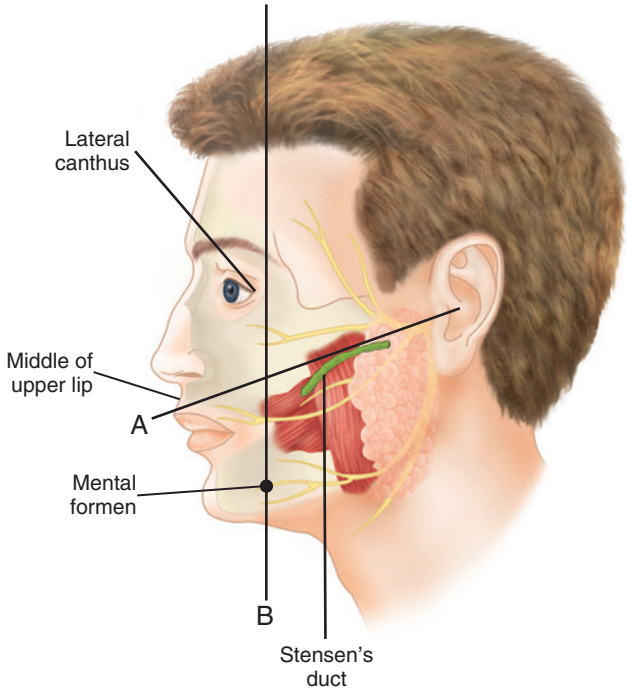
The treatment for Sjögren syndrome includes symptomatic care with artificial tears for the dry eye symptoms and salivary substitutes for the dry mouth symptoms. In addition, cholinergic medications, such as pilocarpine (Salagen) or Biotene products, may be useful to stimulate salivary flow from the little remaining functional salivary gland tissue present.

Traumatic Salivary Gland Injuries

Traumatic injuries, particularly lacerations, involving the salivary glands and their ducts may accompany a variety of facial injuries,



• **Fig. 21.41** Schirmer test for dry eyes in a patient with Sjögren syndrome. Filter paper is placed in the ocular fornix and observed for wetting (15 mm within 5 minutes is normal; <5 mm in 5 minutes is severe and may indicate Sjögren syndrome).



• **Fig. 21.42** Diagram showing the position of the Stensen duct along line *A* drawn from the tragus to the middle of the upper lip. Injuries to the small terminal branches of the facial nerve anterior to line *B* (lateral canthus to mental foramen) do not require surgical repair.

including facial fractures. Injuries that occur in proximity to one of the major salivary glands or ducts require careful evaluation during the head and neck examination.

Facial lacerations may involve not only the gland and its ductal system but also branches of the facial nerve and branches of major facial vessels. These structures require meticulous assessment for appropriate diagnosis and prompt repair, if indicated. Usually facial nerve lacerations that are anterior to a vertical line drawn from the lateral canthus of the eye to the mental foramen are not amenable to surgical repair because the fiber diameters are too small, and spontaneous function usually occurs because of recruitment of adjacent uninjured nerve fibers (Fig. 21.42). Stensen duct repair may include a *direct ductal anastomosis* in which the proximal and distal portions of the duct are identified, a plastic or metal catheter is placed as a stent, and the duct is sutured over the stent (Fig. 21.43). The catheter or stent is placed initially through the orifice of the Stensen duct intraorally and advanced proximally into the duct; then the catheter or stent exits the duct at the laceration site. The proximal stump of the duct is identified and threaded over the catheter toward the distal stump of the duct and sutured to it. The catheter is usually left in place for 10 to 14 days to allow epithelialization of the duct to occur. In addition, facial nerve lacerations may require direct neural anastomoses performed using operating magnification to reapproximate the nerve stumps and placing epineural nonresorbable sutures, with or without the need for nerve grafting. After debridement of the soft tissue wounds to cleanse the sight of entrapped particles such as glass, dirt, or other debris, the facial soft tissue lacerations are then closed over the ductal and neural repair sites in a usual layered fashion. Potential sequelae of trauma involving the major salivary glands include infection, facial paralysis, cutaneous salivary gland fistula, *sialocele* formation, and duct obstruction as a result of scar formation, which results in eventual glandular atrophy and decreased function. The involved nonfunctional gland may then eventually require surgical removal via *superficial parotidectomy (sialoadenectomy)*.

TABLE 21.6 Salivary Gland Tumor Distribution

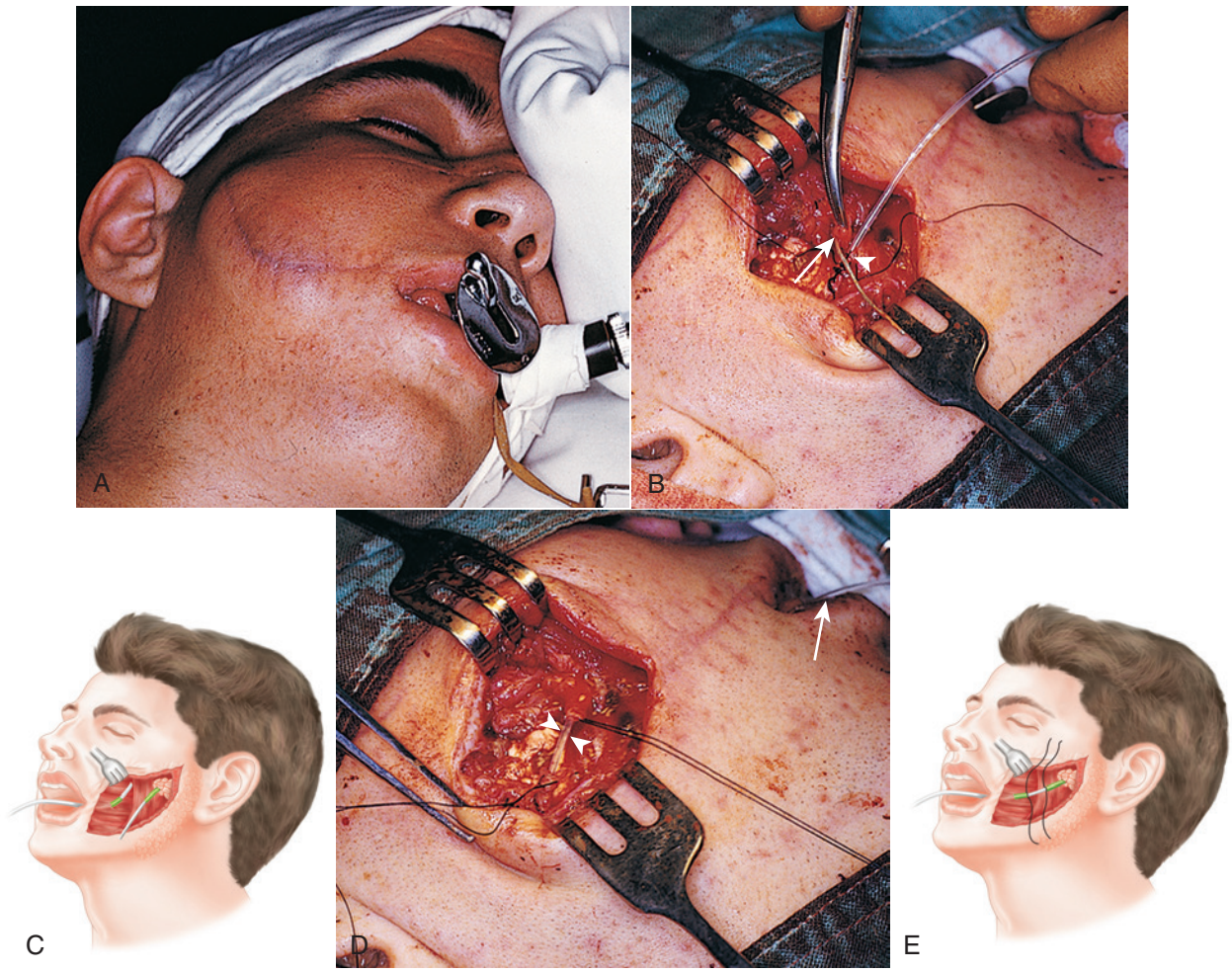
Location of Tumor	Occurrence
Major Glands	80%–85%
Parotid gland	85%–90%
Submandibular gland	5%–10%
Sublingual gland	Rare
Minor Glands	15%–20%
Palate	55%
Lips	15%
Remainder	Rare

Salivary Gland Neoplasms

Although a comprehensive discussion of salivary gland neoplasms is beyond the scope of this chapter and other sources are available for this information, a brief review of several important aspects of the more common lesions is warranted. *Salivary gland tumors* occur much more commonly in the major glands (80% to 85%) as opposed to the minor glands (15% to 20%; Table 21.6). About 75% to 80% of major gland tumors are benign, and 50% to 55% of minor gland tumors are benign. The overwhelming majority of salivary tumors occur in the *parotid gland*, and the majority of those are benign (most commonly *pleomorphic adenoma*).

Benign Salivary Gland Tumors

The *pleomorphic adenoma*, or benign mixed tumor, is the most common salivary gland tumor. The mean age of occurrence is 45 years, with a male-to-female ratio of 3:2. In the major glands, the *parotid gland* is involved in more than 80% of cases; in the minor



• **Fig. 21.43** (A) Cheek laceration repaired with failure to appreciate a Stensen duct laceration. The patient subsequently developed a sialocele (localized collection of saliva). (B) Operative repair of the Stensen duct laceration with a metal probe in the distal duct placed from the orifice of the Stensen duct intraorally *(arrow)* and a plastic catheter *(arrowhead)* placed into the proximal portion of the lacerated duct. (C) Placement of both catheters. The proximal catheter will be removed, and the proximal duct will be threaded over the one distal catheter. (D) Repair of laceration of the Stensen duct via suturing over one catheter *(arrowheads)* placed via intraoral cannulation of the Stensen duct *(arrow)*. (E) Completed repair over the catheter.

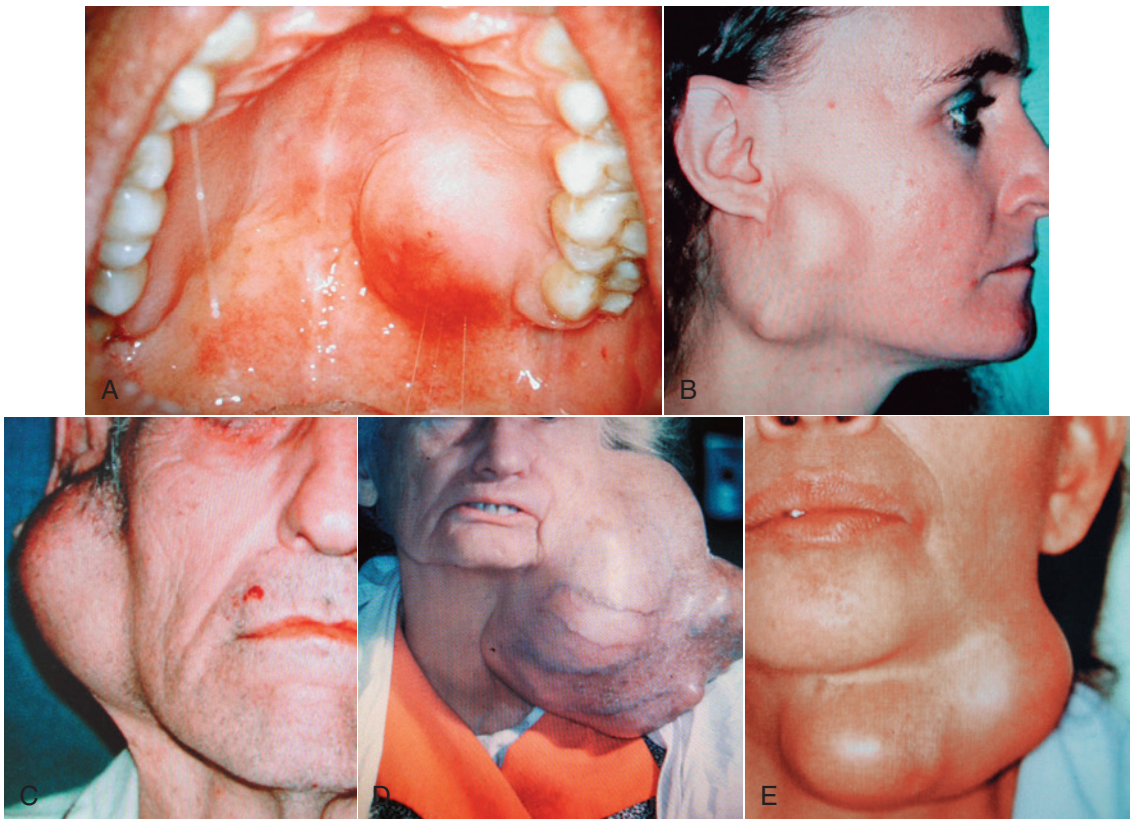
glands the most common intraoral site is the palate (Fig. 21.44). Pleomorphic adenomas are usually slow-growing, painless masses. The histopathologic examination shows two cell types: (1) *ductal epithelial cell* and (2) *myoepithelial cell*, which may differentiate along a variety of cell lines (*pleomorphic,* meaning "many forms"). A connective tissue capsule exists around the pleomorphic adenoma, which may be incomplete. The treatment involves complete surgical excision with a margin of normal uninvolved tissue to account for possible irregular projections of the lesion. Parotid lesions are treated with removal of the involved lobe (superficial and/or deep lobes) along with the tumor. Recurrence is possible in rare cases, as well as a small risk (5%) of malignant transformation with longstanding lesions to a *carcinoma ex pleomorphic adenoma*.

Warthin tumor, or papillary cystadenoma lymphomatosum, almost exclusively affects the parotid gland, specifically the tail of the parotid gland (Fig. 21.45). The peak incidence is in the sixth decade of life, with a male-to-female ratio of 7:1 and an association with smoking. This lesion presents as a slow-growing, soft, painless mass. Warthin tumor is believed to be caused by entrapped salivary epithelial rests within developing lymph nodes. The histopathologic examination shows an epithelial component in a papillary pattern and a lymphoid component with germinal centers. The treatment of this lesion is simple surgical excision, and recurrence is rare.

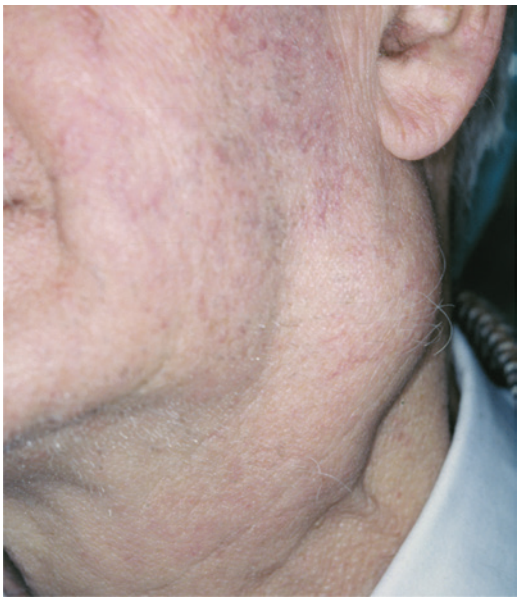
The *monomorphic adenoma* is an uncommon solitary lesion composed of one cell type affecting predominantly the upper lip minor glands (*canalicular adenoma*; Fig. 21.46) and the parotid gland *(basal cell adenoma).* The mean age of occurrence is 61 years, and the lesion usually presents as an asymptomatic, freely movable mass. Histopathologic examination reveals an encapsulated lesion composed of one type (monomorphic) of salivary ductal epithelial cell. The treatment of an adenoma is simple surgical excision.

Malignant Salivary Gland Tumors

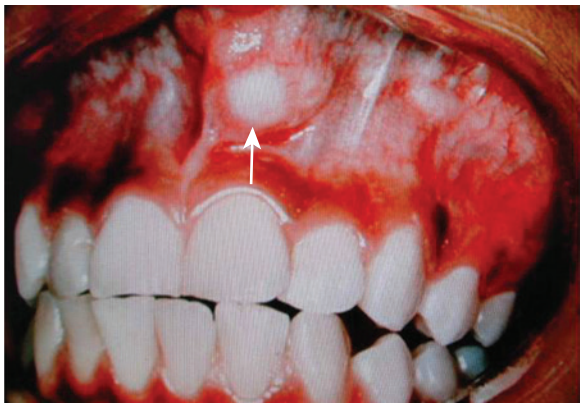
The *mucoepidermoid carcinoma* is the most common malignant salivary gland tumor. This tumor makes up 10% of major gland tumors (mostly parotid) and 20% of minor gland tumors (mostly palatal; Fig. 21.47). This lesion may occur at any age, but the



• **Fig. 21.44** Pleomorphic adenomas. (A) Palate. (B–D) Parotid gland. (E) Submandibular gland.

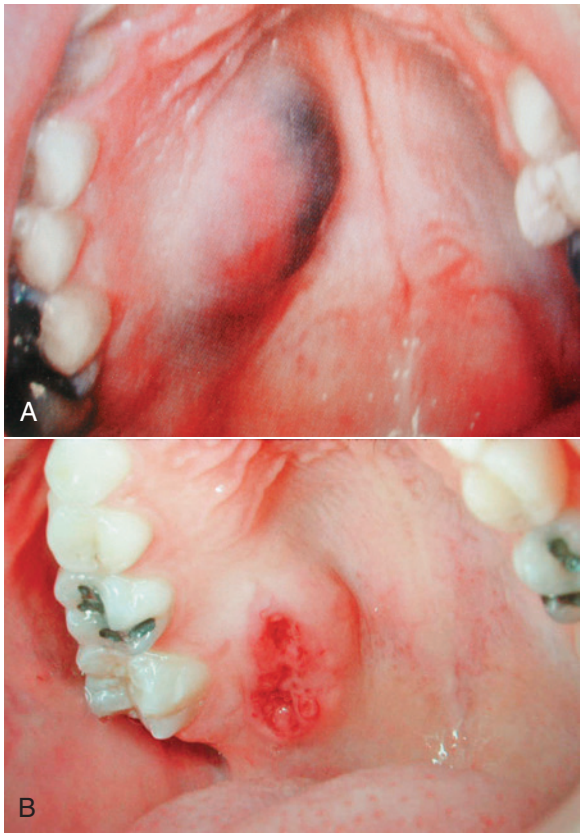


• **Fig. 21.45** Warthin tumor of the tail of the parotid gland.

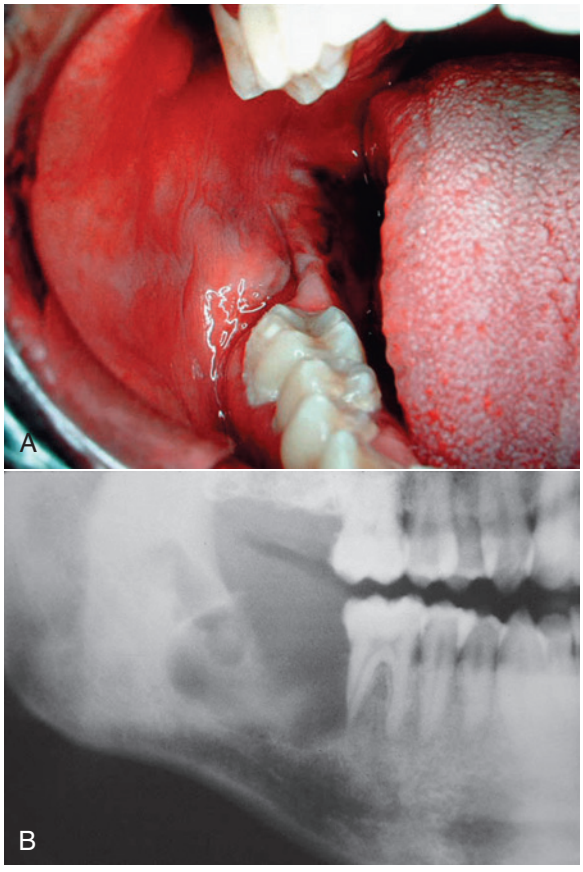


• **Fig. 21.46** Monomorphic (canalicular) adenoma of the left upper lip or vestibule *(arrow)*.

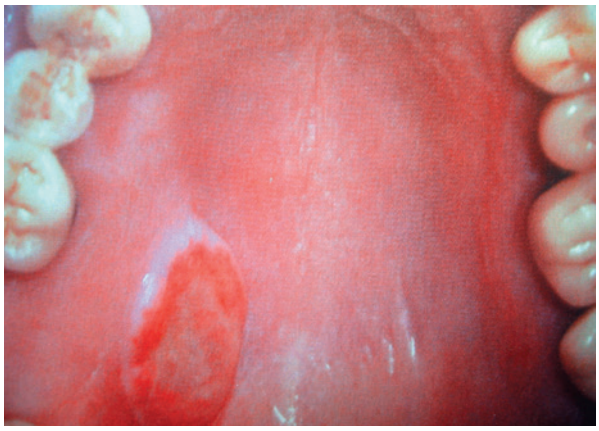
mean age is 45 years. The male-to-female ratio is 3:2. The clinical presentation is a submucosal mass that may be painful or ulcerated. The mass may appear to have a bluish tinge because of the mucous content within the lesion. An *intraosseous form* of mucoepidermoid carcinoma may present as a multilocular radiolucency of the posterior mandible with a raised bluish lesion of the retromolar pad (Fig. 21.48). Histopathologic examination shows three cell types: (1) *mucous cells*, (2) *epidermoid cells*, and (3) *intermediate (clear) cells*. The proportion of each cell type will grade the mucoepidermoid carcinoma as *high-grade*, *intermediate-grade*, or *low-grade* lesions. The higher the grade, the higher are the predominance of epidermoid cells and cellular pleomorphism, lack of mucous cells and cystic areas, and an overall more aggressive behavior. The treatment of low-grade lesions is wide surgical excision with a margin of uninvolved normal tissue; high-grade lesions require more aggressive surgical removal with surgical margins and, possibly, local radiation therapy. The low-grade lesions have a 95% 5-year survival rate, whereas the high-grade lesions have less than a 40% 5-year survival rate.



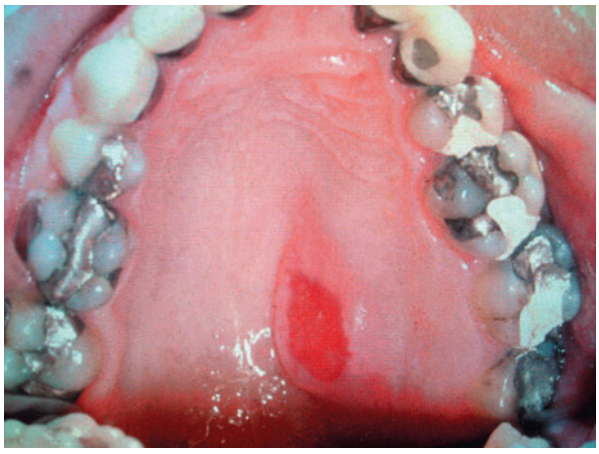
• **Fig. 21.47** (A) Mucoepidermoid carcinoma of the palate. Note the bluish color from mucin content. (B) Mucoepidermoid carcinoma of the palate with ulceration.



• **Fig. 21.48** (A) Central mucoepidermoid carcinoma of the right retromolar pad of minor salivary glands (note bluish appearance). (B) The panoramic radiograph shows the underlying multilocular radiolucency.



• **Fig. 21.49** Polymorphous low-grade adenocarcinoma of the palate.



• **Fig. 21.50** Adenoid cystic carcinoma of the palate (note similar appearance to polymorphous low-grade adenocarcinoma).

Polymorphous low-grade adenocarcinoma is the second most common salivary gland malignancy. This lesion was first described in 1983; before its identification, many cases were likely misdiagnosed as adenoid cystic carcinoma. The most common site is the *junction of the hard and soft palate* (Fig. 21.49). The male-to-female ratio is 3:1, with a mean age of 56 years. These tumors present as slow-growing, asymptomatic masses that may become ulcerated. Histopathologic examination shows many cell shapes and patterns (polymorphous). Histologic appearance shows an infiltrative proliferation of ductal epithelial cells in a single-file pattern. This lesion shows a neurotropic predilection for invasion of and propagation along the surrounding nerves leading clinically to paresthesia in the area supplied by the involved nerve(s). The treatment of this tumor is wide surgical excision, with a relatively high recurrence rate of 14%.

The *adenoid cystic carcinoma* is the third most common intraoral salivary gland malignancy, with a mean age of 53 years and a male-to-female ratio of 3:2. Approximately 50% of these tumors occur in the parotid gland, whereas the other 50% occur in the minor glands of the palate (Fig. 21.50). These tumors present as

slow-growing, nonulcerated masses, with an associated chronic dull pain. Occasionally parotid lesions may result in facial paralysis as a result of *neurotropism*, similar to the polymorphous low-grade adenocarcinoma, and facial nerve involvement. Histopathologic examination demonstrates an infiltrative proliferation of basaloid cells arranged in a cribriform (Swiss cheese) pattern. As seen in the polymorphous low-grade adenocarcinoma, perineural invasion and migration may occur, for example, from a palatal lesion to the foramen rotundum along the second division of the trigeminal nerve. The treatment is wide surgical excision, followed, in some cases, by radiation therapy. The prognosis is poor despite aggressive therapy.

PART V

Management of Oral Pathologic Lesions

Pathologic growths and lesions frequently develop in the mouth and adjacent structures. General dentists encounter more frequent and repetitive exposures to the tissues in patients' oral cavities and contiguous structures than any other health care provider. Although most of these lesions are benign and not threatening to the patient's well-being, dentists nevertheless have the professional responsibility for the maintenance and overall health of their patients' oral and perioral structures. Whether by referral to another health care provider or by directly assuming responsibility for the surgical management of these hard and soft tissue pathologic entities, the dentist is the "gateway" provider who initially recognizes any departure from normal, coordinates the needed definitive care, ensures adequate patient follow-up, and provides any required dental restorative support.

The unique role of general dentists as oral health experts requires them to be constantly vigilant for any abnormalities in the bony and soft tissues of the head and neck area during their routine care of patients. General dentists must be observant clinicians and astute diagnosticians and must remain knowledgeable about the natural history of the more common oral and maxillofacial disease manifestations. Early diagnosis and treatment is always the best practice for managing these pathologic entities.

Chapters 22 and 23 describe the potential roles of the general dentist in the comprehensive management of a patient's pathologic conditions. The most important aspect of this care begins with performing a thorough oral, head, and neck examination; formulating a rational tentative diagnosis; and providing needed treatment or appropriate referrals when indicated. Chapter 22 covers these topics in detail, with emphasis on the role of a general dentist. Chapter 23 describes the surgical management of more complex pathologic lesions of the oral cavity and contiguous structures. Expanded details on surgical technique are provided for management of less complex lesions that might be managed by general dentists. The surgical management of more complex and difficult pathologic conditions, cysts, and tumors of the oral-maxillofacial region are also presented, with emphasis on the general dentist's supportive roles in patient management and referral to specialists.

22

Principles of Differential Diagnosis and Biopsy

EDWARD ELLIS III AND MICHAELL A. HUBER

CHAPTER OUTLINE

Examination and Diagnostic Methods

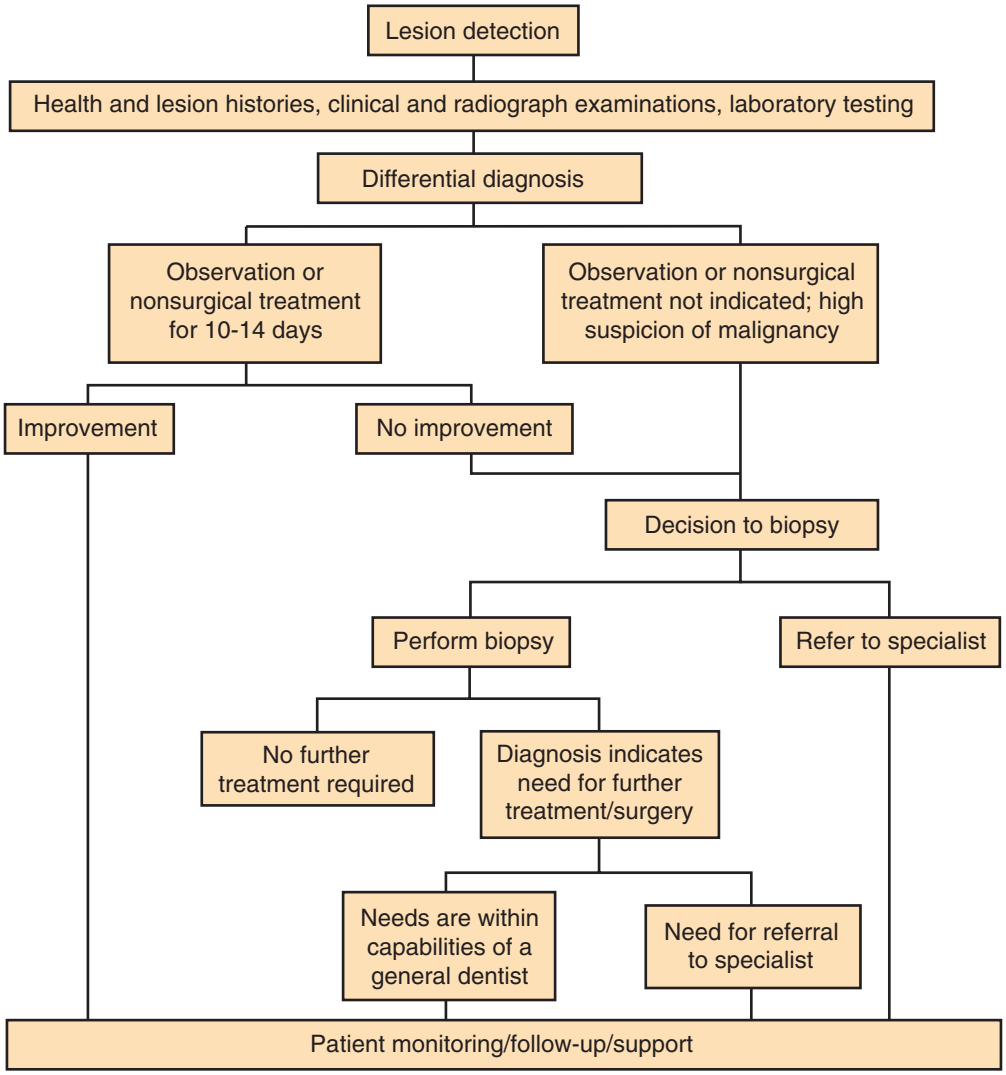
Lesions of the oral cavity and perioral areas must be identified and accurately diagnosed so that appropriate therapy can eliminate them. When abnormal tissue growth is discovered, several important and orderly steps should be undertaken to identify and characterize it (Fig. 22.1). These steps include a comprehensive health history, history of the identified lesion(s), clinical and radiographic examinations, and relevant laboratory testing if indicated. These steps lead to a period of close observation, referral to another health care provider when indicated, and initiation of surgical procedures to obtain a specimen for histologic examination (biopsy), which, in turn, will lead to appropriate treatment decisions.

When the dentist discovers or confirms the presence of a lesion, the information must be discussed with the patient in a sensitive manner that conveys the importance of urgent attention to the problem without alarming the patient. Words such as *lesion*, *tumor*, *growth*, and *biopsy* can carry terrifying connotations for many patients. The empathetic dentist can spare patients undue anxiety and emotional trauma by carefully wording the discussion relating to the lesion and reminding the patient that most discovered lesions in the head and neck region are benign and that the steps being taken are merely precautionary.

Health History

Discerning the overall medical status of the patient is important during the diagnostic stages. Recent findings have led to a growing realization that frequently a close interrelationship exists between the medical and dental health of patients and that oral lesions can be a reflection of, or contributers to, systemic health problems. Therefore documentation of a detailed and annotated health history coupled with a thorough clinical evaluation (including medical consultation when necessary), is essential for two basic reasons:

1. A preexisting medical problem may affect or be affected by the dentist's treatment of the patient. As outlined in Chapters 1 and 2, patients with certain medical conditions (e.g., those with hypertension or certain cardiac conditions, those taking potentially interactive medications, those taking anticoagulants, and those with implanted orthopedic or cardiovascular prostheses) may require special management precautions when invasive dental surgery is required. In addition, surgical intervention may upset the delicate balance between health and disease in a fragile patient or one with a poorly controlled condition, such as a patient who has diabetes or one who is immunocompromised.



• **Fig. 22.1** Decision tree for treatment of oral lesions.

2. The lesion under investigation may be the oral manifestation of a significant systemic disease. For example, certain conditions (e.g., agranulocytosis, leukemia, Crohn disease) may often present with oral lesions. Surface ulcerations in a chronic smoker should alert the dentist to the possibility of oral or pharyngeal cancer. A number of systemic disease processes can manifest as oral lesions, so the dentist must always maintain awareness of these relationships.

History of the Specific Lesion

An old saying in medicine is "If you listen to the patient long enough, he or she will generally lead you to the diagnosis." The art of history taking sometimes gets lost in modern medicine in the rush to get to the next patient. A generally accepted axiom in medicine is that many systemic diseases (up to 85% to 90%) can be diagnosed by gathering a detailed, annotated medical history. The same can be true of many oral lesions when the diagnostician is familiar with the natural history of the more common diseases. Questioning of the patient who has a pathologic condition should include the following:

1. *How long has the lesion been present?* The duration of a lesion may provide valuable insight into its nature. For example, a lesion that has been present for several years might be congenital and is more likely benign, whereas a rapidly developing lesion is considered more ominous. Although establishing the duration of a lesion provides valuable information, duration must be taken in context with other elements of the history because it is possible that the lesion was present for an extended period before the patient became aware of its presence.
2. *Has the lesion changed in size?* A change in the radiographic or clinical size of a lesion, or both, is an important piece of information. An aggressive, enlarging lesion is more likely to be malignant, whereas a slower-growing lesion suggests a possibly benign condition. By combining information on the growth rate with findings regarding the duration of presence, one can make a more accurate assessment of the nature of the lesion.
3. *Has the lesion changed in character or features* (e.g., a lump becoming an ulcer or an ulcer starting as a vesicle)? Noting changes in the physical characteristics of a lesion can often assist in the diagnosis. For example, if an ulcer began as a vesicle, it could suggest a localized or systemic vesiculobullous or viral disease.
4. *What symptoms are associated with the lesion* (e.g., pain, altered function, anesthesia or paresthesia, abnormal taste or odors, dysphagia, or tenderness of cervical lymph nodes)*?* If painful,

is the pain acute or chronic, constant or intermittent? What increases or decreases the pain? Lesions with an inflammatory component are most often associated with pain. Cancers, erroneously thought by many to be painful, are actually often painless unless secondarily infected. Sensory nerve changes such as numbness or tingling often occur with a malignant or inflammatory process unless other identifiable causes can be ascertained. Dysphagia can suggest changes in the floor of the mouth or in the parapharyngeal tissues. Swelling can often result from and occur with oral lesions, indicating an expansile process from any of a number of causes, including inflammation, infection, cysts, or tumor formation. The patient may indicate feeling a sensation of fullness even before the doctor can actually visualize or verify the swelling during clinical examination. Painful lymph nodes usually indicate an inflammatory or infectious cause but may also be a manifestation of malignancy.

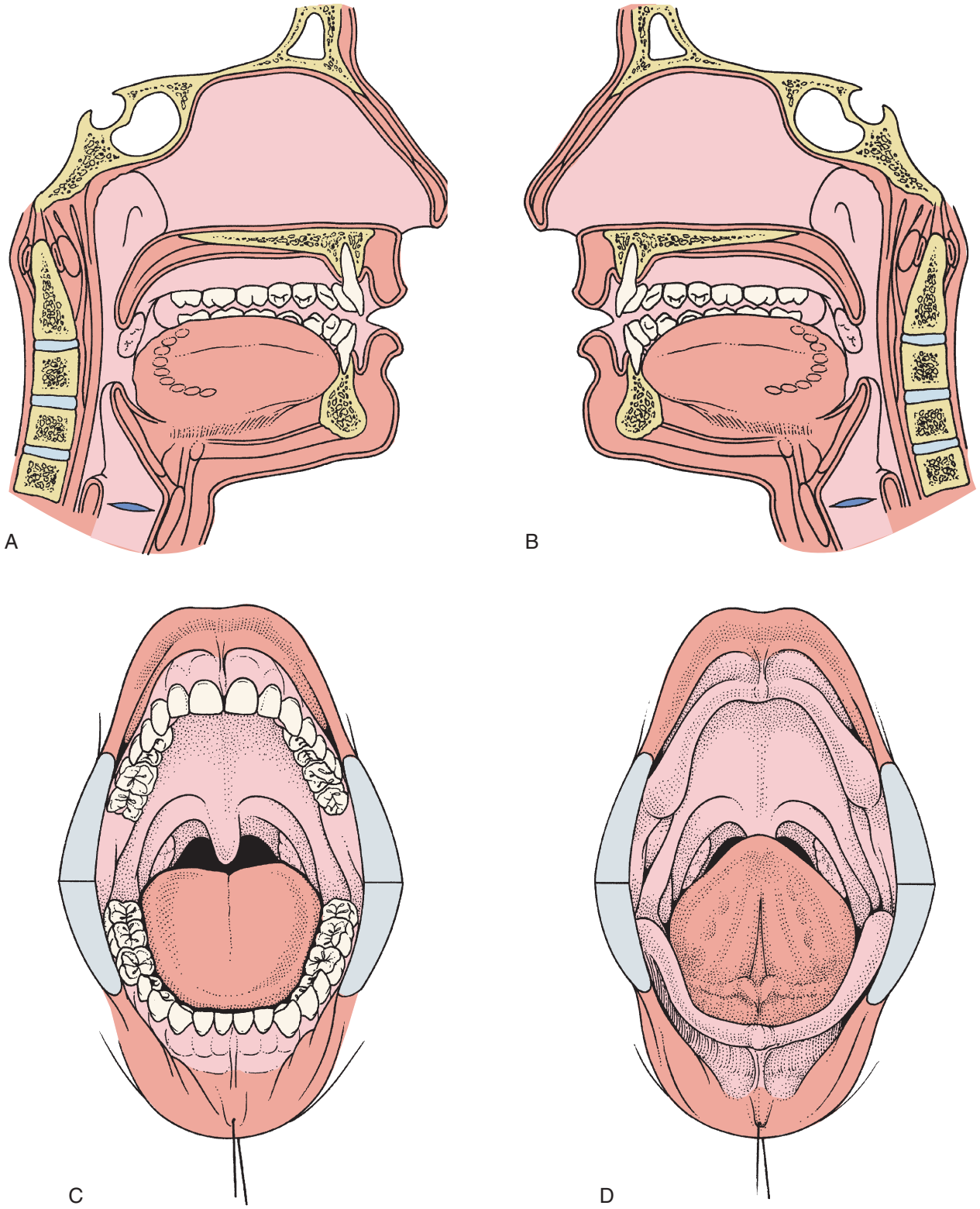
5. *What anatomic locations are involved?* Certain lesions have a predilection for certain anatomic areas or tissues. Noting whether the lesion is confined to keratinized or nonkeratinized tissues, regions with salivary gland tissues or areas of neural or vascular anatomy can sometimes provide clues to the diagnosis.
6. *Are there any associated systemic symptoms* (e.g., fever, nausea, or malaise)*?* Has the patient noted any similar or concurrent changes elsewhere in the body or had similar lesions in the oral or perioral tissues in the past? The dentist should look for possible relationships or manifestations from related systemic diseases or conditions. For example, many systemic viral conditions (e.g., measles, mumps, mononucleosis, herpes, acquired immunodeficiency syndrome) can cause oral manifestations concurrent with the systemic involvement. Autoimmune conditions may also manifest with oral lesions. Many oral ulcerative conditions can also present lesions elsewhere in the body (e.g., pemphigus, lichen planus, erythema multiforme, sexually transmitted infections). Other factors could include drug abuse or injuries from domestic violence.
7. *Is there any historical event associated with the onset of the lesions* (e.g., trauma, recent treatment, exposure to toxins or allergens, visits to foreign countries)*?* One of the initial steps the dentist should take when a lesion is noted is to seek a possible explanation based on the patient's medical, dental, family, or social histories. Frequently oral and perioral lesions can be caused by parafunctional habits, hard or hot foods, application of medications not intended for topical use, recent trauma, conditions involving the dentition (e.g., caries, periodontal disease, fractured teeth), or an identified event or exposure.

Clinical Examination

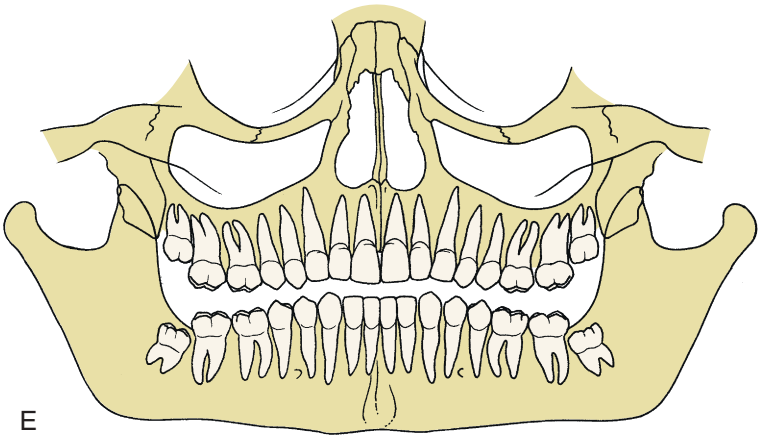
When a lesion is discovered, careful clinical and radiographic examinations and palpation of regional lymph nodes is mandatory. Once the examination is complete, a detailed description of all objective and subjective findings should be documented in the patient's chart. A drawing or a graphic schematic of the location, orientation, general shape, and dimensions of the lesion in the patient record is helpful. The use of standardized illustrations can simplify the documentation (Fig. 22.2). Additionally, good-quality digital photographs are useful for documentation if the dentist has the appropriate camera and accessories. Details, descriptions, and drawings allow the dentist or subsequent referral specialists to evaluate the course of the lesion over time and determine whether it is enlarging, its features are changing, or new lesions are appearing in different anatomic areas.

An examination is classically described as a process that includes inspection, palpation, percussion, and auscultation. In the head and neck region, inspection and palpation are more commonly used as diagnostic modalities, with inspection always preceding palpation. Early inspection facilitates description of the lesion before it is handled because some lesions are so fragile that manipulation of any kind can result in hemorrhage or rupture of a fluid-filled lesion or loss of loosely attached surface tissues, which would compromise any subsequent examinations. Percussion is reserved for examination of the dentition. Auscultation is infrequently used but is important when examining suspected vascular lesions. The following are some important additional points to be considered during the inspection of a lesion.

1. *Anatomic location of the lesion.* Pathologic lesions can arise from any tissue within the oral cavity, including the epithelium, subcutaneous and submucosal connective tissues, muscle, tendon, nerve, bone, blood vessels, lymphatic vessels, or salivary glands. The dentist should attempt to ascertain, as much as possible, which tissues are contributing to the lesion based on the anatomic location of the lesion. For example, if a mass appears on the dorsum of the tongue, the dentist would logically consider an epithelial, connective tissue, lymphatic, vascular, glandular, neural, or muscular origin. Similarly, a mass on the inner aspect of the lower lip would prompt the dentist to include a minor salivary gland origin in the differential diagnosis, along with connective tissue origin and other possibilities. Certain lesions may have unique anatomic characteristics, such as the linear tendencies of herpes zoster lesions as they follow neural pathways. The possible role of trauma should always be entertained as possible sources of the lesion (ill-fitting dental appliances, parafunctional habits such as cheek biting, sharp edges on teeth or restorations, and trauma from acts of domestic or other types of violence). Finally, pulpal, periapical, and periodontal pathologic or inflammatory conditions also cause a significant percentage of oral lesions.
2. *Overall physical characteristics of the lesion.* Appropriate medical terminology should always be used to describe clinical findings in the record because lay terminology can be misleading and nonspecific. Terms such as "ulcer" or "nodule" may be interpreted differently by different examiners. High-quality digital photographs may also be printed and enclosed with the biopsy specimen or can be emailed separately to the pathologist. Photographs are helpful in demonstrating the clinical characteristics of the lesion. Box 22.1 lists several common physical descriptions that are useful in describing oral and maxillofacial pathologic entities. Terms such as those listed in Box 22.1 should generally be used to describe the characteristics of a lesion. Lay terms such as "swelling" and "sore" are generally not helpful and may be subject to misinterpretation.
3. *Single versus multiple lesions.* The presence of multiple lesions is an important feature. When multiple ulcerations are found within the mouth, the dentist should think of specific possibilities for the differential diagnosis. To find multiple or bilateral neoplasms in the mouth is unusual, whereas vesiculobullous, bacterial, and viral diseases commonly present such a pattern. Similarly, an infectious process may exhibit outward spread as one lesion infects the adjacent tissues with which it has had contact.
4. *Size, shape, and growth presentation of the lesion.* Documentation of the size and shape of the lesion should be made, as noted previously. A small metric ruler made of a material that can be disinfected (e.g., metal or plastic) is useful to have on hand.



• **Fig. 22.2** Illustrations of the oral cavity and perioral areas, which are useful for indicating size and location of oral lesions.



• Fig. 22.2, cont'd

• BOX 22.1 Descriptive Pathology Terminology

- *Bulla (pl. bullae):* a blister; an elevated, circumscribed, fluid-containing lesion of skin or mucosa
- *Crusts (crusted):* dried or clotted serum on the surface of the skin or mucosa
- *Dysplasia (dysplastic):* any abnormal development of cellular size, shape, or organization in tissue
- *Erosion:* a shallow, superficial ulceration
- *Hyperkeratosis:* an overgrowth of the cornified layer of epithelium
- *Hyperplasia (hyperplastic):* an increased number of normal cells
- *Hypertrophy (hypertrophic):* an increase in size caused by an increase in the size of cells, not in the number of cells
- *Keratosis (keratotic):* An overgrowth and thickening of cornified (horned layer) epithelium
- *Leukoplakia:* a slowly developing change in mucosa characterized by firmly attached thickened white patches
- *Macule:* a circumscribed nonelevated area of color change that is distinct from adjacent tissues
- *Malignant:* anaplastic; a cancer that is potentially invasive and metastatic
- *Nodule:* a large, elevated, circumscribed and solid palpable mass of the skin or mucosa
- *Papule:* a small, elevated, circumscribed and solid palpable mass of the skin or mucosa
- *Plaque:* any flat, slightly elevated superficial lesion
- *Pustule:* a small, cloudy, elevated and circumscribed pus-containing vesicle on the skin or mucosa
- *Scale:* a thin, compressed, superficial flake of cornified (keratinized) epithelium
- *Stomatitis:* any generalized inflammatory condition of the oral mucosa
- *Ulcer:* a crater-like circumscribed surface lesion resulting from necrosis of the epithelium
- *Vesicle:* a small blister; a small circumscribed elevation of skin or mucosa containing serous fluid

The ruler is valuable for measuring the diameters of clinically evident lesions, which measurements can then be entered into the record with the drawing. The growth presentation should also be noted: whether the lesion is flat or slightly elevated, endophytic (growing inward) or exophytic (growing outward from the epithelial surface), and sessile (broad based) or pedunculated (on a stalk).

5. *Surface appearance of the lesion.* The epithelial surface of a lesion may be smooth, lobulated (verruciform), or irregular. If ulceration is present, the characteristics of the ulcer base and margins should be recorded. Margins of an ulcer may be flat, rolled, raised, or everted. The base of the ulcer may be smooth, granulated, or covered with fibrin membrane or slough or hemorrhagic crust (scab) or it may have the fungating appearance that is characteristic of some malignancies.
6. *Lesion coloration.* The surface color(s) of a lesion can reflect various characteristics and even the origin of many lesions. A dark bluish swelling that blanches on pressure suggests a vascular lesion, whereas a lighter-colored, bluish lesion that does not blanch may suggest a mucus-retaining cyst. A pigmented lesion within the mucosa may suggest a "traumatic tattoo" of restorative material or a more ominous melanotic tumor. Keratinized white lesions can reflect a reaction to repetitive local tissue trauma or represent potentially premalignant changes. An erythematous (or mixed red and white) lesion may represent an even more ominous prognosis for dysplastic changes than a white lesion. Inflammation can be superimposed on areas of mechanical trauma or ulceration, resulting in a varied presentation from one examination to the next.
7. *Sharpness of lesion borders and mobility.* If a mass is present, the dentist should determine whether it is fixed to the surrounding deep tissues or freely movable. Determining the boundaries of the surface lesion will aid in establishing whether the mass is fixed to adjacent bone, arising from bone and extending into adjacent soft tissues, or only infiltrating the soft tissue.
8. *Consistency of the lesion to palpation.* Consistency can be described as soft or compressible (e.g., a lipoma or abscess), firm or indurated (e.g., a fibroma or neoplasm), or hard (e.g., torus or exostosis). *Fluctuant* is a term used to describe the wave-like motion felt during bidigital palpation of a lesion with nonrigid walls that contains fluid. This valuable sign can be elicited by palpating with two or more fingers in a rhythmic fashion. As one finger exerts pressure, the opposing finger feels the impulse transmitted through the fluid-filled cavity.
9. *Presence of pulsation.* Palpation of a mass may reveal a rhythmic pulsation that is suggestive of a significant vascular component. This sensation can be subtle and is especially significant when dealing with intrabony lesions. The pulsation can be accompanied by a palpable vibration, called a *thrill*. If a thrill is palpated, auscultation of the area with a stethoscope may reveal a *bruit*, or audible murmur, in the area. Invasive procedures on lesions with thrills, bruits, or both should be avoided, and patients should be referred to specialists for treatment

because life-endangering hemorrhage can result if surgical intervention (biopsy) is attempted.

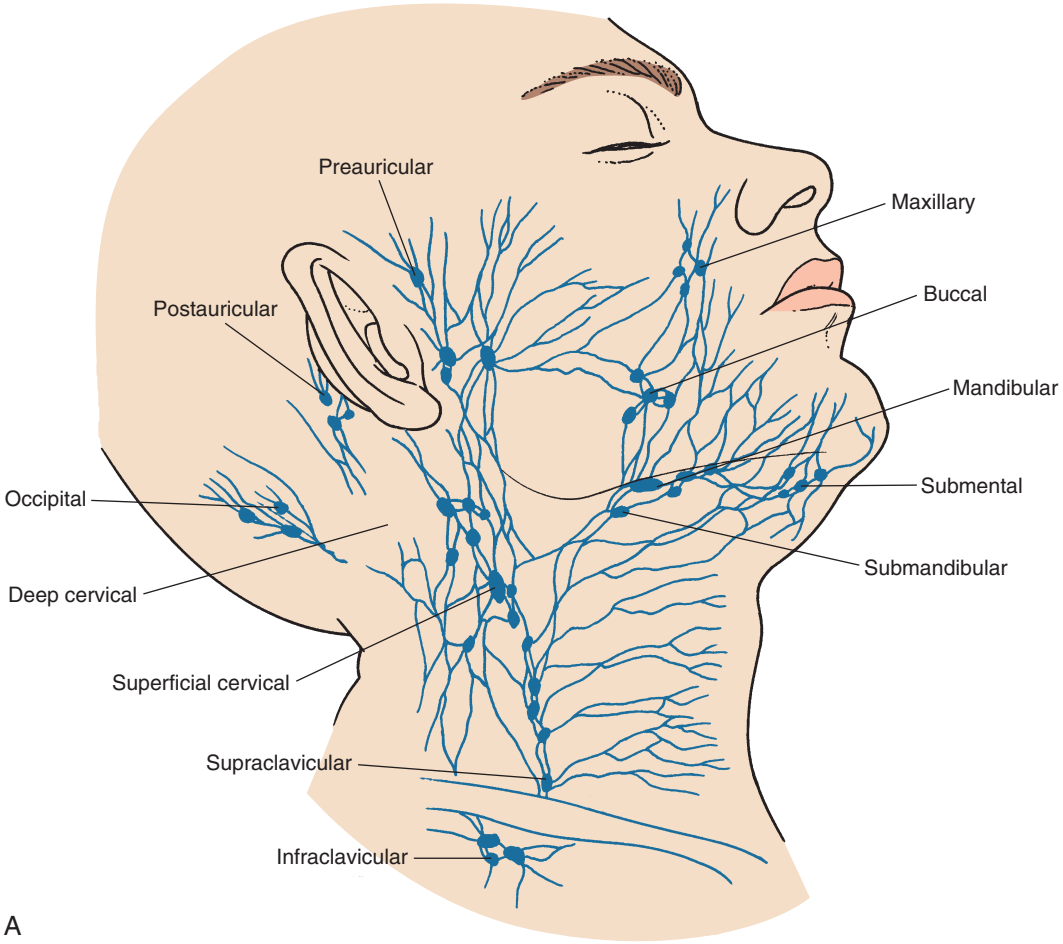
10. *Examination of regional lymph nodes.* No evaluation of an oral lesion is complete without a thorough examination of the regional lymph nodes. This examination should be accomplished before any biopsy procedure. Sometimes lymphadenitis develops in the regional nodes following a surgical procedure such as biopsy, thus creating a subsequent diagnostic dilemma. It can then become difficult to differentiate between reactive lymphadenitis as a surgical sequela, coincidental regional infection or inflammation, or metastatic spread of the tumor in question. Fig. 22.3 illustrates the primary lymph nodes of significance in the cervicofacial region.

The standard examination of lymph nodes requires only simple inspection and palpation. Comparison of left and right sides, using the middle three fingers for light palpation, is often useful. Movements during palpation should be slow and gentle, with the fingers moving lightly across each area in vertical and horizontal directions as well as in a rotary motion. In adults, normal lymph nodes are not palpable unless they are enlarged by inflammation or neoplasia, but cervical nodes of up to 1 cm in diameter can often be palpated in children up to the age of 12 years and are generally not considered an abnormal finding. In recording lymph node findings, the following five characteristics should be routinely documented: (1) location, (2) size (preferably recording the diameters in centimeters), (3) presence of pain or tenderness, (4) degree of fixation (fixed, matted, or movable), and (5) texture (soft, firm, or hardened). When multiple nodes are slightly enlarged but barely palpable, they can feel like bird shot and are described as "shotty nodes."

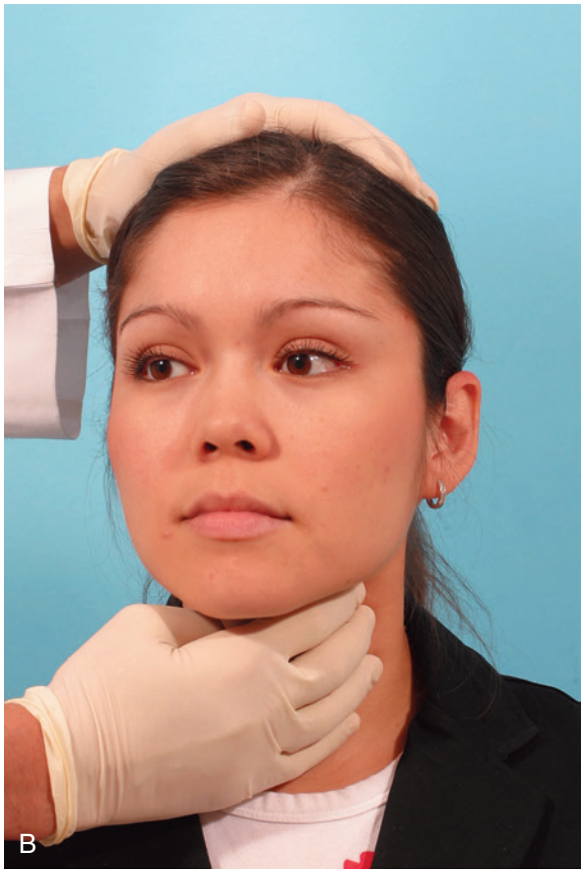
The lymph node examination should be methodical and should include the following groups: (1) occipital, (2) preauricular and postauricular; (3) mandibular, submandibular, and submental; (4) deep anterior cervical chain; (5) superficial cervical nodes (along the sternocleidomastoid muscle); (6) deep posterior cervical chain; and (7) supraclavicular nodes. Buccal lymph nodes may or may not be routinely palpable.

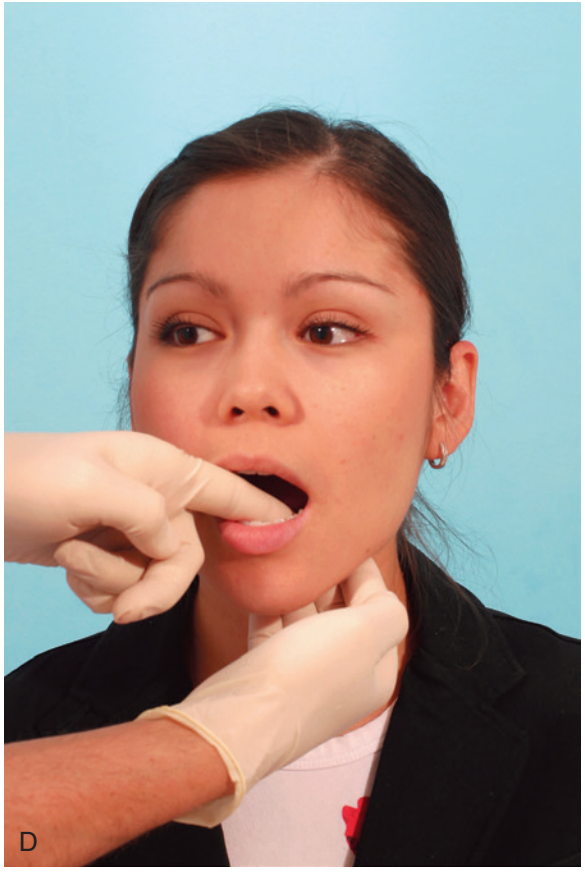
Diagnostic Adjuncts

A variety of adjunctive diagnostic aids have been promoted to the practitioner to screen for and identify oral and pharyngeal cancers (OPCs) and oral premalignant lesions at their earliest presentation (Tables 22.1 and 22.2).[1-15] They are all marketed as aids for the clinician to use in addition to, not in lieu of, the accomplishment of the conventional head and neck examination and are often promoted as advanced "must-have" products. Some adjuncts are marketed as "discovery" or "screening" enhancements, whereas others are marketed as case assessment utilities to further assess a visually identified lesion. The use of these products in the profession remains a topic of much debate. As there is currently



• **Fig. 22.3** (A) Anatomic location of cervicofacial lymph nodes.





• **Fig. 22.3, cont'd** (B) Anterior approach to cervical lymph node examination. Gently move the fingers in a circular motion along the full length of the sternocleidomastoid muscle. (C) Posterior approach to cervical lymph node examination. It is generally helpful for the patient to move the head from side to side and to tilt the head forward to make the lymph nodes more palpable. (D) Bimanual palpation of floor of mouth and submandibular lymph nodes.

TABLE 22.1 Available Cytology-Based, Vital Stain–Based, and Light-Based Adjunctive Diagnostic Technologies[1–12]

	Product	Contact
Cytology-based	OralCDx Brush Test	CDx Diagnostics
	CytID	Forward Science
Vital stain–based	Toluidine chloride stain (component of ViziLite Plus with TBlue)	Den-Mat Holdings
	OraBlu	AdDent, Inc.
Light-based	ViziLite TBlue	Den-Mat Holdings
	Microlux DL	AdDent, Inc.
	VELscope Vx	LED Dental
	Sapphire Plus	Den-Mat Holdings
	Identafi	DentalEZ
	Bio/Screen	AdDent, Inc.
	DOE SE Kit	DentLight Inc.
	OralID	Forward Science
	ViziLite PRO	Den-Mat Holdings, LLC

TABLE 22.2 Available Molecular-Based Adjuncts to Diagnose Oral Premalignant Lesions/Oral and Pharyngeal Cancer[12–15]

Product	Company	Biomarkers Assessed
OraRisk HPV Complete Genotype	OralDNA Labs	HPV strains 2a, 6, 11, 16, 18, 26, 30–35, 39–45, 49, 51–62, 64, 66–77, 80–84, 89
OraRisk HPV 16/18/HR	OralDNA Labs	HPV strains 16, 18, 31, 33, 35, 39, 45, 51, 52, 56, 58, 59, 66, 68
MOP	PCG Molecular	HPV, cytology, cellular changes
SaliMark OSCC	PeriRx, LLC	DUSP1, SAT, and OAZ1

HPV, Human papillomavirus.

insufficient evidence to draw a firm conclusion, clinicians should be both cautious in choosing to use such devices and aware of their limitations.

Cytology-Based Adjuncts

Available since 1999, the Oral CDx BrushTest is specifically marketed to the dental professional to "test common oral spots (subtle red or white spots) that may appear in your mouth from time to time."[16] As such it is a case assessment adjunct. This adjunctive test is a refinement of the pap smear technique used in gynecology, in which a special sampling brush is used to harvest a full transepithelial specimen that is forwarded to a centralized laboratory for assessment. The appropriate CDT code to use is D7288, "brush biopsy—transepithelial sample collection."[17] At the laboratory, a sophisticated computer protocol is employed that helps the pathologist render a final report. Variants of this technology (WATS^{3D}, EndoCDx TNE—Transnasal Esophagoscopy, EndoCDx LP—Laryngeal) are marketed to gastroenterologists and otolaryngologists.[18]

The CytID case assessment adjunct utilizes a liquid cytology sampling technique; its recommendation for use is similar to that of the previously described Oral CDx BrushTest for assessing lesions when biopsy is not warranted or possible.[19] The appropriate CDT code to use is D7287, "oral cytology brush."[17] The use of liquid cytology is claimed to provide a more accurate sampling compared with the Oral CDx BrushTest.[20,21] Tested lesions that receive a "malignancy" or "atypical" result with CytID must undergo a scalpel biopsy to determine the definitive diagnosis.

The clinical value of using cytology to assess suspicious lesions remains controversial, and many consider cytology an unnecessary intermediate procedure.[22-28] Cytology is not diagnostic and all "positive" or "atypical" reports must undergo a scalpel biopsy to establish a firm diagnosis. Furthermore, lesions that report back as negative but that persist clinically will often have to undergo biopsy to obtain a diagnosis. In a recent study addressing the efficacy of the BrushTest in assessing 41 small cancerous lesions (carcinoma in situ and ≤2 cm), the authors determined the sensitivity of the brush technique to be 74.5%.[29] Thus when this test is used, as marketed, to "test common oral spots," OPC may be missed.

Vital Stain–Based Adjuncts

Vital staining with toluidine blue has been advocated for decades as a method to better assess suspicious mucosal lesions.[23,30,31] It uses a topically applied metachromatic dye that has an affinity for tissues expressing high cellular activity (e.g., dysplasia, neoplasia, inflammatory, regenerative). Tissues that retain the dye appear dark blue clinically. False-positive results are common and are primarily associated with inflammatory lesions and healing ulcers, which also have high cellular metabolic rates.[22,32] As a consequence, operator experience is essential for proper interpretation.

Toluidine blue is not currently approved by the U.S. Food and Drug Administration (FDA) as a stand-alone adjunctive screening aid. It is marketed as a case assessment marking aid to the ViziLite TBlue, Bio/Screen, and MicroLux DL light-based adjuncts (see further on), where it is used as a case assessment marker to further enhance the visualization of an area initially identified by the light-based adjunct.[2,9] The appropriate CDT code to apply in using toluidine blue is D0431, "adjunctive prediagnostic test that aids in detection of mucosal abnormalities including premalignant and malignant lesions, not to include cytology or biopsy procedures."[17]

Light-Based Adjuncts

From the perspective of the FDA, the light-based adjuncts are all cleared for marketing by the FDA as illumination devices.[33] All are marketed to help the practitioner discover new or potentially overlooked mucosal abnormalities. Some are also marketed to help the surgeon define appropriate surgical margins for excision.[23,34] These devices can be categorized into two basic groups according to the manner in which a specific spectrum of light is used to interrogate the tissue.

The ViziLite TBlue and Microlux DL use a blue-white light (spectral wavelengths of 430 and 580 nm) to assess the tissues. The blue-white light for the ViziLite TBlue product is generated via chemiluminescence, whereas a battery powered light-emitting diode is used to generate the blue-white light for the Microlux DL product. A 60-second prerinse with a 1% acetic acid solution is used to remove the surface glycoprotein layer and improve visualization with either product.[22,35] The examination is performed in a darkened room or with the use of special eyewear to negate the effects of ambient light. Normal cells absorb the blue-white light, whereas dysplastic cells with abnormal nuclei and high nuclear/

cytoplasmic ratios reflect the blue-white back to the examiner as "aceto-white."[35-37]

The VELscope Vx, Sapphire Plus, Identafi, BioScreen, DOE Oral Exam System, OralID, and ViziLite PRO products use light spectra in the 390- to 460-nm range to assess the autofluorescent character of the mucosal tissues. Narrow-band filtration (either in the device's viewfinder or via eyewear) further highlights the autofluorescent character of the lesion. Dysplastic or carcinogenic tissues are associated with a decrease in natural fluorophore concentration and an increased absorption and scattering of light.[35] Normal or healthy tissue appears pale green utilizing autofluorescence, whereas suspect tissues appear dark (loss of fluorescence).[38] The Identafi product includes an additional green-amber light (545 nm) option to better visualize the increase in angiogenesis associated with carcinoma.[39,40]

Although light-based adjuncts do offer the clinician a different perspective in viewing a given lesion (e.g., assessment utility), their value and efficacy as screening adjuncts remain unproven.[35,38,41] In a recent report of 14 available studies addressing the effectiveness of the VELscope, ViziLite, and Microlux DL adjuncts, the authors determined that the adjuncts demonstrated widely variable sensitivities and specificities and did not effectively discriminate between high- and low-risk lesions.[35]

Practitioners choosing to use any of the available visualization adjuncts in assessing their patients should understand their limitations and ensure that an appropriate referral and/or biopsy is accomplished for any lesion deemed suspicious. The appropriate CDT code to apply in using one of these adjunctive aids is D0431, "adjunctive prediagnostic test that aids in detection of mucosal abnormalities including premalignant and malignant lesions, not to include cytology or biopsy procedures."[17]

Molecular-Based Adjuncts

The assessment of saliva to identify potential tumor biomarkers (e.g., nonorganic compounds; proteins and peptides; DNA, mRNA, and miRNA; carbohydrates; and other metabolites) is being aggressively researched.[42-44] The number of potential biomarkers associated with OPC exceeds 800, and the challenge will be to identify the unique molecular fingerprint of OPC.[45] Four molecular-based adjunctive tests (see Table 22.2) have been introduced as putative aids to assess for OPC or OPC risk.

The OraRisk human papillomavirus (HPV) Complete Genotype and the OraRisk HPV 16/18/HR are two saliva-based polymerase chain reaction (PCR)–based tests available for determining the presence of HPV.[12,13] The value of routinely using either of these tests in clinical practice remains unknown, as the prognostic value of current or persistent HPV detection in oral rinses to predict the risk for OPC is unknown and there are available therapies to address chronic HPV infection.[46,48] In a recent analysis the authors estimated that 10,500 patients would need to be tested to detect one case of OPC.[48] The use of this test is likely to generate significant anxiety for those who screen positive for a high risk HPV.[49]

The MOP screening test from PCG Molecular claims to test for oral cancer risk earlier than traditional testing methods by assessing for HPV, cytologic changes, and DNA damage.[50] Information on this test appears to be restricted to its promotional website, and there is no peer-reviewed literature addressing the overall clinical value of this product.

The SaliMark oral squamous cell carcinoma adjunctive test is a commercially available assessment utility intended to help the practitioner stratify the risk of malignancy for a clinically discovered oral lesion.[15] The test interrogates for the levels of the putative cancer markers DUSP1, SAT, and OAZ1. The company claims that the sensitivity and specificity of the SaliMark for oral squamous cell carcinomas are 91.7% and 59.0%, respectively.[51] However, the performance of this product in assessing the variety of nonmalignant oral lesions encountered in general practice remains unknown. This test, like cytology, is marketed as a negative predictor; patients with moderate or high test results should be referred for further evaluation and/or biopsy, whereas patients with low risk results should be followed up to ensure resolution. However, a biopsy will often be necessary to diagnose a low-risk lesion, rendering use of the SaliMark an often unnecessary intermediate procedure.

Radiographic Examination

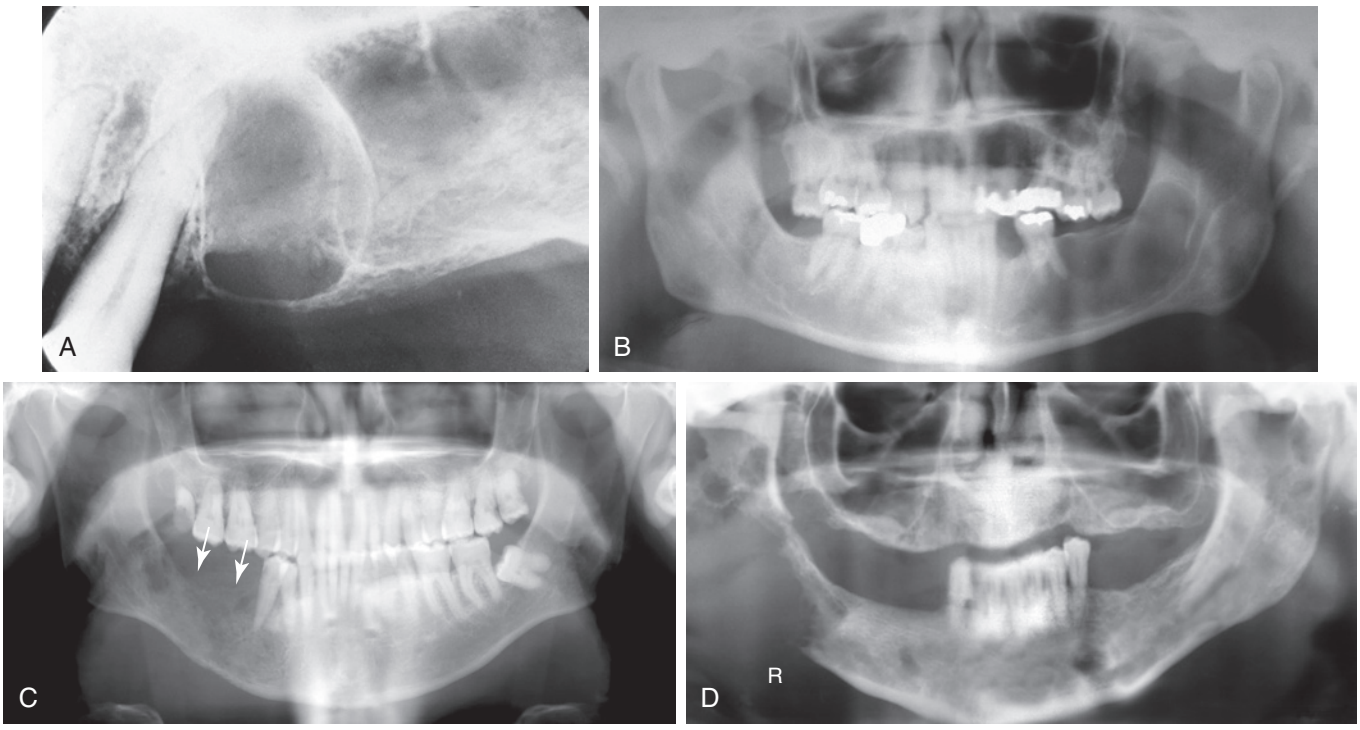
Radiographs are useful diagnostic adjuncts after completion of the history and clinical examination, especially for lesions occurring within or adjacent to bone. When soft tissue lesions are close to bone, radiographs may indicate whether the lesion is causing an osseous reaction, eroding into the bone, or arising from an intraosseous origin. Various radiographic techniques may be used depending on the anatomic location of the lesion. Most pathologic conditions of the mandible or maxilla can be adequately viewed on routine plain views (e.g., periapical, occlusal, or panoramic), but occasionally specialized imaging techniques are needed—including computed tomography (CT; with the newer cone-beam CT) or magnetic resonance imaging (MRI) views—to fully delineate the exact nature and location of intrabony lesions.

The radiographic appearance may frequently give clues to the diagnosis of a lesion. For example, a cyst usually appears as a radiolucency with sharp borders (Fig. 22.4A–B), whereas a radiolucency with ragged, irregular borders might indicate a malignant or more aggressive lesion (see Fig. 22.4C–D). In viewing a radiograph, if an intraosseous area shows a deviation from normal structures or appearance, the dentist must determine whether the change is pathologic or simply an atypical presentation of a normal anatomic structure. This is particularly true in viewing certain projections of the maxilla and the mandible in which the complex adjacent anatomy leads to superimpositions of contiguous structures such as the paranasal sinus cavities.

In unique diagnostic situations, radiopaque dyes or markers may be used in conjunction with routine or specialized radiographs. For example, sialography involves the injection of radiopaque dye into glandular ducts to produce an indirect image of the gland architecture and delineate any pathologic lesions within the gland. Cysts may be injected to assist in determining the true extent of their anatomic boundaries. Radiopaque markers such as needles or metal spheres can be used to localize a foreign object or pathologic lesion.

Laboratory Investigation

In certain instances supplementary laboratory tests can assist in lesion identification. Certain oral lesions may be manifestations of a systemic disease process such as hyperparathyroidism, multiple myeloma, leukemia, and certain lymphomas. To cite an example of the role of laboratory testing, examination of a patient with multiple lytic lesions and loss of lamina dura bone might suggest hyperparathyroidism. This diagnosis could be clarified by the dentist requesting serum calcium, phosphorus, and alkaline phosphatase tests. Guidance for requesting such tests can be found in leading oral and maxillofacial pathology textbooks and other resources.



• **Fig. 22.4** (A–B) Radiographic appearance of cysts. (A) Note the peripheral condensing osteitis around radiolucent center. (B) Large unilocular radiolucency in left mandible with well-defined peripheral border. (C–D) Radiographic appearance of bone destruction by malignancy. (C) Squamous cell carcinoma has eroded into the right mandible. Note the ragged appearance and lack of cortication *(arrows).* (D) Intraosseous malignancy has completely destroyed the normal architecture of the right mandibular ramus and produced a pathologic fracture.

In the majority of cases, screening laboratory studies are considered unnecessary because they often have a low diagnostic yield per total cost involved in performing such tests. Once the surgical biopsy has provided a definitive diagnosis, however, laboratory testing can contribute meaningful information that is relevant to the subsequent management of the lesion.

Presumptive Clinical Differential Diagnosis

After completing the initial dental, medical, and lesion histories and clinical, radiographic, and laboratory examinations (as indicated), the dentist next should compile a presumptive list of reasonable differential diagnoses. These diagnoses convey the clinician's impression to the pathologist regarding what the dentist feels the lesion most likely is on the basis of the total assessment. These diagnoses may or may not ultimately be consistent with the final histologic diagnosis but are, nonetheless, important because the pathologist rules out entities that may have similar clinical and pathologic presentations.

Prebiopsy Monitoring

Any undiagnosed or suspicious change in oral tissues that cannot be explained by localized trauma (and the source corrected) or other factors should be followed up in 7 to 14 days, with or without local treatment. If the lesion enlarges or expands, develops an altered appearance, or does not respond as expected to local therapy, biopsy is usually indicated. Areas of *leukoplakia* (which is used as a clinical and not a pathology term) can be problematic, because up to 15% to 20% of those areas (and 100% of erythroplakia lesions) can exhibit histologic evidence of dysplasia or frank malignancy.[52] High-risk areas of the mouth include the floor of the mouth, the lateral and ventral surfaces of the tongue, and the buccal and lower lip mucosa. Areas of redness or pebbling within areas of leukoplakia are especially troubling. Incisional biopsies from one or more of such suspicious areas are generally indicated.

During subsequent examinations, the patient record should provide details on whether the observed lesion has improved or not improved and the dentist's plan for subsequent management (i.e., continued observation on a structured timetable, continued local treatment, biopsy, or referral).

Basic Tenets of Follow-up and Referral

Failure to diagnose and refer a patient with a possible pathologic condition in a timely manner has become one of the leading causes of litigation in the medical profession. Over the years, numerous articles and textbook chapters have provided guidance on how to obtain biopsies of lesions and to formulate differential diagnoses. Little guidance has been provided on the proper follow-up protocols for "suspicious" lesions and guidelines for appropriate referrals between practitioners. One article has attempted to provide this needed guidance without imposing a legal precedent that could be construed as a legal standard.[53]

The dentist should not delegate examination of patients for pathologic conditions to auxiliary staff such as dental hygienists. Although most hygienists are well trained to be observant with

regard to soft tissue changes in the oral cavity, the ultimate responsibility for the detection of pathologic conditions (including oral cancer screening) rests with the dentist. Delegation of this duty is not permitted by law in most if not all, states. If the dentist does not follow up on the hygienist's discovery of abnormal tissues, the patient record should reflect the rationale for that decision.

If the dentist decides to refer the patient for a second opinion or specialty management, the referral appointment should ideally be arranged before the patient leaves the office. If left to make the appointment themselves, many patients may fail to do so because of fear, denial, or procrastination. The arranged appointment should be followed up with a letter, fax, or email from the referring general dentist to the specialist outlining the details of the case, the concerns, and the requested procedures. A copy of this correspondence should be placed in the patient's record. Copies of the specialist's findings, recommendations, procedures, and biopsy findings should also be placed in the patient's record. These formal exchanges provide precise documentation that prevents miscommunications between offices and may provide some element of protection if litigation is initiated later. Returned reports from the pathologist should be acted on promptly. The patient should be notified of the results, and if the results are unexpected or positive, requiring further treatment, the patient should be counseled in person by the dentist.

Biopsy or Referral

Clinicians vary in their surgical interests, training, and skills. Some dentists may feel comfortable performing many biopsy procedures on their patients, whereas others may refer their patients to other specialists. This is a personal choice and should take several points into consideration.

1. *Health of the patient.* The patient pool in the United States is getting older, and a growing number of older patients are seeking treatment in dental offices. Many of these patients have a history of systemic diseases, multiple medications, or physical compromise that pose an increased surgical risk or potential hazards. These conditions are outlined and discussed in Chapters 1 and 2; they may complicate any planned surgical procedures, including biopsy. The presence of such conditions, however, should not significantly delay biopsy or referral in most cases. Patients can be referred to specialists who are trained to deal with patients with special medical needs so that the procedure is carried out as safely as possible.
2. *Surgical difficulty.* If any of the basic surgical principles outlined in Chapter 3 (such as access, lighting, anesthesia, tissue stabilization, and instrumentation) pose a problem for the dentist in terms of treatment, referral should be considered. Similarly, as the size of a lesion increases or its position encroaches on significant anatomic structures, the potential for significant complications (e.g., bleeding and nerve damage) increases. Each dentist must judge whether the biopsy is within his or her surgical abilities or whether the patient would be better managed by a more highly trained specialist.
3. *Malignant potential.* The dentist who suspects that a lesion is malignant has two choices: (1) perform a surgical biopsy after completion of a comprehensive diagnostic workup or (2) before a biopsy is performed, refer the patient to a specialist who is able to provide definitive treatment if the lesion is shown to be malignant. The latter choice usually represents better service to the patient if the referral can be executed in a prompt and timely manner. In such cases it is better for the referral specialist to evaluate the lesion before any surgical intervention has compromised its clinical features. Biopsy can also produce reactive lymph nodes that are possibly unrelated to the original lesion. Allowing the referral specialist to evaluate the patient before biopsy helps obtain a more accurate diagnosis and simplifies the formulation of a suitable treatment plan.

Informed Consent and Shared Risk

Some clinicians argue that all lesions should be removed, a biopsy should be obtained, or both should be done. In some clinical situations, however, patients and their dentists may jointly elect to observe periodically any innocent-appearing lesions that occur in low-risk areas in low-risk patients (e.g., nonsmokers). However, lesions demonstrating any dysplastic changes on histopathologic examination should always be removed in their entirety. It must be remembered that observation over time may be a calculated risk. Many life-threatening conditions can initially masquerade as innocuous lesions, and many different lesions can present similar clinical appearances. The dentist should err on the side of caution and must always ensure that the patient is fully informed of the risks, rationales, and alternatives before deciding that a lesion should not be removed. The patient must understand that he or she is sharing the responsibility for that decision, and the discussions on which the decision is based should be well documented in the patient's record. If the dentist advises removal and the patient declines, that discussion and decision should likewise be thoroughly documented, reflecting the patient's understanding of the potential negative consequences of the decision.

Postbiopsy Monitoring

Following an incisional biopsy for diagnosis, a positive pathology report (indicating dysplastic changes or malignancy) generally mandates appropriate surgical excision of the lesion and contiguous tissues as indicated by the histopathologic diagnosis. This might necessitate referral to an oral-maxillofacial surgeon or other head and neck specialist who is experienced in the management of malignancies. A negative biopsy report, however, should never be taken at face value but interpreted with clinical and historical findings in mind. If doubt exists, a second biopsy might be indicated. At the very least, plans should be developed for a structured schedule of continued close observation at appropriate intervals. Generally it is prudent to reexamine the patient within 1 month and then at 3, 6, and 12 months during the first year. Thereafter, if clinical and radiographic findings are unchanged, the interval between follow-up visits can be increased to 6 and then 12 months, as appropriate. Patients should always be counseled to contact the dentist immediately if any clinical changes or new symptoms are noted between visits.

General Principles of Biopsy

The term *biopsy* indicates removal of tissue from a living body for microscopic diagnostic examination. Biopsy is the most precise and accurate of all diagnostic tissue procedures and should be performed whenever a definitive diagnosis cannot be obtained using less invasive procedures. The primary purpose of biopsy is to determine the diagnosis precisely so that proper treatment can be provided because many different lesions have similar clinical or radiographic appearances. In actuality, a biopsy is more likely to rule out malignancy than to diagnose cancer because the majority of oral and odontogenic lesions are benign. Nevertheless, the term

biopsy leads many patients to a perception that the dentist suspects malignancy, so discussions that include that word must be carefully phrased so that it will not cause undue alarm or anxiety.

Indications for biopsy are summarized in Box 22.2. The typical characteristics of lesions that should raise the dentist's suspicion of malignancy are listed in Box 22.3. Fig. 22.5 shows examples of lesions that should be considered suspect. The four major types of biopsy generally performed in and around the oral cavity include a (1) cytologic biopsy, (2) incisional biopsy, (3) excisional biopsy, and (4) aspiration biopsy.

Incisional Biopsy

An incisional biopsy is a biopsy procedure that removes only a small portion of a lesion. If the lesion is large or demonstrates differing characteristics in different locations, then more than one area of the lesion may require sampling. Incisional sampling is used if the lesion is large (>1 cm in diameter), is located in a risky or hazardous location, or whenever a definitive histopathologic diagnosis (e.g., for suspected malignancy) is desired before planning a complex removal or other treatment.

The biopsy is generally excised as a wedge of tissues in such a manner as to include normal- and abnormal-appearing tissues in the sample (Figs. 22.6 and 22.7). Central areas of a large lesion are often necrotic and therefore of little diagnostic value to the pathologist, whereas active growth is taking place at the perimeter; therefore inclusion of the lesion interface with normal-appearing tissue can demonstrate many significant cellular changes. Care must be taken to include an adequate depth of tissue as well so that cellular features from the base of the lesion are included. Generally it is better to take a narrow, deep specimen than a broad, shallow one. Care should be taken not to compromise significant adjacent anatomic structures such as nerves and major blood vessels unless they seem to have a relationship with the origins or pathology of the lesion.

• BOX 22.2 Indications for Biopsy

- Any persistent pathologic condition that cannot be clinically diagnosed
  - Lesions with no identifiable cause that persist for more than 10–14 days despite local therapy
  - Intrabony lesions that appear to be enlarging
  - Visible or palpable submucosal swelling beneath clinically normal mucosa
- Any lesion that is believed to have malignant or premalignant characteristics (see also Box 22.3)
  - Any lesion that has grown rapidly for no obvious reason
  - Red, white, or pigmented mucosal lesions for which a cause or diagnosis is not evident
  - Any lesion that is firmly attached or fixed to adjacent anatomic structures
  - Any unknown lesion in a high-risk area for the development of cancer (e.g., floor of mouth and tongue)
- Confirmation of clinical diagnostic suspicions
- Any lesion that does not respond to routine clinical management (i.e., removal of local irritant) over a 10- to 14-day period
  - Inflammatory signs that persist for long periods
- Any lesion that is the basis of extreme concern to the patient (cancerphobia)

Data from King RC, McGuff HS. Biopsy: a life saving measure. Tex Dent J. *1996;113(6):13–18.*

• BOX 22.3 Characteristics of Lesions That Raise Suspicion of Malignancy

- *Bleeding:* lesion bleeds on gentle manipulation
- *Duration:* lesion has persisted more than 2 weeks
- *Erythroplasia:* lesion is totally red or has a red-and-white speckled appearance
- *Fixation:* lesion feels attached to adjacent structures
- *Growth rate:* lesion exhibits rapid growth
- *Induration:* lesion and surrounding tissue are firm to the touch
- *Ulceration:* lesion is ulcerated or presents as an ulcer

Excisional Biopsy

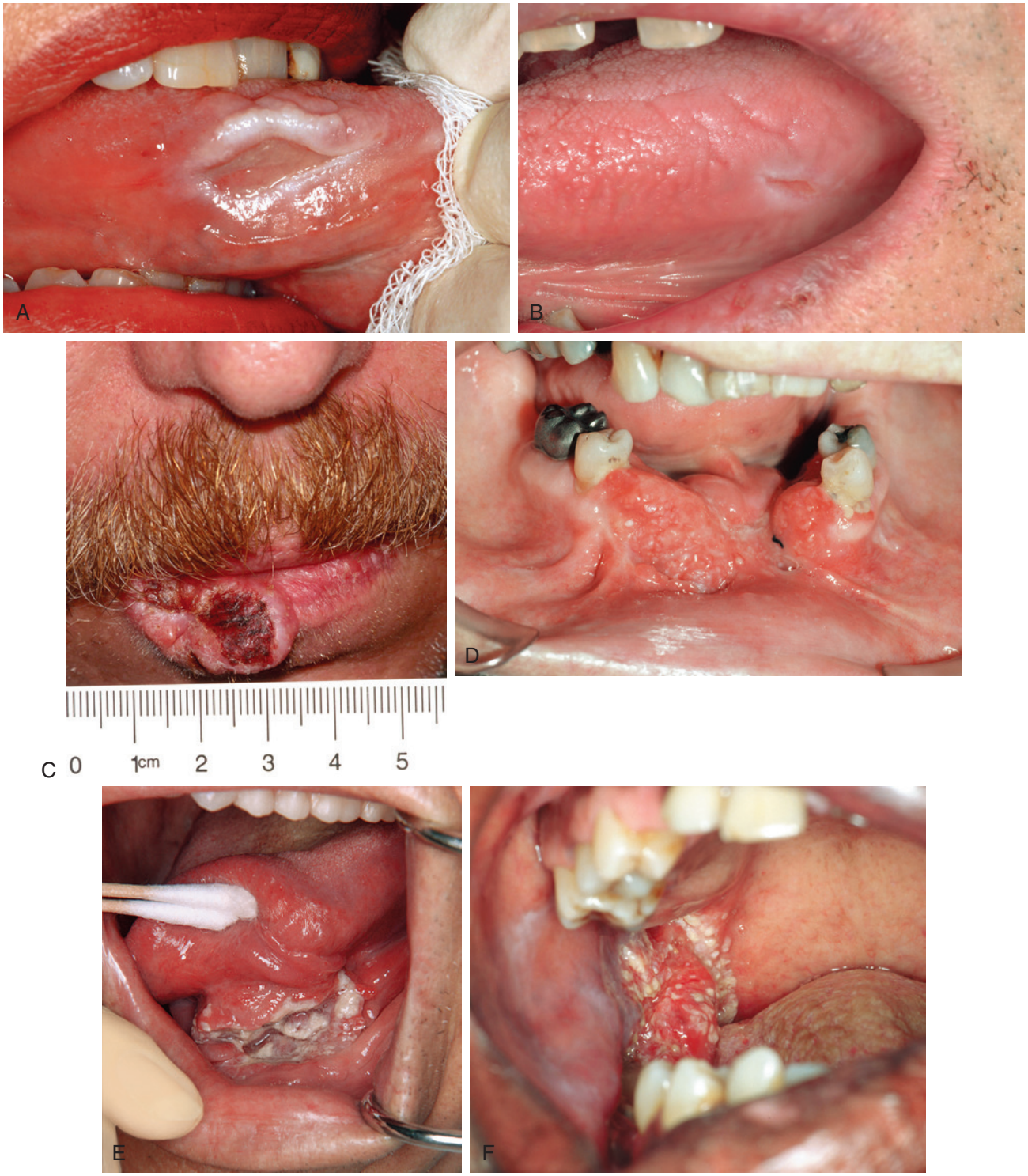
An excisional biopsy implies removal of a lesion in its entirety, to include a 2- to 3-mm perimeter of normal tissue around the lesion (Fig. 22.8). The width of the perimeter of normal tissue may vary depending on the presumptive diagnosis. An additional 2 to 3 mm in tissues may be required for specimens suspected of malignancy, including some pigmented lesions and lesions already diagnosed as having dysplastic or malignant cells. Complete excision often constitutes definitive treatment of the lesion biopsied. Excisional biopsy is reserved for smaller lesions (<1 cm in diameter). Lesions that can be removed in their entirety without excessively compromising the patient's features or oral function must be removed to eliminate the threat to the patient's well-being.

Aspiration Biopsy

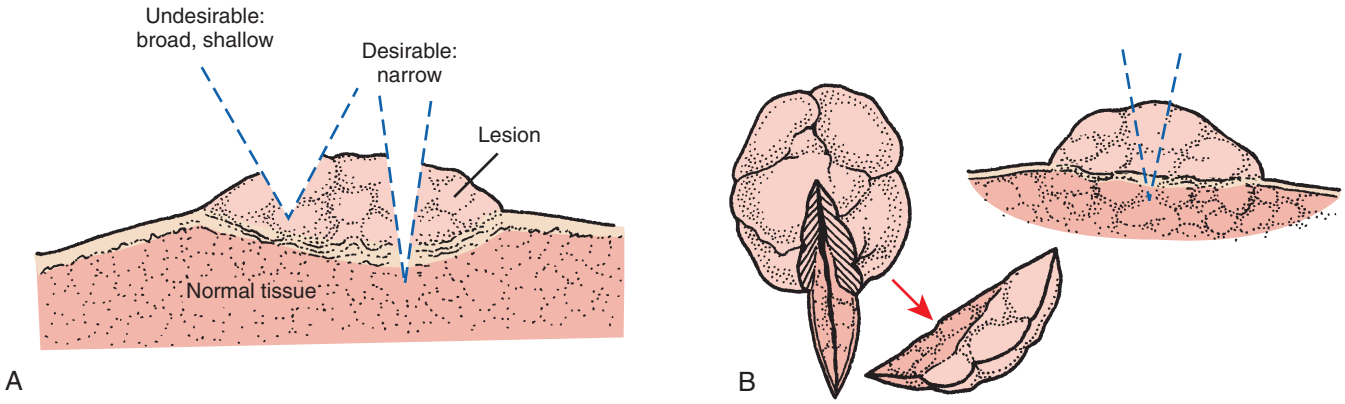
Aspiration biopsy is performed with a needle and syringe by penetrating a suspicious lesion and aspirating its contents. Two main types of aspiration biopsy in clinical practice are (1) biopsy to explore whether a lesion contains a fluid and (2) biopsy to aspirate cells for pathologic diagnosis. This latter is termed *fine-needle aspiration* and is often performed by pathologists trained in the technique. Fine-needle aspiration is used when a soft tissue mass is detected beneath the skin or mucosal surface and the patient wishes to avoid a scar or adjacent anatomic structures pose a risk. Fine-needle aspiration is an especially effective diagnostic tool for neck masses from which it can be difficult to obtain a biopsy surgically. Routine aspiration of intraosseous radiolucent lesions is also performed before entering into the bony defect to rule out the potential of the lesion being vascular in origin and to define whether it is cystic or solid. Details on this can be found later in this chapter. Aspiration is performed on any fluid-filled lesion except a mucocele. A 16- to 18-gauge needle connected to an aspirating syringe is used. The needle tip may have to be repositioned repeatedly in an effort to locate a suitable fluid-containing cavitation.

Soft Tissue Biopsy Techniques and Surgical Principles

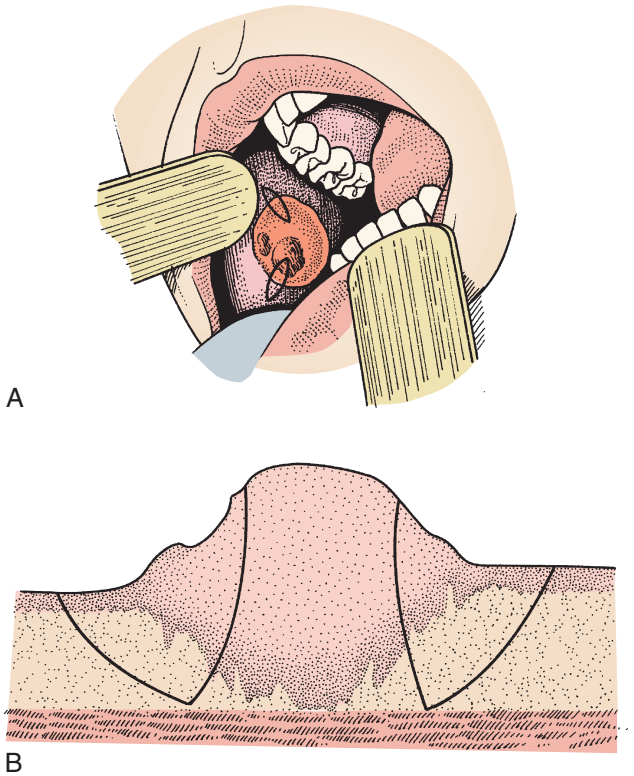
Biopsy of oral soft tissues is a competency that every general dentist should possess. Properly performed, most biopsies are simple procedures that can easily be performed in the dental office by using local anesthesia and minimal instrumentation (Box 22.4). The only variables of the technique relate to areas of anatomic risk or limitations imposed by the size and type of lesion. The surgical principles presented in Chapter 3 apply to biopsy, as do other



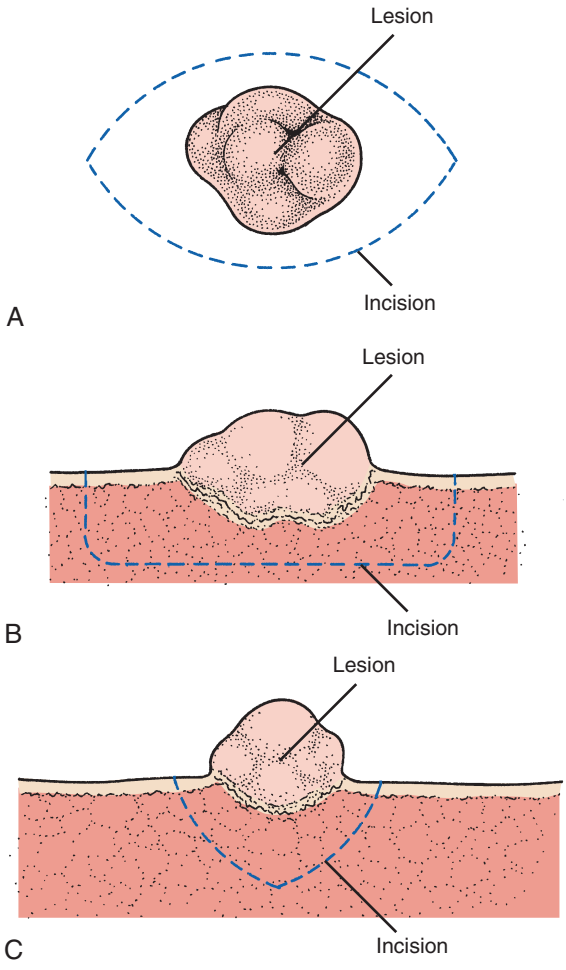
• **Fig. 22.5** Examples of lesions that should be considered for biopsy. (A) Ulcer on lateral border of tongue. In this case, it was a traumatic ulcer from biting. (B) Another ulcer on lateral border of tongue. In this case, it was from the sharp edge of a fractured tooth cusp. (C) Large ulcer of the lower lip, a type that may be seen in a patient with a history of smoking. This lesion was a squamous cell carcinoma. (D) Typical appearance of squamous cell carcinoma of the alveolar ridge. (E) Typical appearance of squamous cell carcinoma of the floor of the mouth. (F) Typical appearance of squamous cell carcinoma of the retromolar area.



• **Fig. 22.6** (A) Desirability of obtaining deep specimen, rather than broad and shallow specimen, when incisional biopsy is performed. If malignant cells are present only at the base of the lesion, a broad and shallow biopsy might not obtain these diagnostic cells. (B) Desirability of obtaining incisional biopsy at the margin of a soft tissue lesion. The junction of the lesion with normal tissue frequently provides the pathologist with more diagnostic information than if the biopsy were taken only from the center of the lesion. This is particularly important when a biopsy of an ulcer is performed.



• **Fig. 22.7** Desirability of obtaining more than one incisional biopsy if the characteristics of the lesion differ from one area to another. (A) One area of the lesion will frequently appear histologically different from another. (B) In obtaining biopsy on buccal or labial mucosa, the incision is usually carried to depth of the musculature.



• **Fig. 22.8** Excisional biopsy of a soft tissue lesion. (A) Surface view. An elliptical incision is made around the lesion at least 3 mm away from the lesion. (B) Side view. The incision is made deep enough to remove the lesion completely. (C) End view. Incisions are made convergent to the depth of the wound. Excision made in this way facilitates closure.

• BOX 22.4 Instruments for Mucosal Soft Tissue Biopsy

- Local anesthesia administration equipment and supplies
- Scalpel handle with No. 15 blade
- Appropriate tissue retractor (Seldin 20, Minnesota, chalazion, or other)
- Small, pointed, fine-tipped scissors (such as curved Iris or Metzenbaum)
- Fine-tipped tissue pickups (such as Adson)
- Small curved hemostat (such as mosquito)
- Suction tip and hose
- 2 × 2, 3 × 3, or 4 × 4 inch sterile gauze sponges
- Needle holder, suture with attached cutting or reverse cutting needle
- 3-0 or 4-0 black silk
- 4-0 resorbable (polyglycolic acid or polyglactin 910)
- Dean suture scissors
- Irrigation syringe and sterile irrigating fluid (0.9% normal saline) in appropriate bowl or basin
- Screw-top, labeled biopsy specimen bottle containing 10% formalin
- Biopsy specimen data input sheet

Additional Instruments for Intraosseous Biopsy

- Soft tissue curettes (angled)
- Periosteal elevator (such as Molt No. 9 or Molt No. 4 curette)
- End-cutting rongeurs (such as Blumenthal)
- Surgical handpiece (air does not discharge around burr), No. 8 round burr
- 5- to 10-mL disposable syringe with 18-gauge Luer-Lok needle

surgical procedures within the oral cavity. These basic surgical principles are briefly summarized in the following sections.

Anesthesia

Block local anesthesia techniques are preferred over infiltration whenever possible so that the anesthetic solution is not inadvertently incorporated in the surgical specimen. This can cause distortion of the cellular architecture of the specimen and make pathologic diagnosis more difficult if not impossible. Peripheral infiltration of local anesthetic with a vasoconstrictor is often helpful, and it should be injected at least 1 cm away from the lesion perimeter to prevent tissue architectural distortions. The vasoconstrictor will decrease hemorrhaging in the wound and improve the surgeon's ability to view the site during surgery.

Tissue Stabilization

Oral and perioral soft tissue biopsies frequently involve mobile surfaces and structures (e.g., lips, cheek, soft palate, and tongue). Accurate surgical incisions can be placed with greater ease when the involved tissues are first stabilized. This can be accomplished by any of several methods. The surgical assistant can grasp the lips on both sides of the biopsy site with his or her fingers, which also retracts and immobilizes the lips (Fig. 22.9A–E). This may also help reduce bleeding by compressing area blood vessels and their tributaries. The surgeon must be careful to avoid iatrogenic scalpel injury to the assistant's stabilizing fingers (see Fig. 22.9B). A variety of retractors are available that can perform the same function. Towel clips, Adson (fine-tip) forceps, chalazion forceps, or a heavy retraction suture can also be used for stabilization and retraction of some mobile soft tissues (Fig. 22.10; see also Fig. 22.9F–G). When used, retraction sutures should be placed deeply into the tissues, away from the planned biopsy site, so that they will function without pulling through and damaging the tissues.

Hemostasis

The use of a suction device for keeping the surgical field free of blood during the procedure should be minimized as much as possible, especially the high-volume suction devices found in modern dental offices. The assistant can often use gauze sponges to blot the site. Suctioning can increase not only bleeding but also the risk of the biopsy tissue sample being accidentally aspirated into the suction. If suction is needed, it is helpful to place a gauze pad over the end of the suction tip to serve as a filter.

Incisions

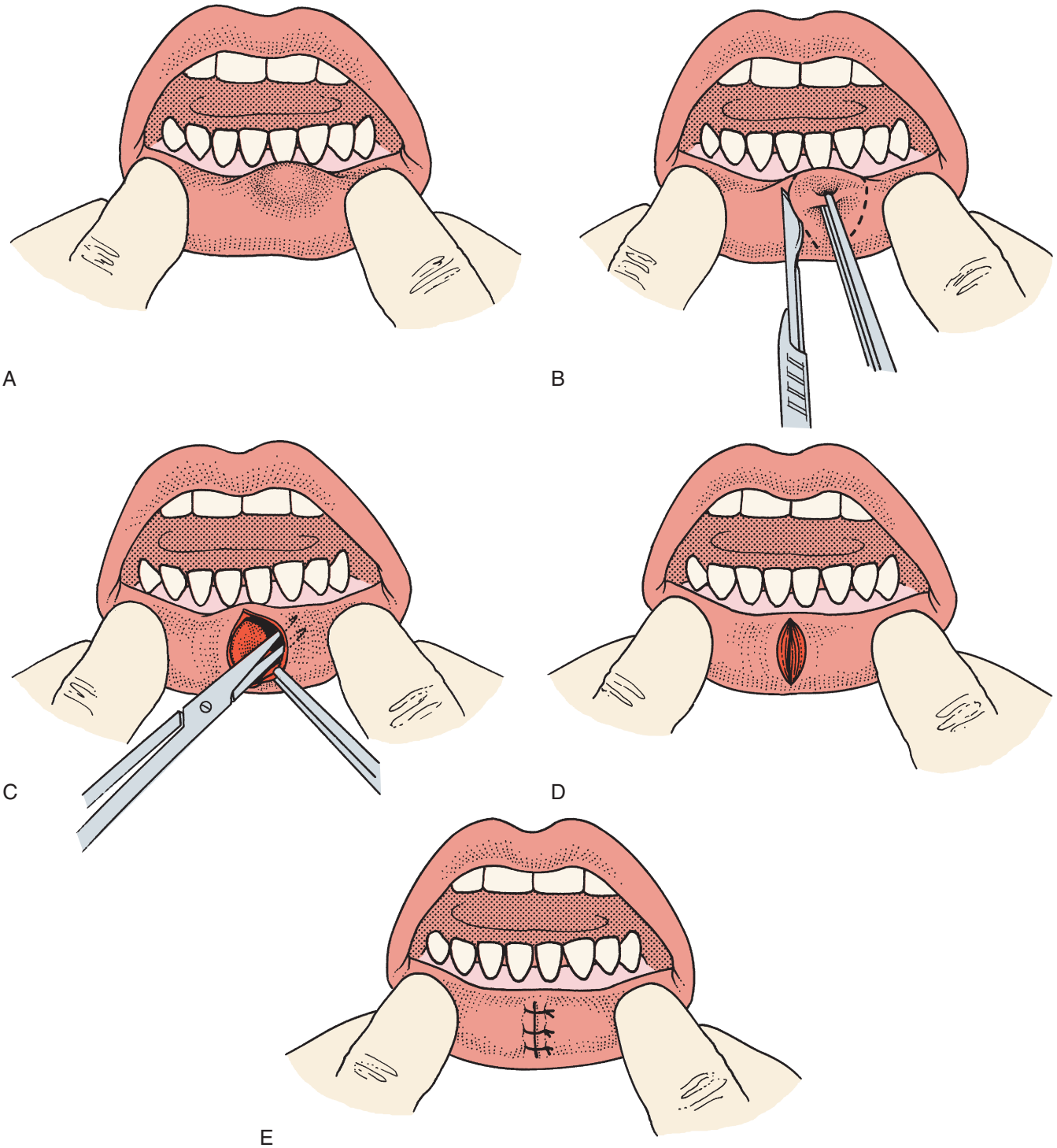
A sharp scalpel, usually with a No. 15 blade, should be used to incise the tissues. Two football-shaped surface incisions can be angled in such a way as to converge at the base; this will yield an optimal specimen and a resulting wound that is easy to close (Fig. 22.11; see also Fig. 22.9). The use of laser devices and electrosurgical equipment for making incisions for biopsies is not desirable because the tissue effects cause destruction of adjacent tissue and may distort the histologic architecture of the specimen to such a degree that definitive microscopic details are destroyed. The carbon dioxide laser in the superpulsed mode with a tight, well-focused beam may be used if necessary (e.g., for hemostasis), but the surgeon should understand that a narrow zone of necrosis will occur next to the margins of the specimen from the laser.

Variations in the size of the ellipse and degree of convergence toward the base of the lesion depend on the depth of encroachment of the lesion on normal tissues. Palpation may offer clues regarding the depth and expanse of the submucosal portions of the lesion. When performing an excisional biopsy, the surgeon must ensure a perimeter of normal tissue beneath the lesion as well. As noted previously, in most cases thin, deep specimens are preferable to wide, shallow ones (see Fig. 22.6). To the maximal extent possible, incisions should parallel the normal course of nerves and blood vessels as well as lines of muscular tension (i.e., smile lines and facial creases) so as to minimize secondary injuries and for esthetic reasons. As noted previously, a 2- to 3-mm band of normal tissue should ideally be included around the specimen during an excisional biopsy. If the lesion appears malignant, pigmented, or vascular or has diffuse borders, an additional 2 to 3 mm of normal-appearing peripheral tissue should be excised with the specimen.

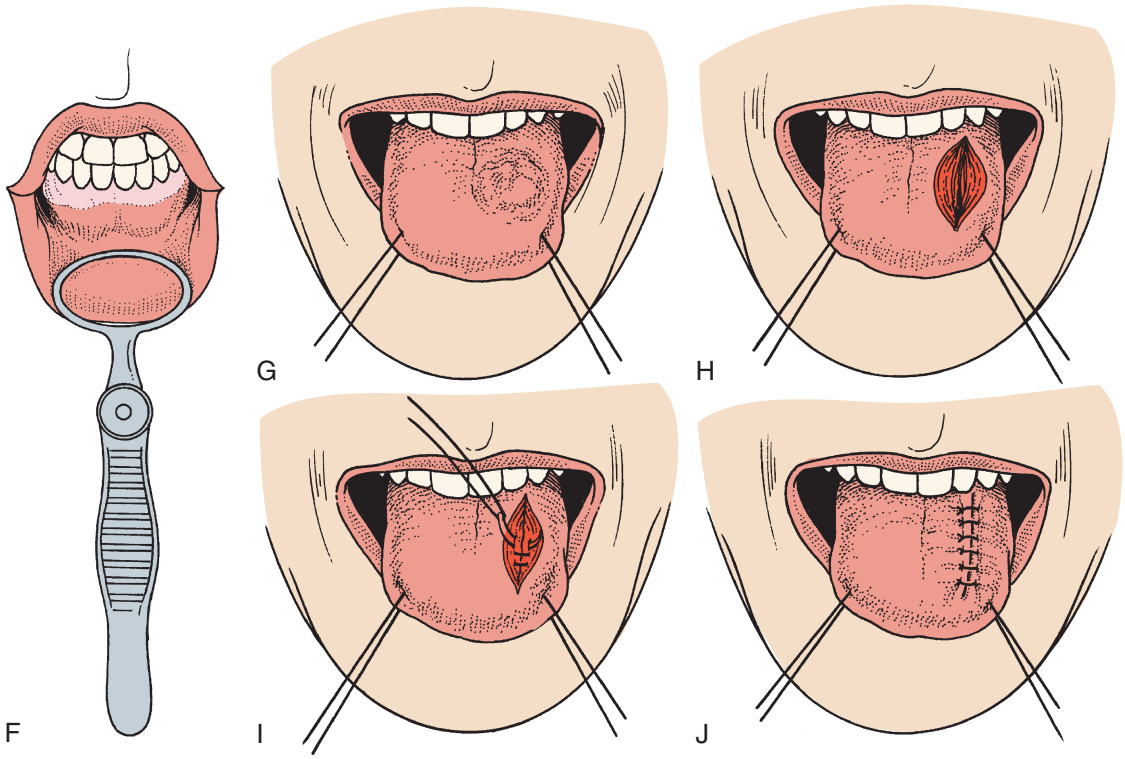
In larger lesions with variable surface characteristics, an incisional biopsy may be indicated; occasionally more than one sample has to be taken from different areas of the lesion (see Fig. 22.7).

Wound Closure

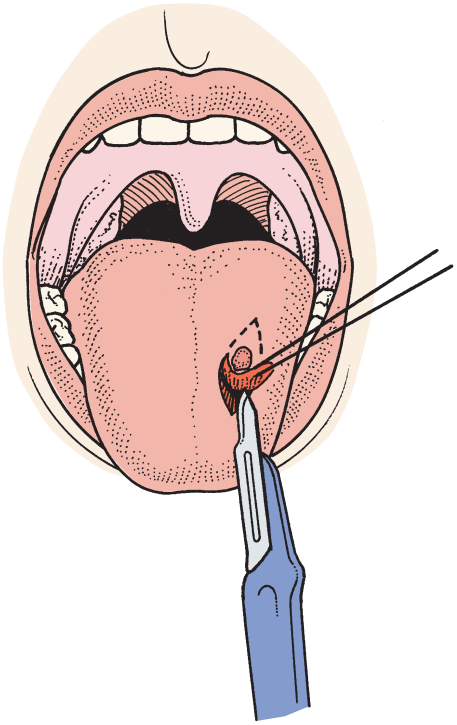
Following removal of the tissue sample, primary closure of the wound is desirable and usually possible. If the wound is deep, incorporating different tissue layers, deep closure should be carried out for each layer, using a resorbable suture material (e.g., polyglycolic acid or chromic gut; see Fig. 22.9I). Following excision of the specimen and any closure of deeper tissues, the mucosa (or skin) is undermined by using a spreading action of the tips of small scissors (e.g., Iris or Metzenbaum scissors) to separate the mucosal from the submucosal tissues (see Fig. 22.11). The submucosal layer is largely loose connective tissue that is easily dissected free from the overlying mucosa without sharp incision or snipping. This permits closure of the mucosa as a separate layer without regard to closure in the deeper layers. The extent to which this undermining is carried out is determined by the size of the wound and the



• **Fig. 22.9** Examples of methods to stabilize tissue for biopsy. (A) The assistant's fingers are used to stabilize the tissue before an excisional biopsy of a mucocele is made. (B) An elliptical incision is made around the lesion. (C) The surgeon makes a submucosal excision of the associated minor salivary glands. (D–E) The mucosa is undermined and closed.



• **Fig. 22.9, cont'd** (F) stabilization of tissue with chalazion-type device; (G) stabilization of tissue with traction sutures, in which two silk sutures, placed through the substance of the tongue (mucosa and muscle) to prevent pulling through tissue, are used to stabilize the tongue before excisional biopsy. (H) The lesion is removed after an elliptical incision was made around it. (I) Resorbable sutures are placed to approximate muscle. (J) The mucosa is closed.

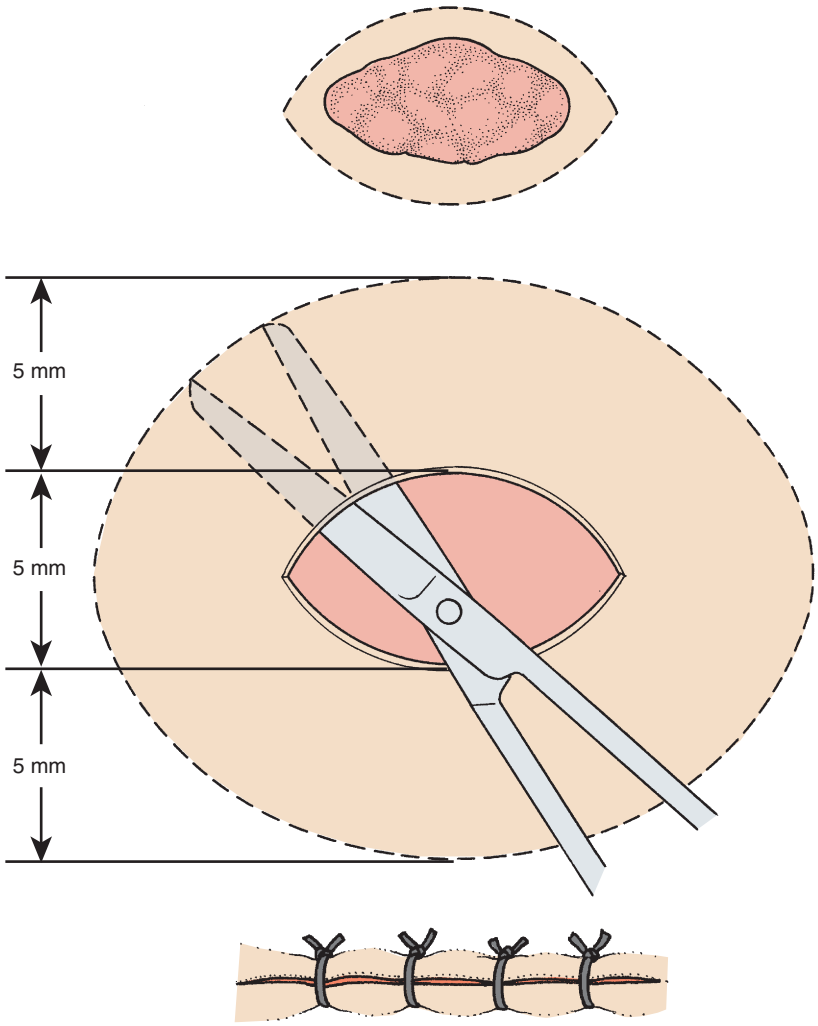


• **Fig. 22.10** The use of a traction suture placed through a specimen. While the lesion is incised, a traction suture is used to lift the specimen from the wound bed. The suture can then be tied and left attached to the lesion to identify the margin of the specimen.

anatomic location. In the lips, cheek, floor of mouth, and soft palate, wound margins are usually undermined in all directions by a distance that is at least the width of the defect before surface closure. Undermining permits tension-free approximation of tissue margins. Suture materials of choice are generally black silk or a nonreactive, slowly resorbable material such as polyglycolic acid (Dexon) or polyglactin 910 (Vicryl) sutures. Wounds on attached mucosal surfaces (e.g., gingiva and hard palate) are generally not closed but are allowed to heal by secondary intention. Protective periodontal dressings or vacuum-formed or acrylic splints lined with a tissue-conditioning liner may be used to protect the healing area(s), enhance patient comfort, and promote healing. If necessary, these customized postsurgical splints may be secured to adjacent teeth with circumdental fine wires or heavy suture material to aid retention. Postsurgical splints are usually left in place for 7 to 10 days. Biopsy wounds on the dorsum or lateral border of the tongue require deeply placed sutures at close intervals to counteract inherent muscle movements and maintain closure (see Fig. 22.9I). Resorbable sutures may be used, but gut sutures are not recommended because they have poor knot security (resulting in lost sutures) and undergo rapid enzymatic degradation. Examples of lip and tongue biopsies are shown in Figs. 22.12 and 22.13.

Handling of Tissues; Specimen Care

Any tissue specimen must be maintained in a condition that is optimal for preserving the histologic and structural architecture of the cells of the lesion. Specimens that have been crushed, frozen, desiccated, burned, or otherwise compromised may not be



• **Fig. 22.11** Principles used in closing an elliptical biopsy wound. The mucosa should be undermined bluntly with scissors to the width of the original ellipse in each direction. This allows approximation of wound margins without tension.

microscopically diagnostic once they reach the oral-maxillofacial pathologist, necessitating a repeat biopsy (which may or may not be feasible). Extreme care should be exercised in removing surgical specimens to avoid instrument damage to the specimen during manipulation. The removed tissue sample should not be wrapped in gauze (wet or dry) because it is then at risk of getting thrown out accidentally along with the gauze. The specimen also should not be set on paper or linen drapes and allowed to dry out while the surgery is being completed. Rather, the specimen should be immediately placed in a glass or plastic container that can be capped and contains a quantity of 10% formalin solution (4% formaldehyde) that is at least 20 times the volume of the specimen itself (Fig. 22.14). The specimen must be totally immersed in the preservative solution at all times, even if the container is tilted sideways during transport. Before turning his or her attention to wound closure, the dentist should also ensure that the tissue sample is not adherent to the container wall above the level of the formalin. If the specimen is mailed to the pathologist, it must be labeled with a biohazard label approved by the Occupational Safety and Health Administration; if the specimen is transported internally (e.g., within a hospital), such labeling is not mandated.

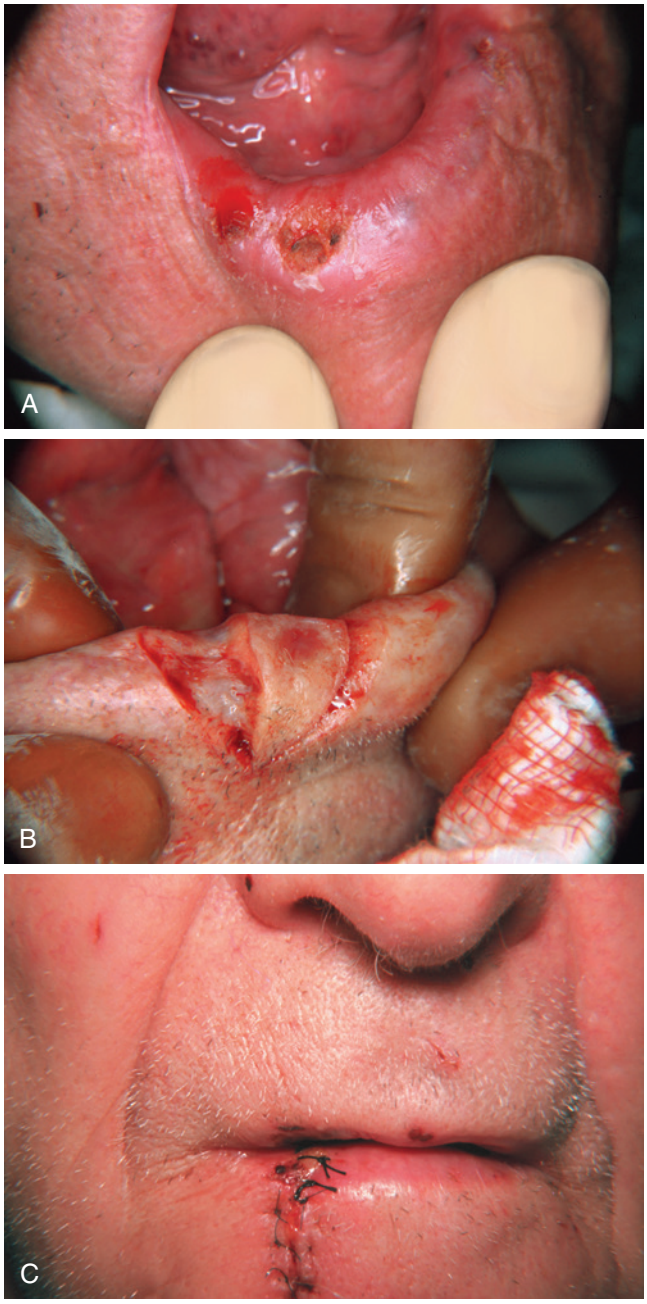
Suture Tagging of Specimens; Margin Identification

If dysplasia or malignancy is suspected, it is helpful to the pathologist if the surgeon "tags" one of the margins of a specimen with a loosely tied suture to orient the anatomic alignment of the specimen. This allows the pathologist to report precisely which specific margins or areas, if any, require wider or deeper excision. The orientation and the location of the marker suture should be illustrated, documented, or both on the oral-maxillofacial pathology service's submission form (Fig. 22.15).

Suture tagging can also be used to identify multiple specimens from one lesion accompanied by a drawing that delineates from which area each specimen was removed and the orientation of each specimen (Fig. 22.16). The first specimen receives one tagging suture, the second receives two, and so on for all other specimens. Each specimen should, however, be submitted in its own container.

Submission of Specimens

Every dental office should prearrange a connection with a local or regional oral-maxillofacial pathology examination service where



• **Fig. 22.12** (A) Excisional biopsy of an ulcer of the lower lip. (B) V-shaped incisions are made with a 2- to 3-mm margin of normal tissue. (C) Appearance after layered closure.

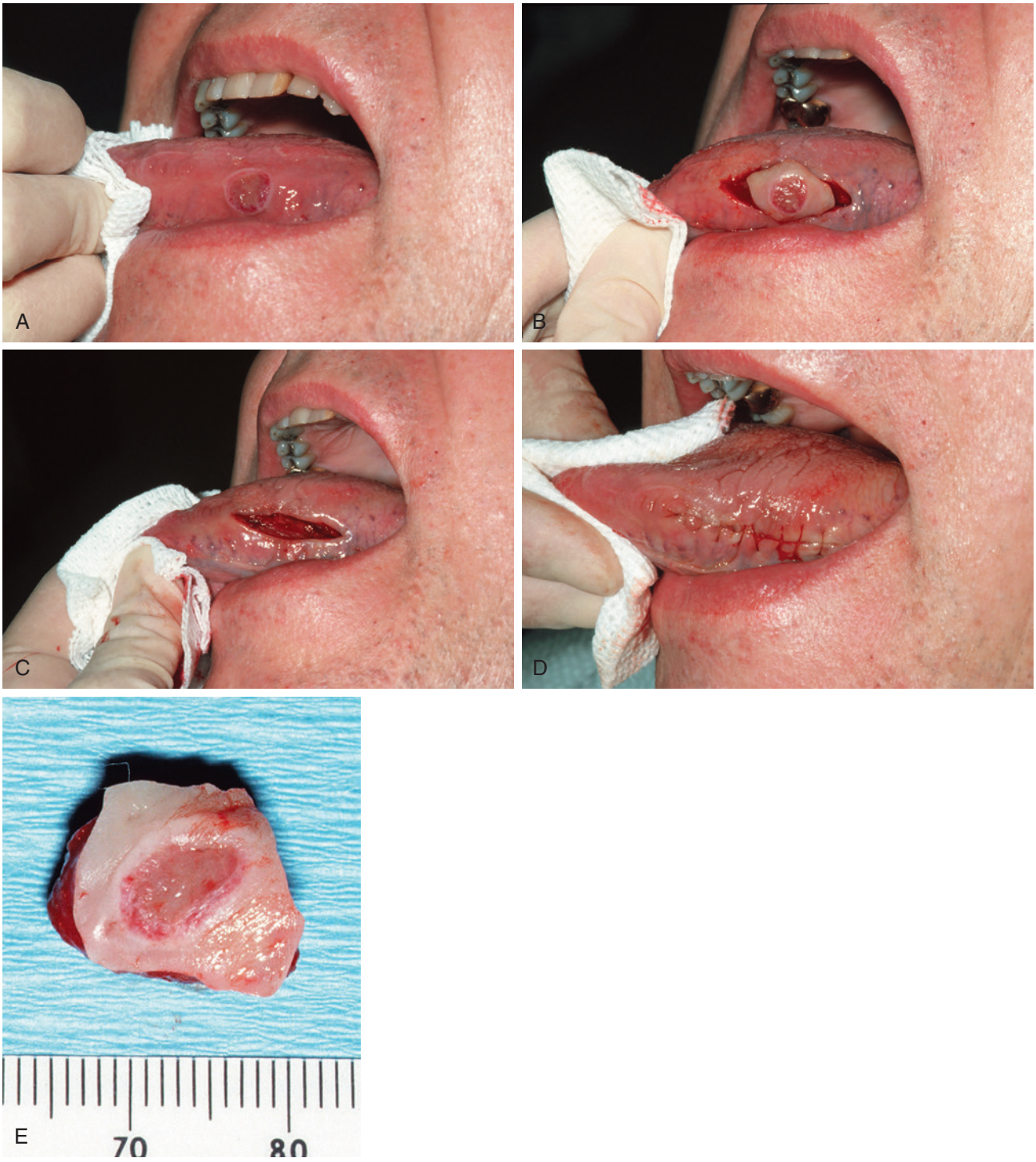
specimens can be submitted. Generally it is preferable to have odontogenic tissues submitted to an oral-maxillofacial pathologist whenever possible. Highly competent general (medical) pathologists may not be familiar with the subtleties of odontogenic cysts and tumors, which can occasionally result in incorrect diagnoses and treatment. If the city or town in which the dental office is located does not have such a service available, many dental schools and oral-maxillofacial pathology practices in most major cities offer mail-based service and provide the dental office, on request, with mailing kits that can be used for submissions. Mailed specimen containers should contain a form with detailed information, a capped, biohazard-labeled container (usually glass or plastic) with an appropriate amount of formalin and labeled with the address of the pathology service. The patient's name and the referring dentist's name should also be entered on the specimen bottle label in case the outer mailing container is damaged in transit and the bottle becomes separated from it (Fig. 22.17).

Biopsy Submission Data Form

Each pathology laboratory has a form unique to its facility for use in submitting specimens for examination (see Fig. 22.15). As noted previously, the specimen container itself must be labeled and identified with the demographic data of the patient and the name and address of the submitting dentist in the event that it should be separated from the submission form, transporting container, or both. Most forms are structured to gather supporting information and data, which generally include the following: demographic data about the patient; name and contact information for the submitting dentist; pertinent medical, family, social, and lesion histories; clinical description of the lesion, specimen, or both; and presumptive clinical differential diagnoses. When dealing with intraosseous lesions, inclusion of a diagnostic-quality radiograph can be useful to the pathologist. For soft tissue lesions, a high-quality color printout of a digital photograph of the lesion may be useful to include with certain specimens, especially if suspicion of dysplasia or malignancy exists. The dentist must take the time to provide as much information on the submission form as possible to aid the pathologist. Insufficient information, incomplete data, or important omitted historical notes often lead to wasted time and inaccurate diagnoses.

Most pathology laboratories have the written microscopic examination report back to the referring dentist within 7 to 14 days following receipt of the specimen. The dentist should plan to see the patient in approximately 1 week to remove sutures and counsel him or her on the biopsy results if available. If the result is not yet received, the dentist may elect to call the patient at home (if the report is negative for malignancy, documenting the call in the patient's record) or have the patient return 2 weeks after surgery (if the microscopic diagnosis is one of malignancy) to discuss the results in person with the patient and arrange for timely referral appointments. As noted previously, patients who must be informed of adverse diagnoses (e.g., cancer) should be counseled with great sensitivity to counteract possible anxiety or depression over the diagnosis. At the same time, the importance of early treatment and close follow-up must be emphasized. Delays in beginning treatment (procrastination) may significantly worsen the prognosis of many lesions, so it is important to arrange prompt referral for such patients to specialists with the ability to manage their conditions.

A negative (benign) pathology report should never be taken as a final assessment, and the dentist should not be lulled into a false sense of security when one is received. An experienced clinician put it this way: "Treat the patient, not the paperwork." If the clinical behavior of a lesion suggests that it is not benign, a second biopsy of the area should be considered. It is also possible that a nondiagnostic or nonrepresentative area of the lesion was sampled and the areas of pathologic cellular changes were not included in the specimen(s). Errors in microscopic diagnosis can also occur, especially if odontogenic tissues are examined by general pathologists who may be unfamiliar with the nuances of oral and odontogenic lesions. It is not inappropriate in such cases to ask for a second pathology opinion from an oral-maxillofacial pathologist before contemplating ablative or disfiguring surgery. General dentists who submit biopsies must also be conversant with the terminology used in reports to fully grasp the meaning of the microscopic diagnosis



• **Fig. 22.13** (A) Excisional biopsy of a tongue ulcer. (B) Elliptical incisions are made around the lesion, with 2 to 3 mm of normal tissue included. (C) Appearance after the specimen has been removed and the muscle has been sutured. Note that the deep sutures have made an almost linear closure of the mucosa possible. (D) Appearance after mucosal closure. (E) Specimen.

• **Fig. 22.14** A specimen being dropped into a biopsy bottle filled with formalin.

and the course of treatment or follow-up that is appropriate for that diagnosis. If any uncertainty about the contents of the report exists, then the dentist should seek clarifications from the pathologist.

Intraosseous (Hard Tissue) Biopsy Techniques and Principles

Any lesion on or within the osseous tissues of the jaws mandates scrutiny of the dentist until a definitive diagnosis is obtained. Often the cause is odontogenic, and the lesion will resolve once the dental problem is addressed. If the lesion appears to be unrelated to the dentition or does not respond to treatment of the presumed odontogenic problem, then the lesion should be removed for definitive diagnosis.

The most common intraosseous lesions encountered by the dentist are periapical granulomas and odontogenic cysts. Because these are generally asymptomatic lesions with characteristic radiographic appearances, a presumptive diagnosis is frequently possible. Treatment generally involves surgical removal of the lesion by way of excisional biopsy (enucleation). When such a lesion is large, perforating into soft tissue overlying the bone, or where a suspicion of malignancy based on history and radiographic characteristics exists, incisional biopsy is indicated so that a definitive diagnosis can be reached.

Before performing intraosseous biopsy, the dentist should carefully palpate the area of the jaw and compare it with the contralateral side. Bone that has a normal contour and feels firm and smooth suggests that the lesion has not expanded or eroded the cortical plate of bone. However, a spongy feel when the jaw is compressed with the fingers usually indicates erosion or thinning of the cortical plate, which suggests a more aggressive neoplastic lesion. Biopsy procedures and principles within hard tissues are no different from those guiding soft tissue biopsy, but some additional aspects must be considered.

Mucoperiosteal Flaps

Because of their proximity to the jaws or their location within the bone, most biopsies require an approach through a mucoperiosteal flap. Several variations of flaps are available, and the choice depends mostly on the size and location of the lesion to be removed. The basic principles of flap design outlined in Chapter 8 are the same whether the dentist is removing a tooth or performing an osseous biopsy. The location of the lesion often dictates where the incisions for the flap must be made, and optimal access may necessitate extension of the flap margins. Major neurovascular structures must be avoided, whenever possible, and the flap should rest entirely on sound bone for closure; that is, it should extend 4 to 5 mm beyond the surgical margins of any bony defects (Fig. 22.18). Flap elevation for any intraosseous lesion that may have eroded the cortical bone of the jaw should be approached in an area well away from the lesion margins over sound bone. This allows establishment of a proper tissue plane for subperiosteal elevation of the mucoperiosteal flap and any required dissection needed to free the overlying tissues from the lesion. All mucoperiosteal flaps for biopsies in or on the jaws should be full thickness with the incisions transecting the mucosa, submucosa, and periosteum.

Precautionary Aspiration

Aspiration of all intraosseous lesions should be performed routinely before opening into the osseous defect to determine whether it contains fluid, including blood. After achieving local anesthesia in the surgical area, use a 16- or 18-gauge needle connected to a 5- or 10-mL syringe. If the cortical plate cannot be penetrated by pressing the needle firmly through the mucoperiosteum with a twisting movement, a flap is reflected and a large round burr, under constant irrigation, is used cautiously to penetrate the cortical plate. The needle is then advanced through the cortical burr hole. The needle tip may have to be repositioned if the initial effort fails to locate an area of fluid to verify that the needle placement is correct.

Inability to aspirate fluid or air suggests that the intraosseous mass is probably a solid tumor. If straw-colored fluid is aspirated, the dentist is likely dealing with a cyst, which can then be enucleated (Fig. 22.19). If pus is aspirated, an inflammatory or infectious process is likely present, whereas aspiration of air without any fluid is suggestive of a traumatic bone cavity. If blood is aspirated, several diagnoses must be entertained, the most significant of which would be a pulsatile vascular lesion within the jaw (e.g., hemangioma or arteriovenous malformation). Surgical invasion into such a lesion can produce a sudden, life-threatening hemorrhage and should not be attempted by the general dentist. Other vascularized intraosseous lesions, including aneurysmal bone cysts and central giant cell lesions, may passively (i.e., nonpulsatingly) produce blood on syringe aspiration. Lesion aspirant may also be submitted for chemical analysis, microbiologic culturing, and even microscopic evaluation. If no aspirant is found, incisional biopsy should be planned on the soft tissue mass within the bone to obtain a definitive microscopic diagnosis before further surgery is planned.

Osseous Window

Intraosseous lesions of the jaws generally require creation of a cortical window for access. If the cortical plate is intact, a round surgical burr under constant fluid irrigation can be used to create an osseous window over the lesion site (see Fig. 22.18B). If expansion

LOCAL ORAL PATHOLOGY LABORATORY

1234 Main Street

Anytown, State Zip

Date: *01/02/200X* **Case Number:** _____

Patient Name: *Perry Osteum* **Gender:** *Male* **Age:** *32 yrs*

Race: *Cauc*

Address: *5678 N. 2nd Street, #401* **City/State/Zip:** *Anytown, State Zip*

Home Phone: *(777)888-9999* **Work Phone:** *(777) 888-0000*

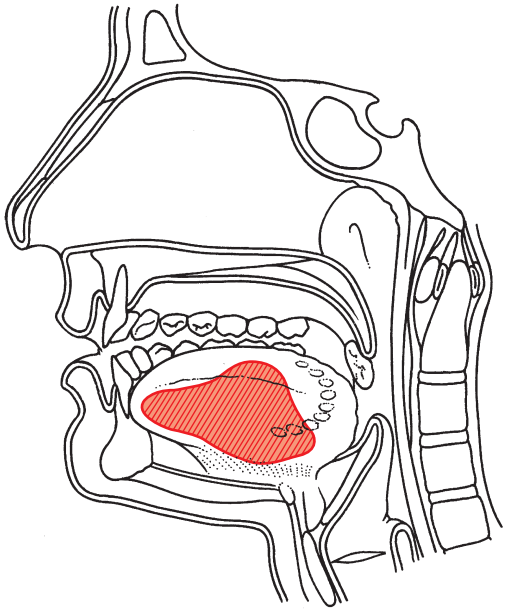
Occupation: *Construction*

Submitting Doctor's Name: *Matt Tikulus*

Mailing Address: *8910 Anystreet, Anytown, State, Zip*

Office Phone: *(777) 888-6666* **E-mail Address:** *mtikdds@server.net*

History: *asymptomatic white plaque of unknown duration but first noticed by patient about 2 months ago, left lateral border of tongue. Not recorded at last dental visit 2 years ago. We observed area X 2 weeks, without change in size, appearance. Patient denies tobacco usage, alcohol abuse, parafunctional habits. No HIV test on record. Lesion has not been painful. No local trauma source noted (sharp edged restoration, etc.). PMH is unremarkable, no known allergies, no meds. Denies lesions elsewhere on body.*



A B

Type of Biopsy: **Excisional** _____ **Incisional**☐✓☐ **Other** ☐☐☐

Clinical Description/Location: *3X5 cm white, rough surfaced plaque, left lateral border of the tongue, extending onto the dorsum of the tongue midlesion (see drawing). Texture is leather-like, nonulcerated. Uniform thickness throughout lesion. No ipsi- or contralateral lymphadenopathy noted. Excised with 1 cm clinical margin. Anterior border tagged with single suture. Superior border tagged with 2 sutures.*

Provisional Clinical Diagnosis/es: *Epithelial Dysplasia, CA in-situ, SCCa? (Your best guess of what the lesion might be)*

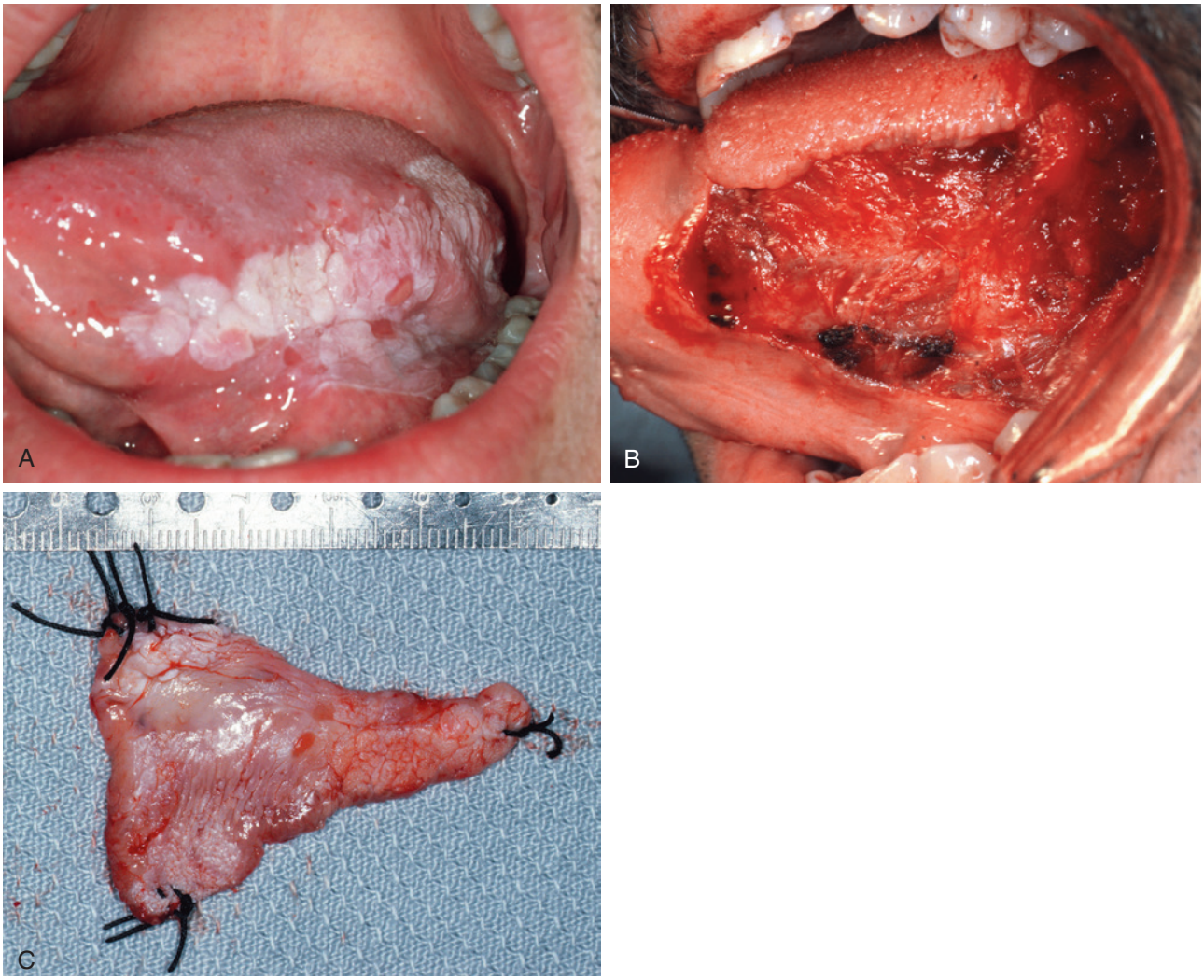
X-rays taken?: Y____ **N**__✓__ **X-rays Enclosed?Y**____**N**__✓__

Photographs Taken?: Y____**N**__✓__

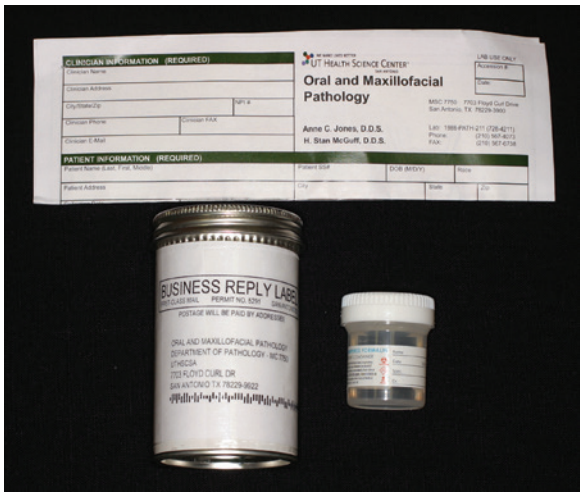
Photographs Enclosed?: Y____**N**__✓__

Additional Comments or Instructions:

• **Fig. 22.15** (A) Sample biopsy data sheet. These sheets vary by laboratory. Information provided on this data sheet describes the lesion shown in Fig. 22.16. (B) Drawing of the lesion that is to be sent with the data sheet.



• **Fig. 22.16** (A) Lesion described in Fig. 22.15. (B) Surgical site after excision of lesion. (C) Specimen after removal. Note the markings of the margins with sutures to orient the pathologist.

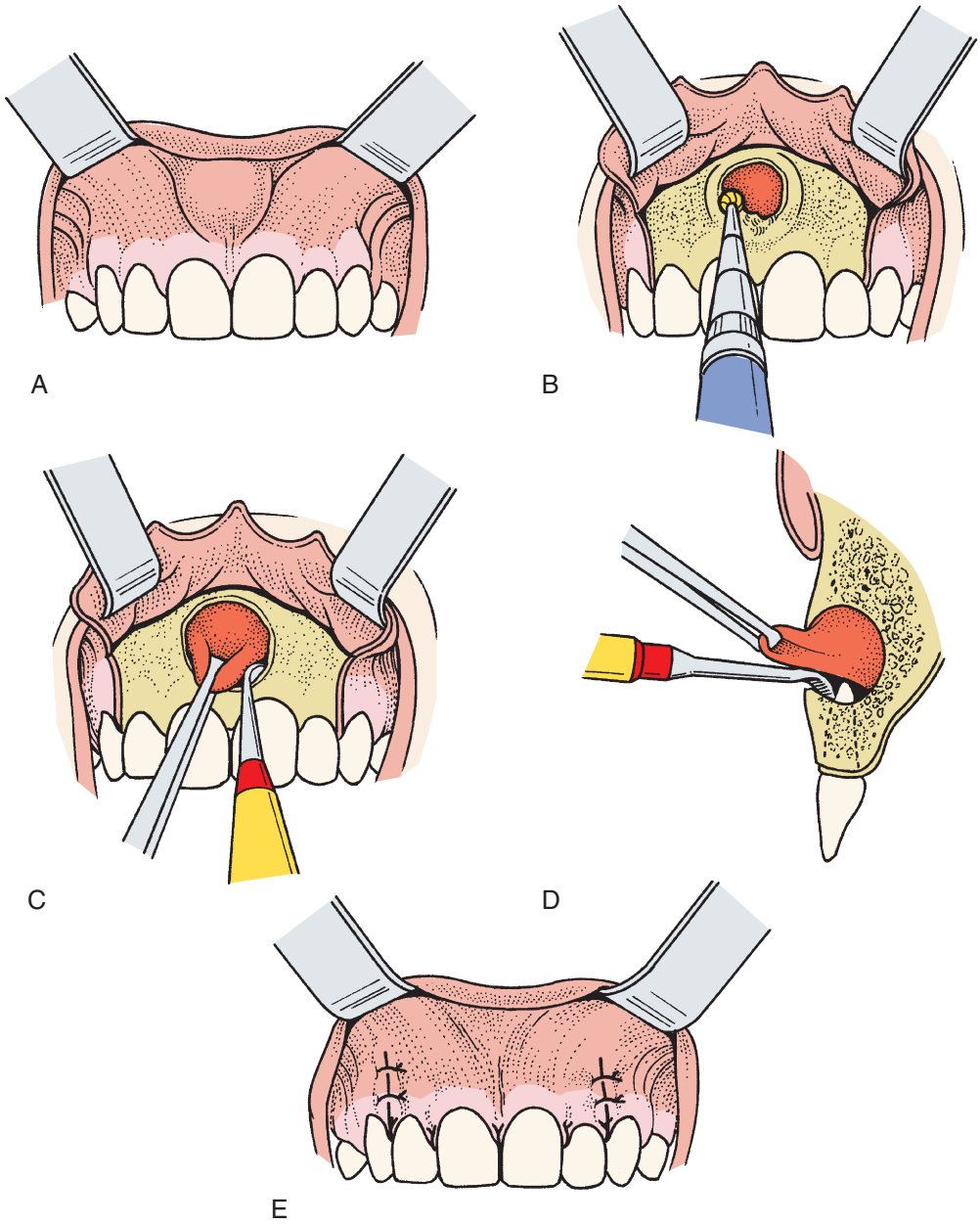


• **Fig. 22.17** Typical biopsy kit available from a number of pathology laboratories. Kit includes a specimen bottle containing formalin, a biopsy data sheet detailing information about the patient and specimen, and packaging to send the specimen back to the laboratory.

has caused erosion of the cortical plate and an osseous defect is noted when the surgical flap is elevated, that pathologic defect can then be enlarged with rongeurs or a round surgical burr to create the osseous window. The size of the window depends on the size of the lesion and the proximity of significant anatomic structures, such as tooth roots and neurovascular structures. Once the window is created, it can be progressively enlarged with a rongeur, as necessary, for access. The removed bone that composed the window should be submitted along with the primary specimen if the lesion is a solid tumor.

Specimen Management

The technique for removal of the specimen depends on whether an incisional or excisional biopsy is planned and the consistency of the tissue encountered. Most small lesions that have a connective tissue capsule (e.g., cysts) are enucleated in their entirety. A dental curette is used progressively to peel the specimen away from surrounding bone and dentition, keeping the instrument constantly in contact with the osseous surface of the bone cavity (see Fig. 22.18C–D). Once the lesion has been completely freed from attachment, it is removed and placed immediately into the formalin

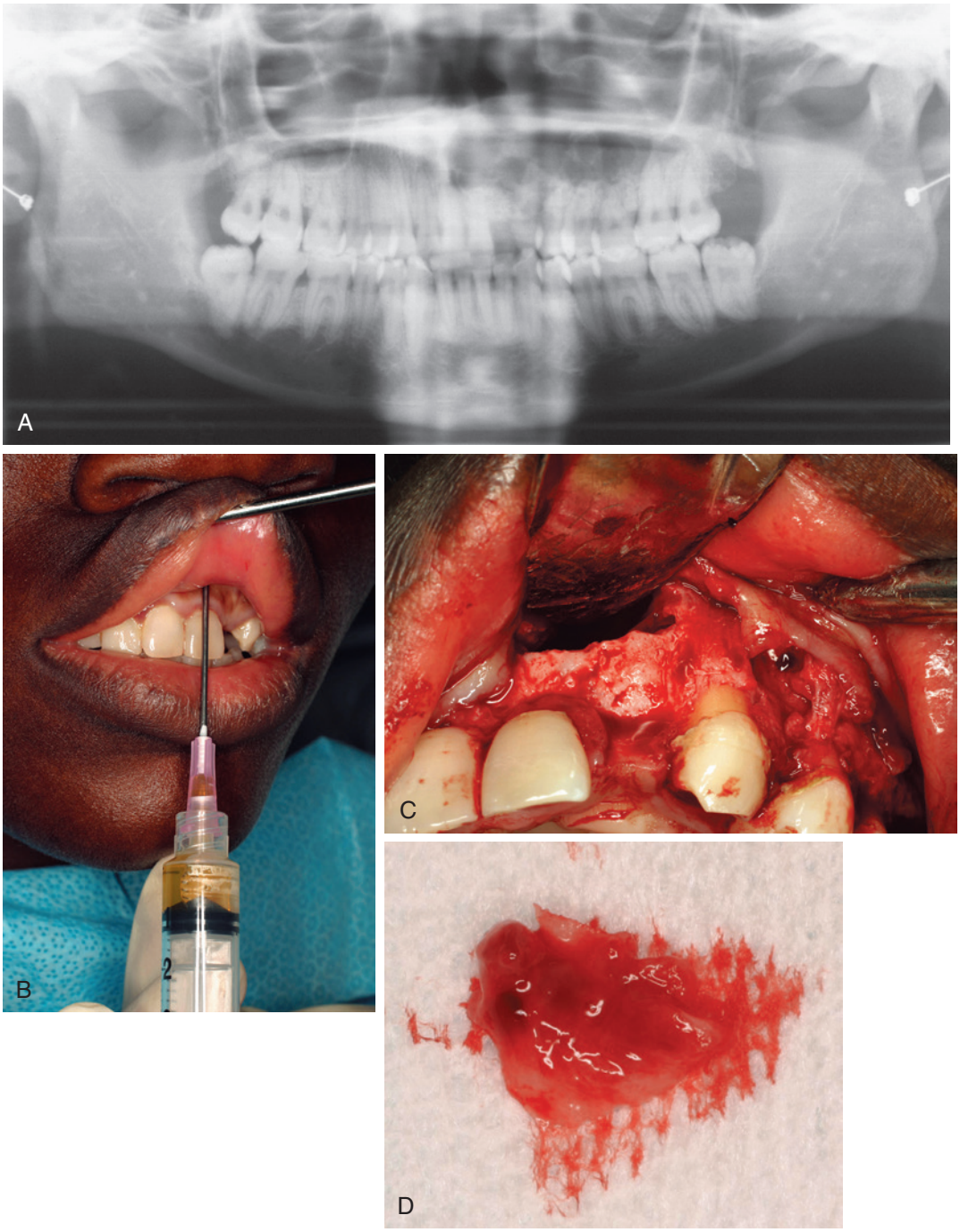


• **Fig. 22.18** Enucleation of a cyst. (A) Mild swelling in the area of a periapical cyst. (B) A mucoperiosteal flap is elevated from around the necks of teeth, and a burr is used to remove thinned cortical bone overlying the cyst. Care is taken to prevent rupturing of cystic contents during this and the following steps. (C–D) A spoon-type curette is used to strip the cyst from bone. Note that the concave side of the curette is kept in contact with the bone. The convex surface is the working end of the instrument. (E) Closure.

preservative. If resistance to enucleation is noted and the lesion does not separate from the bone easily, that detail should be noted on the specimen submission form, along with the exact location(s) of adherence. The resulting bone cavity should then be irrigated, suctioned, and examined for any residual fragments of soft tissue. If any are noted, they should be curetted out so that the cavity is devoid of any residual pathologic tissues. Following final irrigation, the mucoperiosteal flap is repositioned and sutured.

If the dentist encounters a solid soft tissue lesion of small size that separates readily from surrounding bone, it can be curetted and enucleated in the same manner as the cystic lesion and submitted as a specimen. If resistance to curettage is noted during removal, the dentist should try to remove a millimeter of adjacent osseous tissue after the bulk of the lesion is removed. Tooth root surfaces within the bone defect should be thoroughly curetted. If incisional biopsy is indicated, a section of tissue is removed and the remaining lesion is left undisturbed until the pathologic diagnosis is available.

Whenever possible, diagnostic radiographs should be included with the intraosseous specimen or digitally transmitted to the pathology facility. As previously noted, the pathologist should be provided with as much clinical information as possible when the accompanying specimen submission data form is filled out. Also important is to note whether the specimen contains hard (osseous) and/or soft tissues. If decalcification of osseous tissues is required before microscopic evaluation, the pathology report may take 2 weeks or longer to be completed.



• **Fig. 22.19** Incisional biopsy of an intraosseous lesion. (A) Panoramic radiograph showing a large radiolucency in the left maxilla. (B) Aspiration of a lesion by passing a needle through the mucosa and thin bone over the lesion, revealing straw-colored fluid. (C) After raising a soft tissue flap and removal of bone in the area of the lesion. (D) Removal of a specimen for pathologic examination.

Postbiopsy Follow-up

If the lesion is thought to be benign, then routine follow-up is carried out, with periodic radiographs to monitor osseous healing. If an incisional biopsy was performed, the patient should be reevaluated once the microscopic diagnosis becomes available, and plans should be formulated for any required definitive treatment, referral for additional treatment, or both.

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23

Surgical Management of Oral Pathologic Lesions

EDWARD ELLIS III

CHAPTER OUTLINE

The specific surgical techniques for the treatment of oral pathologic lesions can be as varied as those for the surgical management of any other entity. Each clinician surgically treats patients using techniques that are based on previous training, biases, experience, personal skill, intuition, and ingenuity. The purpose of this chapter is not to describe the specifics of surgical techniques for the management of individual oral pathologic lesions, but to present basic principles that can be applied to a variety of techniques to treat patients satisfactorily. Discussion of this topic is made easier by the fact that many different lesions can be treated in much the same manner, as outlined later.

Basic Surgical Goals

Eradication of Pathologic Condition

The therapeutic goal of any ablative surgical procedure is to remove the entire lesion and leave no cells that could proliferate and cause a recurrence of the lesion. The methods used to achieve this goal vary significantly and depend on the nature of the pathologic condition of the lesion. Excision of an oral carcinoma necessitates an aggressive approach that must sacrifice adjacent structures in an attempt to thoroughly remove the lesion. Using this approach

on a simple cyst would be a tragedy. Therefore it is imperative to identify the lesion histologically with a biopsy before undertaking any major ablative surgical procedure. Only then can the appropriate surgical procedure be chosen to eradicate the lesion with as little destruction of adjacent normal tissue as is feasible.

Functional Rehabilitation of Patient

As noted, the primary goal of surgery to remove a pathologic condition is total removal of the lesion. Although eradication of disease may be the most important goal of treatment, by itself it is frequently inadequate in the comprehensive treatment of patients. The second goal of any treatment used for eradication of disease is an allowance for the functional rehabilitation of the patient. After the primary objective of eradicating a lesion has been achieved, the most important consideration is dealing with the residual defects resulting from the ablative surgery. These defects can range from a mild obliteration of the labial sulcus resulting from the elimination of an area of denture epulis to a defect in the alveolus after removal of a benign odontogenic tumor to a hemimandibulectomy defect resulting from carcinoma resection. The best results are obtained when future reconstructive procedures are considered before excision of lesions. Methods of grafting, fixation principles, soft tissue deficits, dental rehabilitation, and patient preparation must be thoroughly evaluated and adequately handled preoperatively.

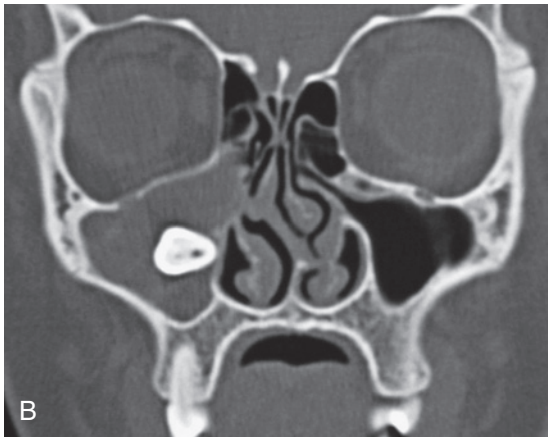
Surgical Management of Cysts and Cystlike Lesions of the Jaws

Surgical management of oral pathologic lesions can best be discussed by broadly classifying pathologic lesions into the following major categories: (1) cysts and cystlike lesions of the jaws, (2) benign tumors of the jaws, (3) malignant tumors, and (4) benign lesions of oral soft tissues.

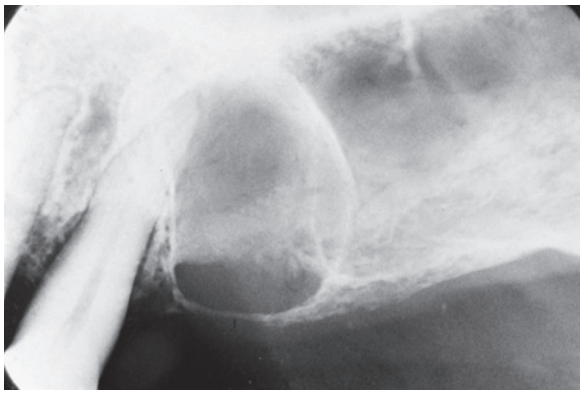
A *cyst* is defined generally as an epithelium-lined sac filled with fluid or soft material. The prevalence of cysts in the jaws can be related to the abundant epithelium that proliferates in bone during the process of tooth formation and along lines where the surfaces of embryologic jaw processes fuse. Cysts of the jaws may be divided into two types: (1) those arising from odontogenic epithelium (i.e., odontogenic cysts) and (2) those arising from oral epithelium that is trapped between fusing processes during embryogenesis (i.e., fissural cysts). The stimulus that causes resting epithelial cells to proliferate into the surrounding connective tissue has not been determined. Inflammation seems to play a major role in those cysts arising in granulomas from infected dental pulps.

Residual fragments of cystic membrane tend to produce recurrent cysts, which necessitates complete excision of the epithelial lining of the cyst at the time of operation. Some cysts (e.g., keratocysts) behave more aggressively in destructive characteristics and recurrence rates. Cysts have been known to destroy large portions of the jaws and to push teeth into remote areas of the jaws (i.e., mandibular condyle or angle and coronoid process; Fig. 23.1). Enlargement of cysts is caused by a gradual expansion, and most are discovered on routine dental radiographs. Cysts are usually asymptomatic unless they are secondarily infected. The overlying mucosa is normal in color and consistency, and no sensory deficits from encroachment on nerves are found.

If the cyst has not expanded or thinned the cortical plate, normal contour and firmness are noted. Palpation with firm pressure may indent the surface of an expanded jaw with characteristic rebound resiliency. If the cyst has eroded through the cortical plate, fluctuance may be noted on palpation.

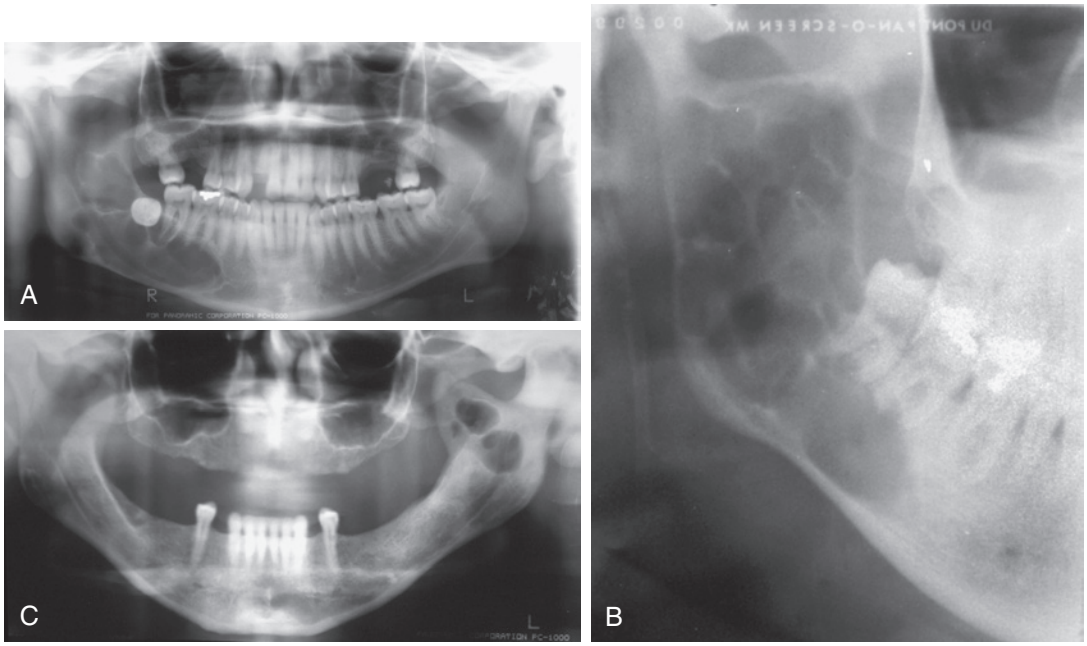


• **Fig. 23.1** Examples of dentigerous cysts that have displaced teeth. (A) A mandibular third molar is displaced into the ramus by a cyst. (B) A maxillary molar is displaced into the maxillary sinus by a cyst that fills the entire sinus.



• **Fig. 23.2** Typical radiographic appearance of cyst. The radiolucent center is surrounded by a zone of reactive bone (condensing osteitis).

The radiographic appearance of cysts is characteristic and exhibits a distinct, dense periphery of reactive bone (i.e., condensing osteitis) with a radiolucent center (Fig. 23.2). Most cysts are unilocular; however, multilocular forms are often seen in some keratocysts and cystic ameloblastomas (Fig. 23.3). Cysts do not usually cause resorption of the roots of teeth; therefore, when resorption is seen, the clinician should suspect a neoplasm. The epithelial lining of cysts on rare occasions undergoes ameloblastic or malignant changes.



• **Fig. 23.3** Multilocular appearance of cysts. (A) Right mandibular cyst associated with an impacted tooth. (B) Right mandibular cyst not associated with an impacted tooth. (C) Left ramus cyst not associated with teeth. All of these lesions were diagnosed histologically as odontogenic keratocysts.

Therefore all excised cystic tissue must be submitted for pathologic examination.

Although cysts are broadly classified as odontogenic and fissural, this classification is not relevant to the discussion of surgical techniques to remove cysts. The surgical treatment of cysts is discussed without regard to type of cyst, except for types that warrant special consideration. The principles of surgical management of cysts are also important for managing the more benign odontogenic tumors and other oral lesions.

Cysts of the jaws are treated using one of the following four basic methods: (1) enucleation, (2) marsupialization, (3) a staged combination of the two procedures, and (4) enucleation with curettage.

Enucleation

Enucleation is the process by which the total removal of a cystic lesion is achieved. By definition, it means a shelling-out of the entire cystic lesion without rupture. A cyst lends itself to the technique of enucleation because of the layer of fibrous connective tissue between the epithelial component (which lines the interior aspect of the cyst) and the bony wall of the cystic cavity. This layer allows a cleavage plane for stripping the cyst from the bony cavity and makes enucleation similar to stripping the periosteum from bone.

Enucleation of cysts should be performed with care in an attempt to remove the cyst in one piece without fragmentation, which reduces the chances of recurrence by increasing the likelihood of total removal. In practice, however, maintenance of the cystic architecture is not always possible, and rupture of the cystic contents may occur during manipulation.

Indications

Enucleation is the treatment of choice for removal of cysts of the jaws and should be used with any cyst of the jaw that can be safely removed without unduly sacrificing adjacent structures.

Advantages

The main advantage to enucleation is that pathologic examination of the entire cyst can be undertaken. Another advantage is that the initial excisional biopsy (i.e., enucleation) has also appropriately treated the lesion. The patient does not have to care for a marsupial cavity with constant irrigations. Once the mucoperiosteal access flap has healed, the patient is no longer bothered by the cystic cavity.

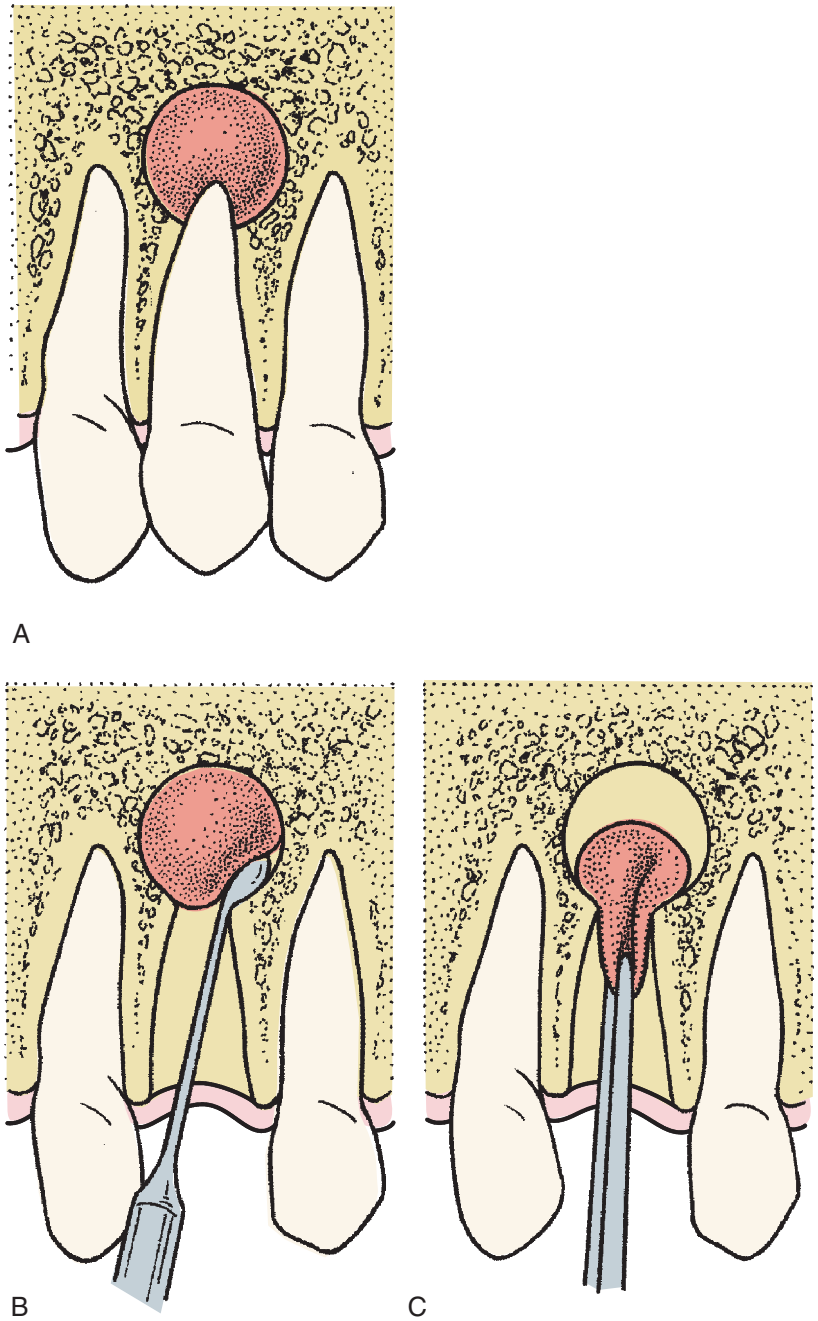
Disadvantages

If any of the conditions outlined under the section on indications for marsupialization exist, enucleation may be disadvantageous. For example, normal tissue may be jeopardized, fracture of the jaw could occur, devitalization of teeth could result, or associated impacted teeth that the clinician may wish to save could be removed. Thus each cyst must be addressed individually, and the clinician must weigh the pros and cons of enucleation versus marsupialization (with or without enucleation; see "Enucleation After Marsupialization").

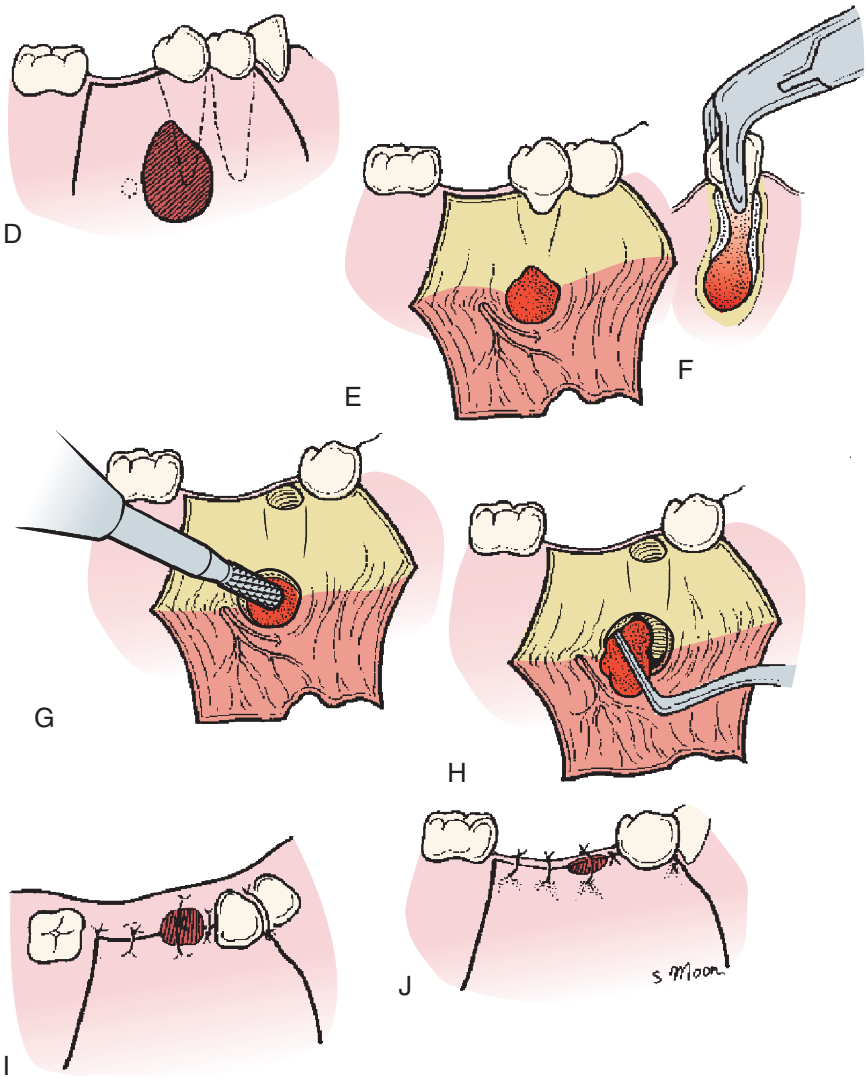
Technique

The technique for enucleation of cysts was described in Chapter 21; however, the clinician must address special considerations. The use of antibiotics is unnecessary unless the cyst is large or the patient's health condition warrants it (see Chapters 1 and 2).

The periapical (i.e., radicular) cyst is the most common of all cystic lesions of the jaws and results from inflammation or necrosis of the dental pulp. Because it is impossible to determine whether a periapical radiolucency is a cyst or a granuloma, removal at the time of the tooth extraction is recommended. If, however, the tooth is restorable, endodontic treatment followed by periodic radiographic follow-up allows assessment of the amount of bone fill. If none occurs or the lesion expands, the lesion probably represents a cyst and should be removed by periapical surgery. When extracting teeth with periapical radiolucencies, enucleation via the tooth socket can be readily accomplished by using curettes when the cyst is small (Fig. 23.4). Caution is used in teeth with apices



• **Fig. 23.4** Apical cystectomy performed at time of tooth removal. (A–C) Removal of a cyst with curette via a tooth socket is visualized. An apical cystectomy must be performed with care because of the proximity of the apices of teeth to other structures such as the maxillary sinus and the inferior alveolar canal.



• **Fig. 23.4, cont'd** (D–J) Removal of an apical cyst by flap reflection and creation of osseous window are demonstrated at the time of tooth removal.

that are close to important anatomic structures such as the inferior alveolar neurovascular bundle or the maxillary sinus because the bone apical to the lesion may be very thin or nonexistent. With large cysts, a mucoperiosteal flap may be reflected and access to the cyst obtained through the labial plate of bone, which leaves the alveolar crest intact to ensure adequate bone height after healing (Fig. 23.5).

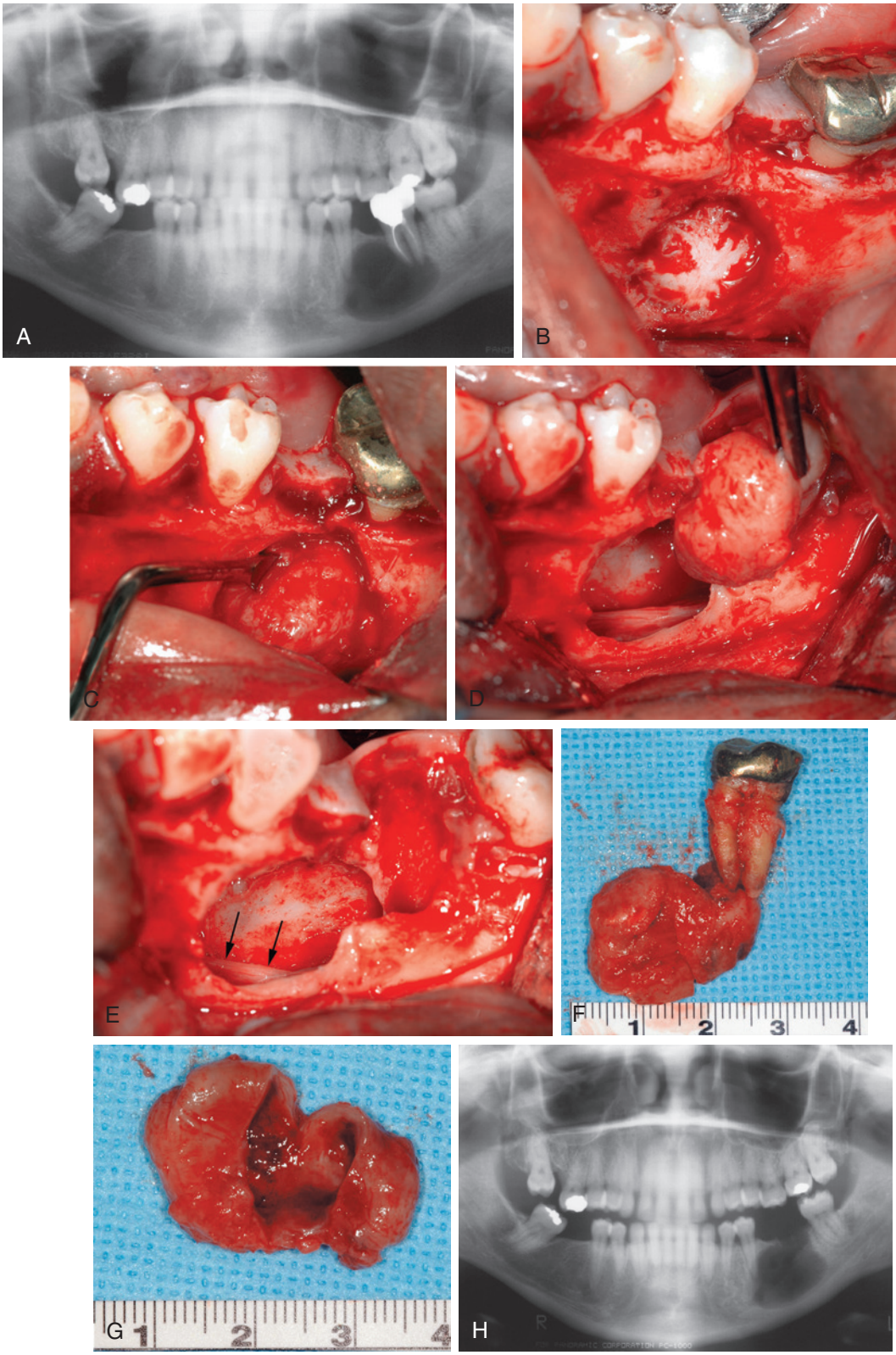
Once access to a cyst has been achieved through the use of an osseous window, the dentist should begin to enucleate the cyst. A thin-bladed curette is a suitable instrument for cleaving the connective tissue layer of the cystic wall from the bony cavity. The largest curette that can be accommodated by the size of the cyst and of the access should be used. The concave surface should always be kept facing the bony cavity; the edge of the convex surface performs the stripping of the cyst. Care must be exercised to avoid tearing the cyst and allowing the cystic contents to escape because margins of the cyst are easier to define if the cystic wall is intact. Furthermore, the cyst separates more readily from the bony cavity when the intracystic pressure is maintained.

In large cysts or cysts proximal to neurovascular structures, nerves and vessels are usually found pushed to one side of the cavity by the slowly expanding cyst and should be avoided or handled as atraumatically and as little as possible. Once the cyst has been removed, the bony cavity should be inspected for remnants of tissue. Irrigating and drying the cavity with gauze aids in visualizing the entire bony cavity. Residual tissue is removed with curettes. The bony edges of the defect should be smoothed with a file before closure.

Cysts that surround tooth roots or are in inaccessible areas of the jaws require aggressive curettage, which is necessary to remove fragments of cystic lining that could not be removed with the bulk of the cystic wall. Should obvious devitalization of teeth occur during a cystectomy, endodontic treatment of the teeth may be necessary in the near future, which may help prevent odontogenic infection of the cystic cavity from the necrotic dental pulp.

After enucleation, a watertight primary closure should be obtained with appropriately positioned sutures. The bony cavity fills with a blood clot, which then organizes over time. Radiographic evidence of bone fill will take 6 to 12 months. Jaws that have been expanded by cysts slowly remodel themselves to a more normal contour.

If the primary closure should break down and the wound open, the bony cavity should then be packed open to heal by secondary



• **Fig. 23.5** A clinical case of apical cystectomy performed at time of tooth extraction. (A) Pretreatment panoramic radiograph showing large radiolucent lesion at the apices of teeth No. 18 and 20. (B) Incision designed to ensure that the incisions are located over intact bone after cystectomy. (C) Appearance of the lesion after the buccal flap is elevated. Note that the lesion has eroded the bone. (D) Curette used to elevate the lesion from the bony walls. (E) Cyst being removed. (F) Note the inferior alveolar neurovascular bundle passing along the inferior aspect of the bony cavity. (G) Surgical specimen. (H) When opened, the specimen appeared to be cystic. The patient should be monitored with periodic radiographs to ensure bone fill and no recurrence of the lesion.

intention. The wound should be irrigated with sterile saline, and an appropriate length of strip gauze lightly impregnated with an antibiotic ointment should be gently packed into the cavity. This procedure is repeated every 2 to 3 days, gradually reducing the amount of packing until no more is necessary. Granulation tissue is seen on the bony walls in 3 to 4 days and slowly obliterates the cavity and obviates the need for packing. The oral epithelium then closes over the top of the opening, and osseous healing progresses.

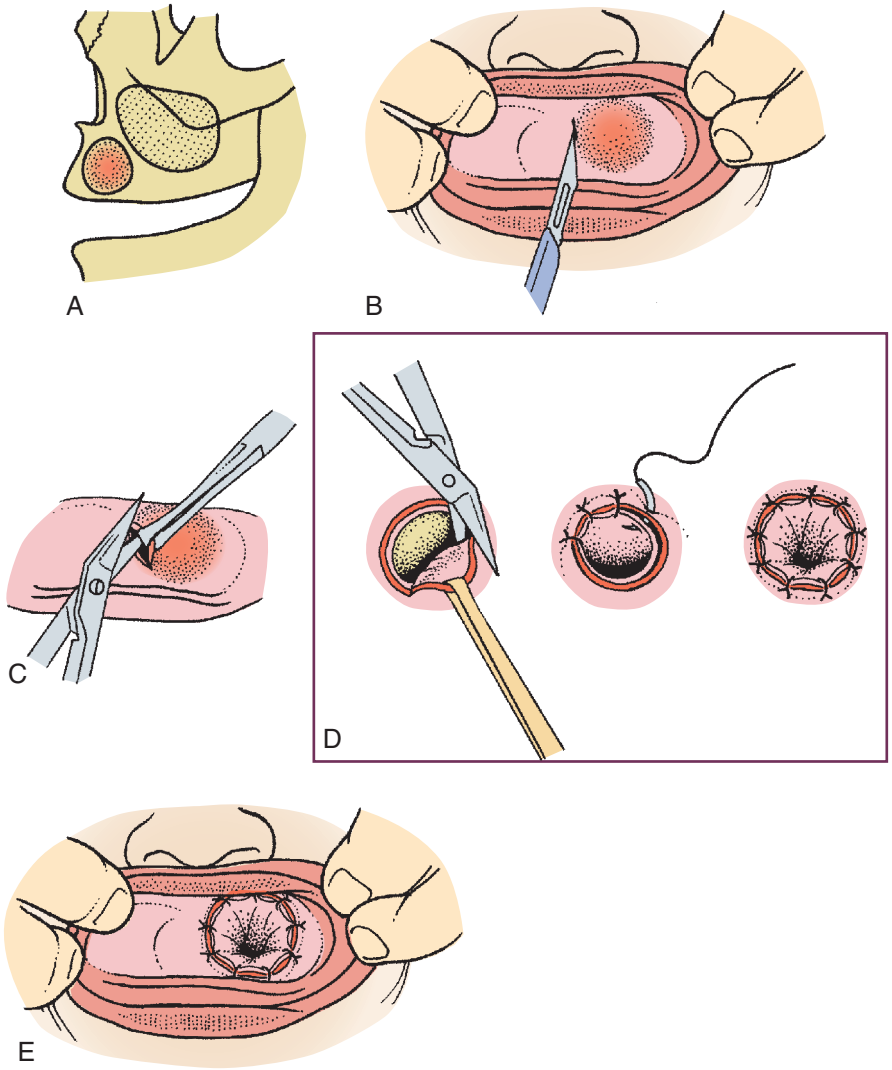
Marsupialization

Marsupialization, decompression, and the Partsch operation refer to creating a surgical window in the wall of the cyst, evacuating the contents of the cyst, and maintaining continuity between the cyst and the oral cavity, maxillary sinus, or nasal cavity (Fig. 23.6). The only portion of the cyst that is removed is the piece removed to produce the window. The remaining cystic lining is left in situ. This process decreases intracystic pressure and promotes shrinkage of the cyst and bone fill. Marsupialization can be used as the sole therapy for a cyst or as a preliminary step in management, with enucleation deferred until later.

Indications

The following factors should be considered before deciding whether a cyst should be removed by marsupialization:

1. *Amount of tissue injury.* Proximity of a cyst to vital structures can mean unnecessary sacrifice of tissue if enucleation is used. For example, if enucleation of a cyst would create oronasal or oroantral fistulae or cause injury to major neurovascular structures (e.g., the inferior alveolar nerve) or devitalization of healthy teeth, marsupialization should be considered.

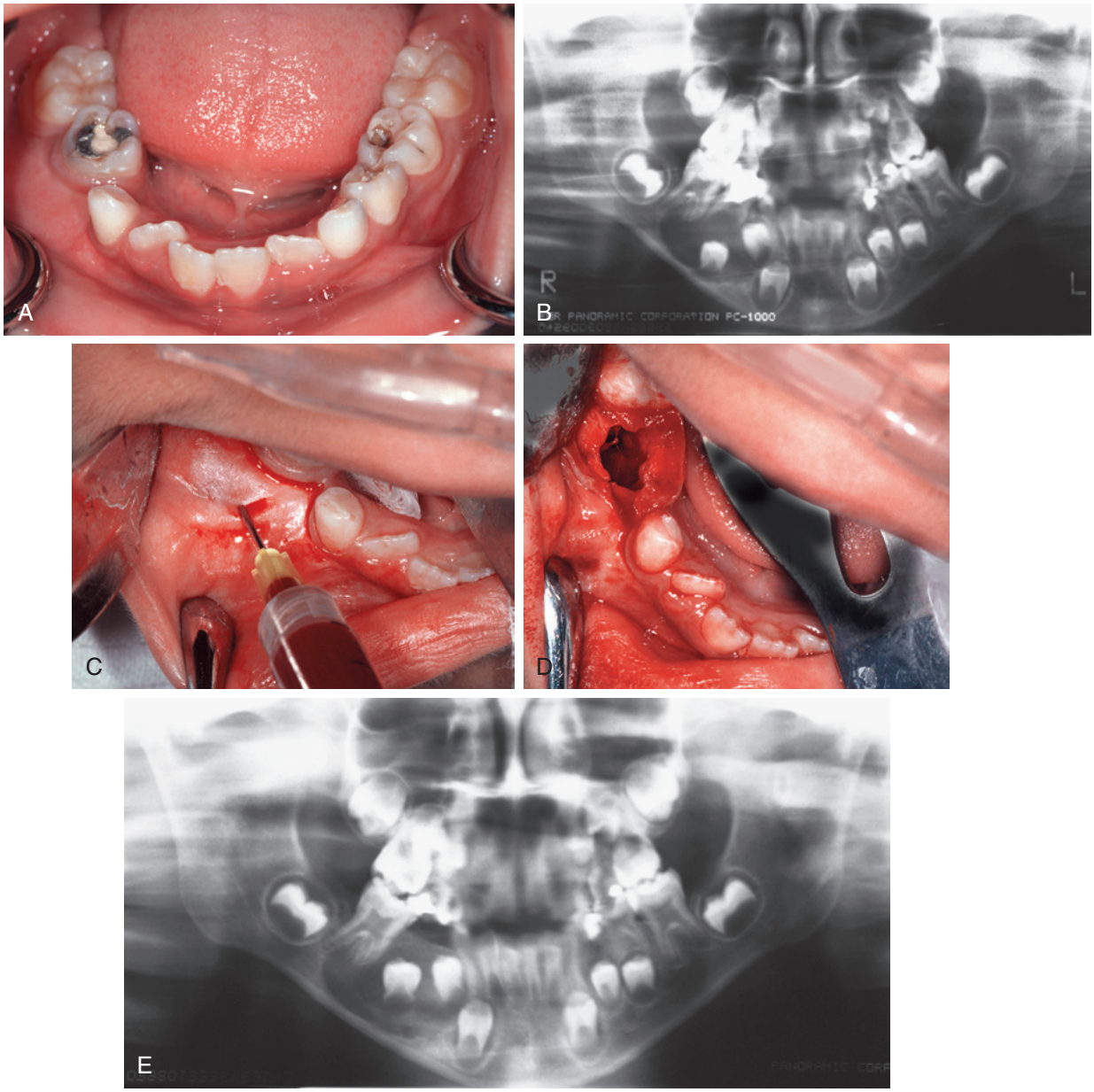


• **Fig. 23.6** Marsupialization technique. (A) Cyst within the maxilla. Palpation of the mucosa often reveals a compressible firmness, indicating that the bone has been eroded. The undersurface of the oral mucosa and the undersurface of the cyst (fibrous) capsule will therefore be fused together. (B) Incision through the oral mucosa and cystic wall into the center of the cyst. (C) Scissors are used to complete excision of the window of mucosa and cystic wall. This specimen is submitted for pathologic examination. (D) Oral mucosa and mucosa of the cystic wall sutured together around the periphery of the opening. This effectively "decompresses" the cyst, and it will now shrink as new bone fills in the cystic cavity.

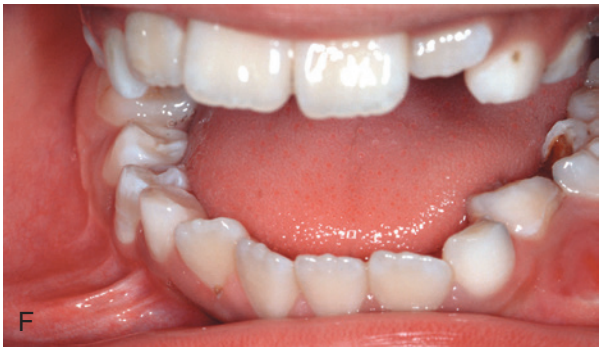
2. *Surgical access.* If access to all portions of the cyst is difficult, portions of the cystic wall may be left behind, which could result in recurrence. Marsupialization should therefore be considered.
3. *Assistance in eruption of teeth.* If an unerupted tooth that is needed in the dental arch is involved with the cyst (i.e., a dentigerous cyst), marsupialization may allow its continued eruption into the oral cavity (Fig. 23.7).
4. *Extent of surgery.* In a patient with ill health or any debilitation, marsupialization is a reasonable alternative to enucleation because it is simple and may be less stressful for the patient.
5. *Size of cyst.* In very large cysts, a risk of jaw fracture during enucleation is possible. It may be better to perform marsupialization of the cyst and defer enucleation until after considerable bone fill has occurred.

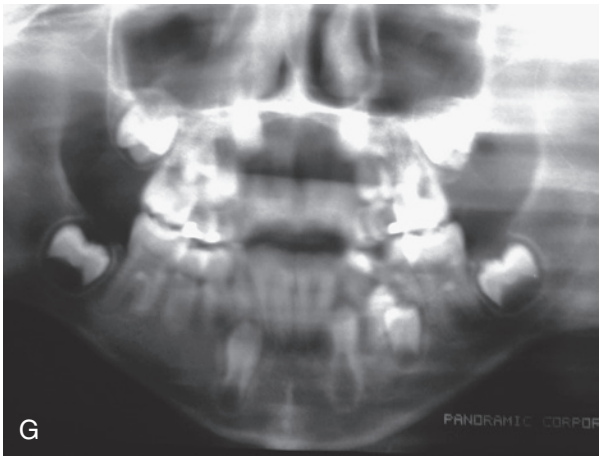
Advantages

The main advantage of marsupialization is that it is a simple procedure to perform. Marsupialization may also spare vital structures from damage should immediate enucleation be attempted.



• **Fig. 23.7** Marsupialization of a cyst in the right mandible associated with unerupted teeth. (A) Swelling around the right second deciduous molar. (B) Radiographic appearance before marsupialization. Note the large radiolucent lesion and displacement of the second right premolar toward the inferior border (compare with the opposite side). Cystectomy would probably injure or necessitate the removal of the premolars, so it was marsupialization of the cyst that was performed instead. (C) Aspiration to determine whether the lesion was fluid filled (cystic). (D) The lower right deciduous second molar was removed, and the cyst was opened through the socket (decompressed). (E) Panoramic radiograph taken 5 months after surgery showing bone fill and eruption of the premolars.





• **Fig. 23.7, cont'd** (F) Clinical image taken 1 year after surgery. Both premolars have erupted. (G) Panoramic radiograph taken at 1 year showing complete fill of the bone defect and eruption of the premolars.

Disadvantages

The major disadvantage of marsupialization is that pathologic tissue is left in situ, without thorough histologic examination. Although the tissue taken in the window can be submitted for pathologic examination, a more aggressive lesion may be present in the residual tissue. Another disadvantage is that the patient is inconvenienced in several respects. The cystic cavity must be kept clean to prevent infection because the cavity frequently traps food debris. In most instances, this means that the patient must irrigate the cavity several times every day with a syringe. This may continue for several months, depending on the size of the cystic cavity and the rate of bone fill.

Technique

Prophylactic administration of systemic antibiotics is not usually indicated in marsupialization, although antibiotics should be used if the patient's health condition warrants it (see Chapters 1 and 2). After anesthetization of the area, the cyst is aspirated as discussed in Chapter 21. If the aspirate confirms the presumptive diagnosis of a cyst, the marsupialization procedure may proceed (Fig. 23.8). The initial incision is usually circular or elliptical and creates a large (1 cm or larger) window into the cystic cavity. If the bone has been expanded and thinned by the cyst, the initial incision may extend through bone into the cystic cavity. If this is the case, the tissue contents of the window are submitted for pathologic examination. If overlying bone is thick, an osseous window is removed carefully with burrs and rongeurs. The cyst is then incised to remove a window of the lining, which is submitted for pathologic examination. The contents of the cyst are evacuated, and if possible, visual examination of the residual lining of the cyst is undertaken. Irrigation of the cyst removes any residual fragments of debris. Areas of ulceration or thickening of the cystic wall should alert the clinician to the possibility of dysplastic or neoplastic changes in the wall of the cyst. In this instance, enucleation of the entire cyst or incisional biopsy of the suspicious area or areas should be undertaken. If the cystic lining is thick enough and if access permits, the perimeter of the cystic wall around the window can be sutured to the oral mucosa.

Otherwise the cavity should be packed with strip gauze impregnated with tincture of benzoin or an antibiotic ointment. This packing must be left in place for 10 to 14 days to prevent the oral mucosa from healing over the cystic window. By 2 weeks, the lining of the cyst should be healed to the oral mucosa around the periphery of the window. Careful instructions to the patient regarding cleansing of the cavity are necessary.

With marsupialization of cysts of the maxilla, the clinician has two choices of where the cyst will be brought to the exterior: (1) The cyst may be surgically opened into the oral cavity, as just described, or (2) it may be opened into the maxillary sinus or nasal cavity. In the case of a cyst that has destroyed a large portion of the maxilla and has encroached on the antrum or nasal cavity, the cyst may be approached from the facial aspect of the alveolus, as just described. Once a window into the cyst has been made, a second unroofing can be widely performed into the adjacent maxillary antrum or nasal cavity. (If access permits, the entire cyst can be enucleated at this point, which allows the cystic cavity to become lined with respiratory epithelium that migrates from the adjoining maxillary sinus or nasal cavity.) The oral opening is then closed and allowed to heal. The cystic lining is thereby continuous with the lining of the antrum or nasal cavity.

Marsupialization is rarely used as the sole form of treatment for cysts. In most instances, enucleation is done after marsupialization. In the case of a dentigerous cyst, however, no residual cyst may exist to be removed once the tooth has erupted into the dental arch. In addition, if further surgery is contraindicated because of concomitant medical problems, marsupialization may be performed without future enucleation. The cavity may or may not obliterate totally with time. If it is kept clean, the cavity should not become a problem.

Enucleation After Marsupialization

Enucleation is frequently done (at a later date) after marsupialization. Initial healing is rapid after marsupialization, but the size of the cavity may not decrease appreciably past a certain point. The objectives of the marsupialization procedure have been accomplished at this time, and a secondary enucleation may be undertaken without injury to adjacent structures. The combined approach reduces morbidity and accelerates complete healing of the defect.

Indications

The indications for this combined modality of surgical therapy are the same as those listed for the technique of marsupialization. These indications are predicated on a thorough evaluation of the amount of tissue injury enucleation would cause, the degree of access for enucleation, whether impacted teeth associated with the cyst would benefit from eruptional guidance with marsupialization, the medical condition of the patient, and the size of the lesion. However, if the cyst does not totally obliterate after marsupialization, enucleation should be considered. Another indication for enucleation of a cyst after marsupialization is a cystic cavity that the patient

is finding difficult to cleanse. The clinician may also desire to examine the entire lesion histologically.

Advantages

The advantages of combined marsupialization and enucleation are the same as those listed for marsupialization and enucleation. In the marsupialization phase, the advantage is that this is a simple procedure that spares adjacent vital structures. In the enucleation phase, the entire lesion becomes available for histologic examination. Another advantage is the development of a thickened cystic lining, which makes the secondary enucleation an easier procedure.

Disadvantages

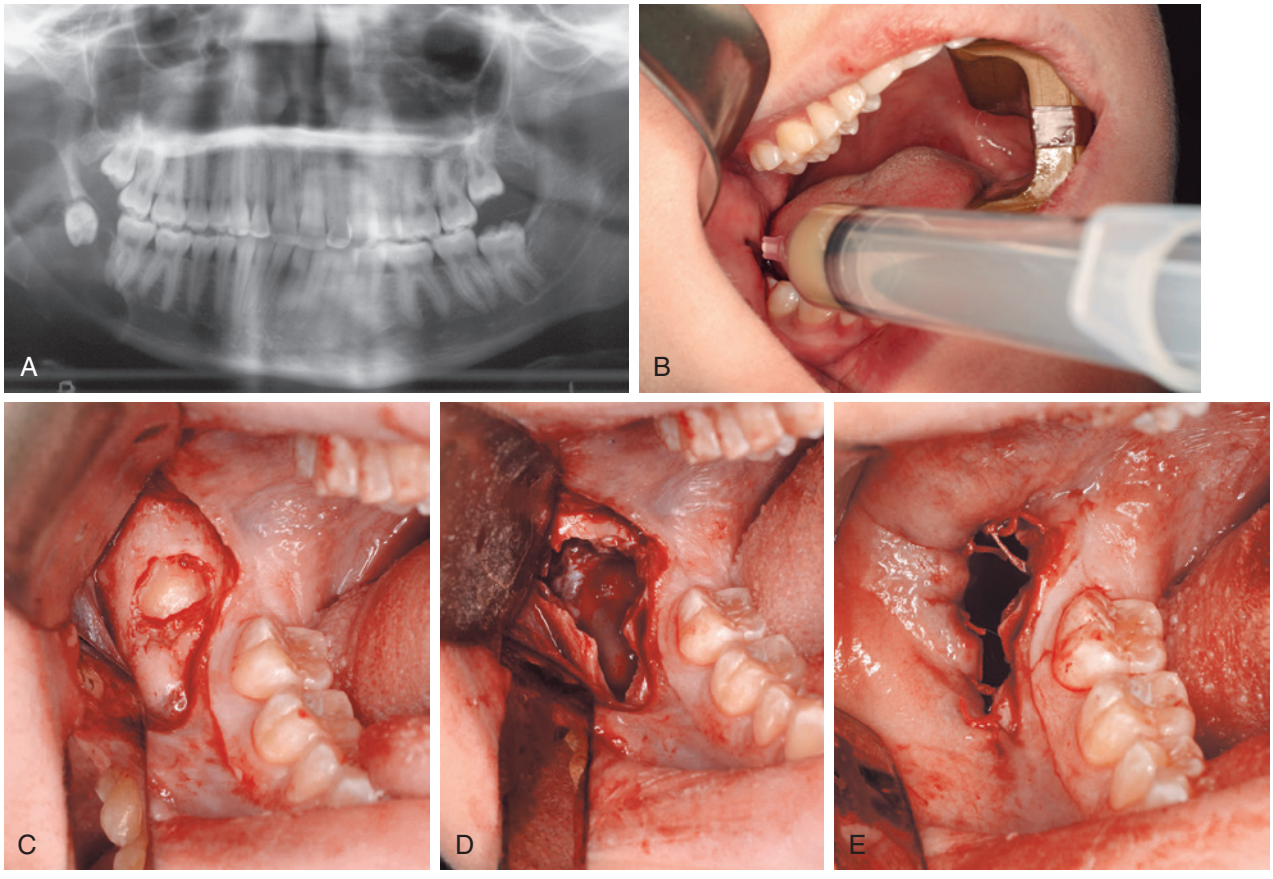
The disadvantages of this modality of surgical intervention are the same as those for marsupialization. The total cyst is not removed initially for pathologic examination. However, subsequent enucleation may then detect any occult pathologic condition.

Technique

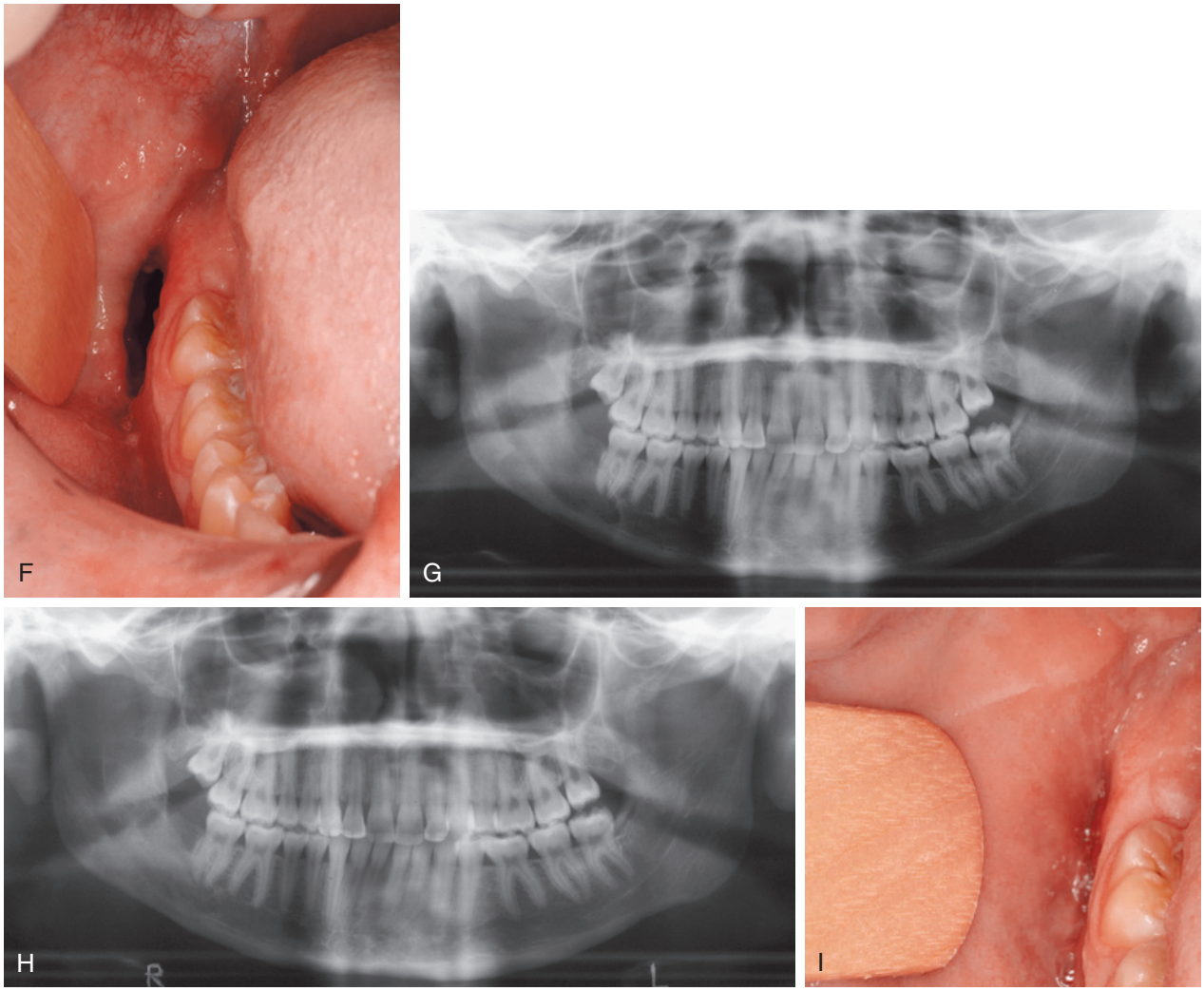
First, marsupialization of the cyst takes place, and osseous healing is allowed to progress. Once the cyst has decreased to a size that makes it amenable to complete surgical removal, enucleation is performed as the definitive treatment. The appropriate time for enucleation is when bone is covering adjacent vital structures, which prevents their injury during enucleation, and when adequate bone fill has provided enough strength to the jaw to prevent fracture during enucleation.

The initial incisions for enucleation of the cyst differ, however, from those when marsupialization of the cyst does not take place first. The cyst has a common epithelial lining with the oral cavity after marsupialization. The window initially made into the cyst contains the epithelial bridge between the cystic cavity and the oral cavity. This epithelium must be removed completely with the cystic lining; an elliptical incision completely encircling the window must be made down to sound bone. The clinician then has the opportunity to begin stripping the cyst from the window into the cystic cavity. The plane of dissection is easily established with this approach, and the cyst can be enucleated without difficulty.

Once the cyst has been enucleated, the oral soft tissues must be closed over the defect, if possible, which may require the development and mobilization of soft tissue flaps that can be advanced and sutured in a watertight manner over the osseous window. If complete closure of the wound cannot be achieved, packing the cavity with strip gauze impregnated with an antibiotic



• **Fig. 23.8** Marsupialization of an odontogenic keratocyst in the right mandible associated with an impacted third molar. (A) Panoramic radiograph showing a large multilocular radiolucent lesion associated with tooth #32. (B) Aspiration of the lesion reveals a creamy liquid (keratin). (C) Exposure and removal of bone behind the second molar reveals the impacted third molar crown. (D) The impacted tooth was removed, as was additional bone to provide a large window into the lesion. A portion of the lining was excised and sent for pathologic examination. The cavity was inspected through the opening to ensure there was no solid mass that might indicate a tumor. (E) Holes were drilled around the periphery of the bony opening to pass sutures from the oral mucosa, through the holes in the bone, and through the cyst lining. This provided a stable opening from the oral cavity into the cyst.



• **Fig. 23.8, cont'd** (F) Patent opening into the cavity 1 month after surgery. (G) Panoramic radiographs taken at 5 months after surgery show bone fill. (H) At 10 months. (I) By 10 months, the opening into the cyst has completely closed.

ointment is acceptable. This packing must be changed repeatedly with cleansing of the cavity until granulation tissue has obliterated the opening and epithelium has closed over the wound.

Enucleation With Curettage

Enucleation with curettage means that after enucleation a curette or burr is used to remove 1 to 2 mm of bone around the entire periphery of the cystic cavity. This is done to remove any remaining epithelial cells that may be present in the periphery of the cystic wall or bony cavity. These cells could proliferate into a recurrence of the cyst.

Indications

The clinician should perform curettage with enucleation in two instances. The first instance is if the clinician is removing an odontogenic keratocyst. In this case, the more aggressive approach of enucleation with curettage should be used because odontogenic keratocysts exhibit aggressive clinical behavior and a considerably high rate of recurrence.[1] Reported recurrence rates have been between 20% and 60%.[2] Reasons for locally aggressive behavior are based on the increased mitotic activities and cellularity of the epithelium of the odontogenic keratocyst.[3-5] Daughter cysts, or satellite cysts, found in the periphery of the main cystic lesion may be incompletely removed, which contributes to the increased rate of recurrence. The cystic lining is usually very thin and readily fragmented, making thorough enucleation difficult. Therefore, when an odontogenic keratocyst is clinically suspected, the minimal treatment should be careful enucleation with aggressive curettage of the bony cavity. Should the lesion recur, treatment must be predicated on the following factors: If the area is accessible, another attempt at enucleation could be undertaken; if inaccessible, bony resection with 1-cm margins should be considered. Whatever the treatment, the patient must be followed closely for recurrence because odontogenic keratocysts have recurred years after treatment.

The second instance in which enucleation with curettage is indicated is with any cyst that recurs after what was deemed a thorough removal. The reasons for curettage in this case are the same as those outlined previously.

Advantages

If enucleation leaves epithelial remnants, curettage may remove them, thereby decreasing the likelihood of recurrence.

Disadvantages

Curettage is more destructive of adjacent bone and other tissues. The dental pulps may be stripped of their neurovascular supply when curettage is performed close to the root tips. Adjacent neurovascular bundles can be similarly damaged. Curettage must always be performed with great care to avoid these hazards.

Technique

After the cyst has been enucleated and removed, the bony cavity is inspected for proximity to adjacent structures. A sharp curette or a bone burr with sterile irrigation can be used to remove a 1- to 2-mm layer of bone around the complete periphery of the cystic cavity. This should be done with extreme care when working proximal to important anatomic structures. The cavity is then cleansed and closed.

Principles of Surgical Management of Jaw Tumors

A discussion of the surgical management of jaw tumors is made easier by the fact that many tumors behave similarly and therefore can be treated in a similar manner. The three main modalities of surgical excision of jaw tumors are (1) enucleation (with or without curettage), (2) marginal (i.e., segmental) or partial resection, and (3) composite resection (Box 23.1). Many benign tumors behave nonaggressively and are therefore treated conservatively with enucleation, curettage, or both (Table 23.1).

Another group of benign oral tumors behaves more aggressively and requires margins of uninvolved tissue to lessen the chance of recurrence. Marginal (i.e., segmental) or partial resection is used for removal of these lesions (Fig. 23.9). The last group of tumors includes the malignant varieties. These tumors require more radical intervention, with wider margins of uninvolved tissue. Surgery may include the removal of adjacent soft tissues and dissection of lymph nodes. Radiotherapy, chemotherapy, or both, alone or in addition to surgery, may be used.

• BOX 23.1 Types of Surgical Operations Used for the Removal of Jaw Tumors

Enucleation and/or Curettage

Removal of tumor by instrumentation in direct contact with the lesion; used for benign types of lesions

Resection

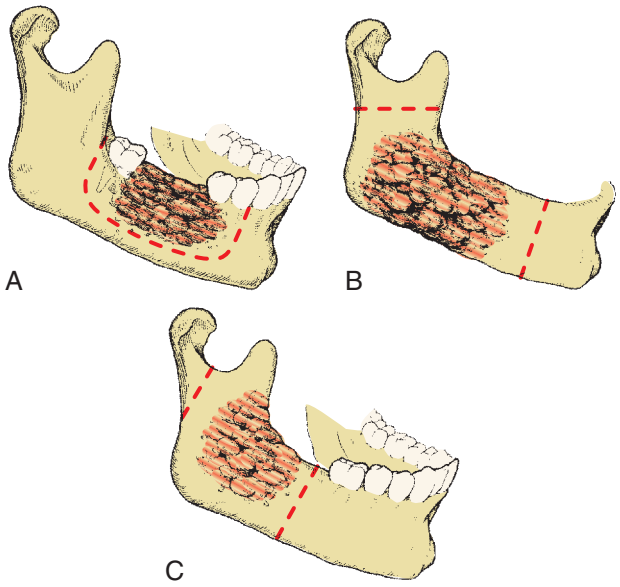
Removal of a tumor by incising through uninvolved tissues around the tumor, thus delivering the tumor without direct contact during instrumentation (also known as *en bloc resection*)

- *Marginal (i.e., segmental) resection:* Resection of a tumor without disruption of the continuity of the bone.
- *Partial resection:* Resection of a tumor by removing a full-thickness portion of the jaw in the mandible; this can vary from a small continuity defect to a hemimandibulectomy (jaw continuity is disrupted).
- *Total resection:* Resection of a tumor by removal of the involved bone (e.g., maxillectomy and mandibulectomy).
- *Composite resection:* Resection of a tumor with bone, adjacent soft tissues, and contiguous lymph node channels (an ablative procedure used most commonly for malignant tumors).

TABLE 23.1 Types of Jaw Tumors and Primary Treatment Modalities

Enucleation and/or Curettage	Marginal or Partial Resection	Composite Resection[a]
Odontogenic Tumors		
Odontoma	Ameloblastoma	Malignant ameloblastoma
Ameloblastic fibroma	Calcifying epithelial odontogenic tumor	Ameloblastic fibrosarcoma
Ameloblastic fibro-odontoma		Ameloblastic odontosarcoma
Adenomatoid odontogenic tumor	Myxoma	Primary intraosseous carcinoma
Calcifying odontogenic cyst	Ameloblastic odontoma	
Cementoblastoma	Squamous odontogenic tumor	
Central cementifying fibroma		
Fibro-Osseous Lesions		
Central ossifying fibroma	Benign chondroblastoma	Fibrosarcoma
Fibrous dysplasia (if necessary)		Osteosarcoma
Cherubism (if necessary)		Chondrosarcoma
Central giant cell granuloma		Ewing sarcoma
Aneurysmal bone cyst		
Osteoma		
Osteoid osteoma		
Osteoblastoma		
Other Lesions		
Hemangioma	Hemangioma	Lymphomas
Eosinophilic granuloma		Intraosseous salivary gland malignancies
Neurilemmoma		Neurofibrosarcoma
Neurofibroma		Carcinoma that has invaded the jaw
Pigmented neuroectodermal tumor		

These are generalities. Treatment is individualized for each patient and each lesion.
[a]These lesions are malignancies and may be treated variably. For lesions occurring totally within the jaw, partial resection may be performed without adjacent soft tissue and lymph node dissections. Radiotherapy and chemotherapy may also play a role in the overall therapy.



• **Fig. 23.9** Common types of mandibular resection. (A) Marginal or segmental resection, which does not disrupt mandibular continuity. (B–C) Partial mandibular resections, which disrupt mandibular continuity. Attempts to leave mandibular condyle to facilitate reconstruction are demonstrated.

Besides cysts, the most common jaw lesions the dentist encounters are inflammatory or are benign neoplasms. Most of these cysts lend themselves to removal by simple excisional biopsy techniques. However, more aggressive lesions are occasionally encountered, and several factors must be considered to determine the most appropriate type of therapy. The most important of these factors is the aggressiveness of the lesion. Other factors that must be evaluated before surgery are the anatomic location of the lesion, its confinement to bone, the duration of the lesion, and the possible methods for reconstruction after surgery.

Aggressiveness of Lesion

Surgical therapy of oral lesions ranges from enucleation or curettage to composite resection. Histologic diagnosis positively identifies the lesion and thus directs the treatment. Because of the wide range in behavior of oral lesions, the prognosis is related more to the histologic diagnosis, which indicates the biologic behavior of the lesion, than to any other single factor.

Anatomic Location of Lesion

The location of a lesion within the mouth or perioral areas may severely complicate surgical excision and therefore jeopardize the prognosis. A nonaggressive, benign lesion in an inaccessible area such as the pterygomaxillary fissure presents an obvious surgical problem. Conversely, a more aggressive lesion in an easily accessible and resectable area such as the anterior mandible often offers a better prognosis.

Maxilla Versus Mandible

Another important consideration with some oral lesions such as the more aggressive odontogenic tumors and carcinomas is whether they are within the mandible or the maxilla. The adjacent maxillary sinuses and nasopharynx allow tumors of the maxilla to grow asymptomatically to large sizes, with symptoms occurring late. Thus maxillary tumors have a poorer prognosis than those within the mandible.

Proximity to Adjacent Vital Structures

The proximity of benign lesions to adjacent neurovascular structures and teeth is an important consideration because preservation of these structures should be attempted. Frequently the apices of adjacent tooth roots are completely uncovered during a surgical procedure. The dental pulps are stripped of their blood supply. These teeth should be considered for endodontic treatment to prevent an odontogenic infection, which would complicate healing and jeopardize the success of bone grafts placed in an adjacent area.

Size of Tumor

The amount of involvement within a particular site such as the body of the mandible has a bearing on the type of surgical procedure necessary to obtain a cure with the more aggressive lesions. When possible, the inferior border of the mandible is left intact to maintain continuity. This can be accomplished by marginal resection of the involved area. When the tumor extends through the entire thickness of the involved jaw, a partial resection becomes mandatory.

Intraosseous Versus Extraosseous Location

An aggressive oral lesion confined to the interior of the jaw, without perforation of the cortical plates, offers a better prognosis than one that has invaded surrounding soft tissues. Invasion of soft tissues indicates a more aggressive tumor, which, because of its presence in soft tissues, makes complete removal more difficult and sacrifices more normal tissues. In the latter case, the soft tissue in the area of the perforation should be locally excised. A supraperiosteal excision of the involved jaw should be undertaken if the cortical plate has been thinned to the point of being eggshell thick without obvious perforation.

Duration of Lesion

Several oral tumors exhibit slow growth and may become static. An odontoma, for example, may be discovered in the second decade of the patient's life, and its size may remain unchanged for many years. Slower-growing lesions seem to follow a more benign course, and treatment should be individually tailored to each case.

Reconstructive Efforts

As previously noted, the goal of any surgical procedure to remove a pathologic lesion should be not only the eradication of disease but also the facilitation of the patient's functional well-being. Thus reconstructive procedures should be planned and anticipated before initial surgery is performed. Frequently the goals of reconstruction dictate a surgical technique that is just as effective as another technique in the removal of the disease but more optimal for facilitating future reconstructive efforts.

Jaw Tumors Treated With Enucleation, Curettage, or Both

Most jaw tumors with a low rate of recurrence can be treated with enucleation or curettage—for example, most of the odontogenic tumors, including odontomas, ameloblastic fibromas, ameloblastic fibro-odontomas, keratinizing and calcifying odontogenic cysts, adenomatoid odontogenic tumors, cementoblastomas, and central cementifying (i.e., ossifying) fibromas. Table 23.1 lists other lesions that are treated in this manner.

Technique

The technique for enucleation or curettage of jaw tumors is not unlike that described for cysts. However, additional procedures, such as sectioning large calcified masses with burrs in odontomas and cementomas, may be required. In these instances, the principles discussed in Chapter 9 for the removal of impacted teeth are used.

Jaw Tumors Treated With Marginal or Partial Resection

When the lesion is determined to be aggressive, by histopathologic determination or by its clinical behavior, or if it is of such a consistency that total removal by enucleation, curettage, or both would be difficult, removal may be facilitated by resecting the lesion with adequate bony margins. Odontogenic lesions treated in this manner are the ameloblastoma, the odontogenic myxoma (i.e., fibromyxomas), the calcifying epithelial odontogenic tumor (i.e., Pindborg), the squamous odontogenic tumor, and the ameloblastic odontoma. Table 23.1 lists other lesions treated in this manner.

Technique

As a general principle, the resected specimen should include the lesion and 1-cm bony margins around the radiographic boundaries of the lesion. If this can be achieved with the inferior border of the mandible left intact, marginal resection is the preferred method. Reconstruction then is limited to replacing the lost osseous structure, including the alveolus (Fig. 23.10). If the lesion is close to the inferior border, the full thickness of the mandible must be included in the specimen, which disrupts mandibular continuity (Fig. 23.11). Reconstruction in this instance is much more difficult because the remaining mandibular fragments must be secured in their proper relationship to one another for proper function and symmetry to be restored.

The surgical technique for marginal (i.e., segmental) resection is straightforward. A full-thickness mucoperiosteal flap is developed and stripped from the bone to be removed. Air-driven surgical saws or burrs are then used to section the bone in the planned locations, and the segment is removed. Whenever marginal or partial resection is used, the clinician must determine whether the tumor has perforated the cortical plates and invaded adjacent soft tissue, in which case it is necessary to sacrifice a layer of soft tissue to eradicate the tumor, and a supraperiosteal dissection of the involved bone is performed. Immediate reconstruction is more difficult because enough remaining soft tissue may not be available to close over the bone grafts.

If the clinician is concerned about the adequacy of the soft tissue surgical margins around a lesion when surgery is being performed in a hospital setting, specimens along the margins can be removed and sent immediately to the pathologist for histopathologic examination. This process is performed in approximately 20 minutes by freezing the tissue in liquid carbon dioxide or nitrogen and then sectioning and staining the tissue for immediate examination. Frozen-section examination is accurate when used for detecting adequacy of surgical margins. However, such examination is less accurate when trying to diagnose a lesion histopathologically for the first time.

Malignant Tumors of the Oral Cavity

Malignancies of the oral cavity may arise from a variety of tissues such as the salivary gland, muscle, and blood vessels or may even present as metastases from distant sites. Most common, however, are epidermoid carcinomas of the oral mucosa, which are the form of cancer that is first discovered by a dentist during thorough oral examinations. The seriousness of an oral malignancy can vary from the necessity for a simple excisional biopsy to composite jaw resection with neck dissection (i.e., removal of the lymph nodes and other visceral structures adjacent to lymph node channels in neck) to effect a cure. Because of the variation in clinical presentation, clinical staging is usually undertaken before a treatment plan is formulated.

Clinical staging refers to assessing the extent of the disease before undertaking treatment and has two purposes: (1) selection of the best treatment and (2) meaningful comparison of the end results reported from different sources. Clinical staging of the lesion is performed for several varieties of oral malignancies, including epidermoid carcinomas and oral lymphomas. Staging is performed differently for each type of malignancy and may involve extensive diagnostic tests such as radiography, blood tests, and even surgical exploration of other body areas to evaluate the extent of possible tumor metastasis. Once the tumor is staged, the treatment plan is formulated. Several types of malignancies have well-defined treatment protocols that have been designed by surgeons and oncologists in an effort to study the effectiveness of treatment regimens more carefully.

Treatment Modalities for Malignancies

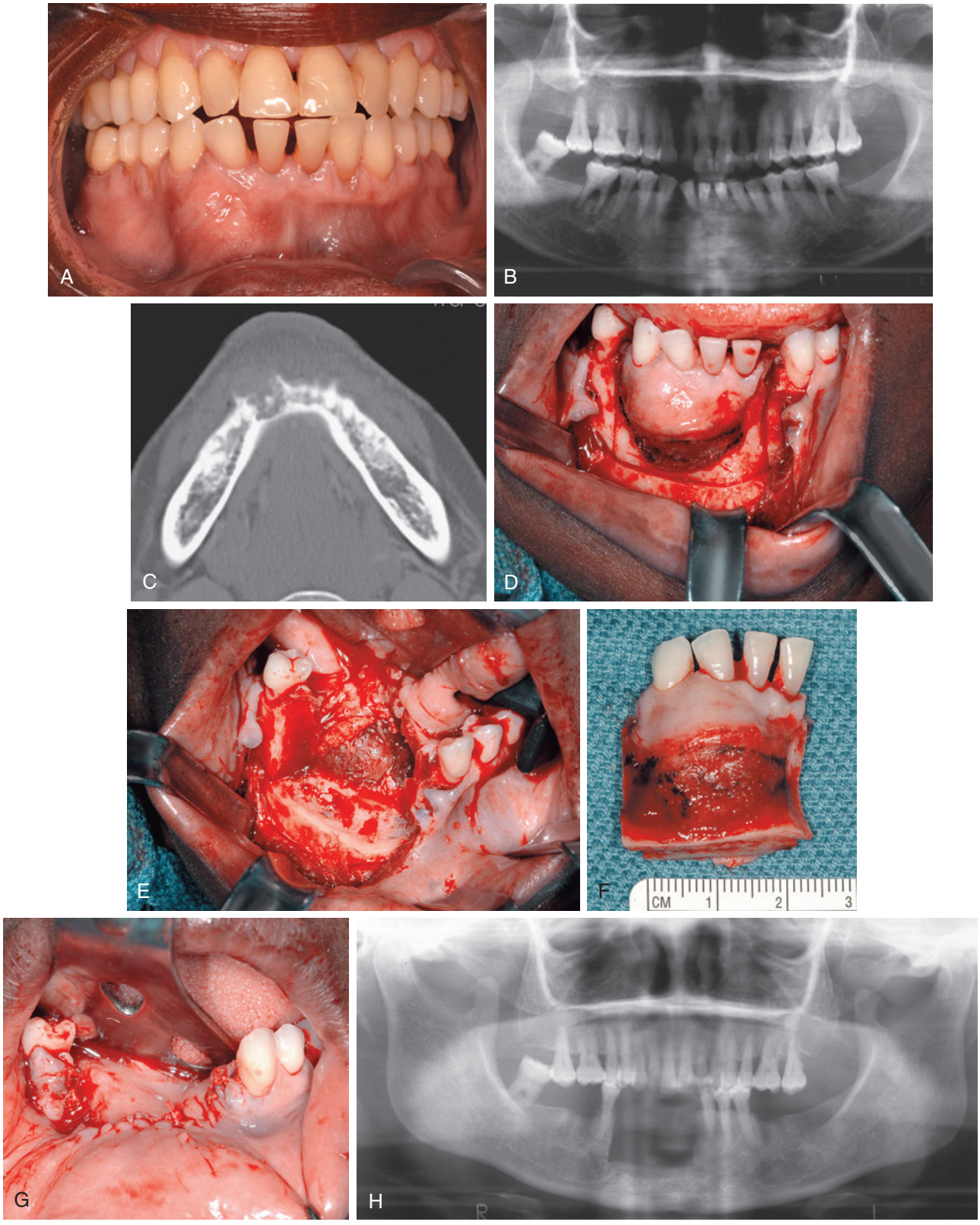
Malignancies of the oral cavity are treated with surgery, radiation, chemotherapy, or a combination of these modalities. The treatment for any given case depends on several factors, including the histopathologic diagnosis, the location of the tumor, the presence and degree of metastasis, the radiosensitivity or chemosensitivity of the tumor, the age and general physical condition of the patient, the experience of the treating clinicians, and the wishes of the patient. In general, if a lesion can be completely excised without mutilating the patient, this is the preferred modality. If spread to regional lymph nodes is suspected, radiation may be used before or after surgery to help eliminate small foci of malignant cells in adjacent areas. If widespread systemic metastasis is detected or if a tumor such as a lymphoma is especially chemosensitive, chemotherapy is used with or without surgery and radiation.

Currently malignancies are often treated in an institution where several specialists evaluate each case and discuss treatment regimens. These "tumor boards" include at least a surgeon, a chemotherapist, and a radiotherapist. Most head and neck tumor boards also include a general dentist, a maxillofacial prosthodontist, a nutritionist, a speech pathologist, and a sociologist or psychiatrist.

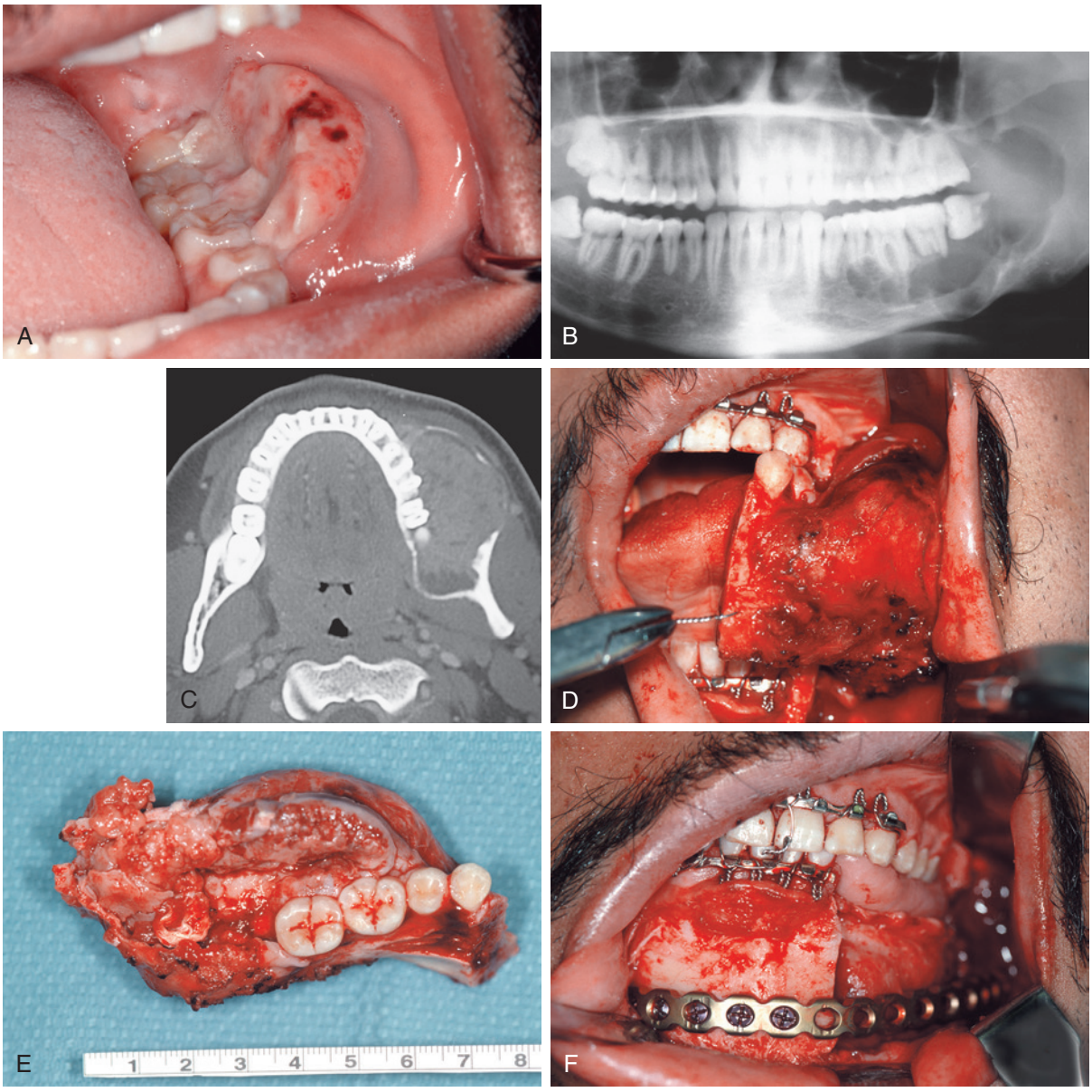
Radiotherapy

Radiotherapy for the treatment of malignant neoplasms is based on the fact that tumor cells in stages of active growth are more susceptible to ionizing radiation compared with adult tissue. The faster the cells are multiplying or the more undifferentiated the tumor cells, the more likely it is that radiation will be effective. Radiation prevents the cells from multiplying by interfering with their nuclear material. Normal host cells are also affected by radiation and must be protected as much as possible during treatment.

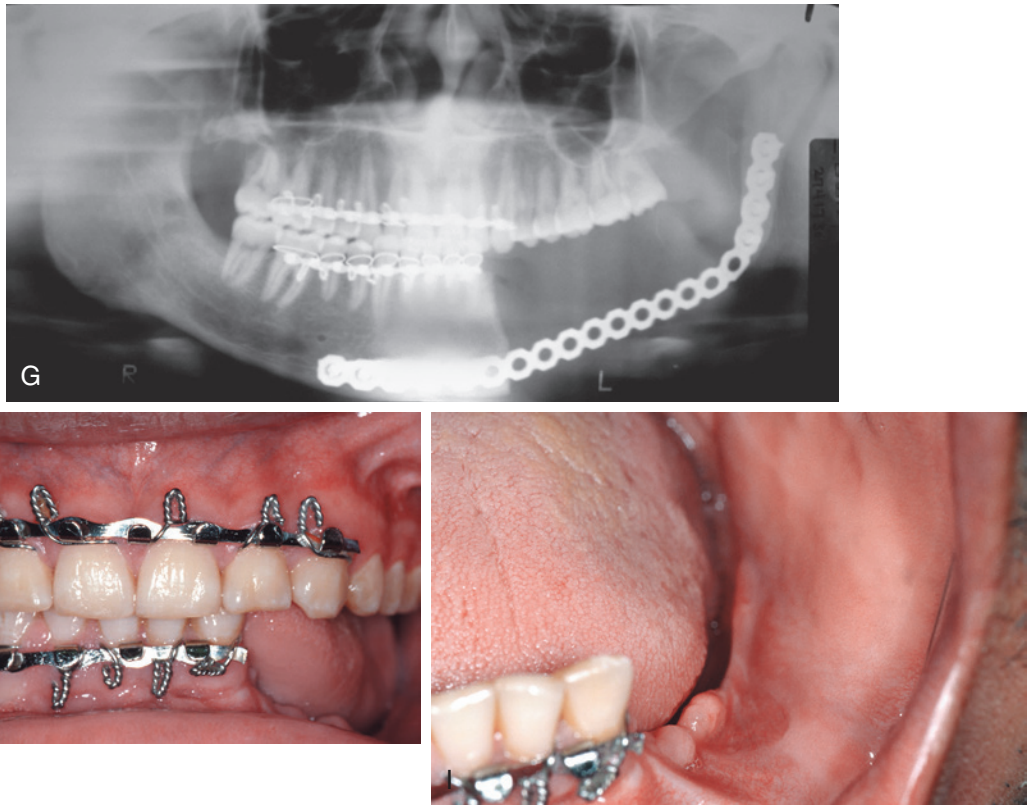
Radiation can be delivered to the patient in several forms, including implantation of radioactive material into the tumor. Most commonly, however, radiation is delivered externally with the use of large x-ray generators. The amount of radiation that a person may normally tolerate is not exceeded, and adjacent



• **Fig. 23.10** Marginal (or segmental resection) of ameloblastoma. (A) Preoperative photograph showing swelling of anterior mandible around roots of teeth. (B) Panoramic radiograph shows spacing of the roots from an ill-defined radiolucency. (C) Computed tomography scan shows an exophytic lesion that seems to be coming out of bone. (D) Intraoral exposure of mandible and osseous cuts made around lesion. The inferior border was left intact. (E) Intraoral defect after removal of lesion. Height of bone along the inferior border was sufficient to maintain continuity of the mandible. Bony reconstruction of the alveolar process was delayed until a later date. (F) Surgical specimen. (G) Appearance of the defect after soft tissue closure. (H) Panoramic radiograph taken after surgery.



• **Fig. 23.11** Partial mandibular resection for ameloblastoma. (A) Lesion in the left mandibular molar area. (B) Panoramic radiographic appearance on initial presentation showing multilocular radiolucency associated with an impacted tooth. Incision biopsy proved the lesion to be an ameloblastoma. (C) Computed tomography scan showing extent of lesion. (D) Intraoral resection of tumor. (E) Surgical specimen. (F) Reconstruction of the mandible with a large bone plate.



• **Fig. 23.11, cont'd** (G) Panoramic radiograph taken after surgery showing resection margins and bone plate reconstruction. (H) Occlusion of patient 6 weeks after surgery. (I) Intraoral appearance 6 weeks after surgery. Bony reconstruction was performed later.

uninvolved areas are spared by the use of protective shielding. Two mechanisms of delivery, fractionation and multiple ports, spare the patient's host tissues in the immediate area of the tumor.

Fractionation of the delivery of radiation means that instead of giving the maximal amount of radiation a person can withstand at one time, smaller increments of radiation (i.e., fractions) are given over several weeks, which allows the healthier normal tissues time to recover between doses. The tumor cells, however, are less able to recover between doses. The other delivery method uses multiple ports for radiation exposure. Instead of delivering the entire dose through one beam (i.e., port), multiple beams are used. All beams are focused on the tumor but from different angles. Thus the tumor is exposed to the entire dose of radiation. However, because different beams are used, the normal tissues in the path of the x-ray beams are spared maximal exposure and instead receive only a fraction of the tumor dose.

Chemotherapy

Chemicals that act by interfering with rapidly growing tumor cells are used for treating many types of malignancies. As with radiation, the chemicals are not totally selective but affect normal cells to some extent. Most of these agents are given intravenously; however, recently injections into the arteries feeding the tumor have been used. Because the agents are delivered systemically, they adversely affect many body systems; most notable is the hematopoietic system, which is considerably affected because of its rapid rate of cellular turnover. Thus in patients who are undergoing chemotherapy, a delicate balance exists between effectiveness in killing the tumor cells and the occurrence of anemia, neutropenia, and thrombocytopenia (see Chapter 19). Infections and bleeding are thus common complications in these patients.

To reduce the toxicity of a single agent given in large quantities, multiple-agent therapy is frequently administered. Many patients are given three to five agents at the same time. Each may work at a different point in the life cycle of the tumor cell, thus increasing effectiveness with less toxicity to the host.

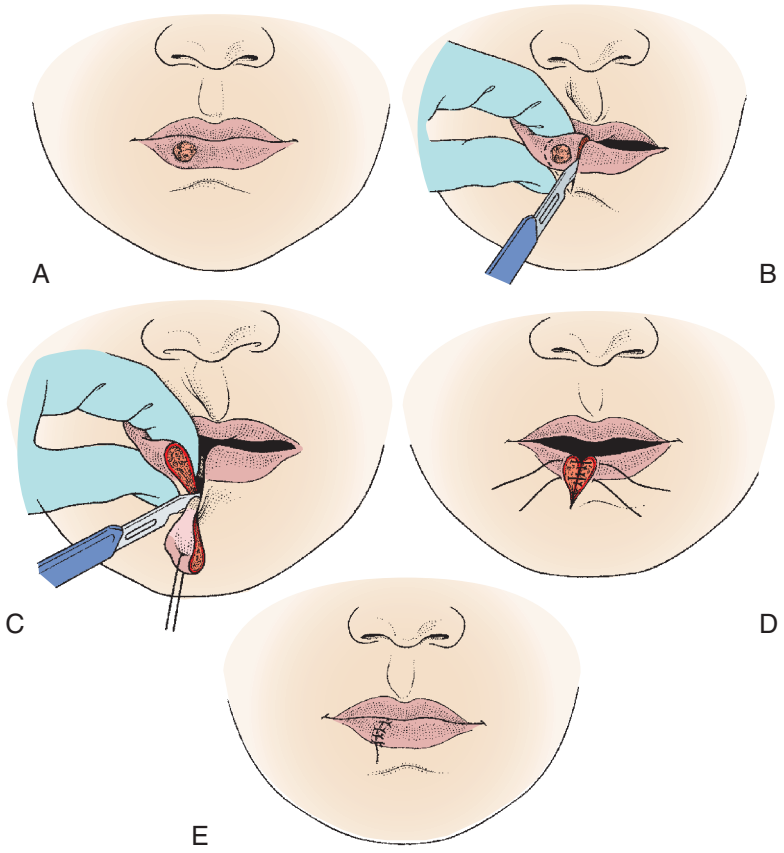
Surgery

The surgical procedures for excision of oral malignancies vary with the type and extent of the lesion. Small epidermoid carcinomas that are in accessible locations (e.g., the lower lip) and are not associated with palpable lymph nodes can be excised (Fig. 23.12). A larger lesion associated with palpable lymph nodes or a similar lesion in the area of the tonsillar pillar may require extensive surgery to remove it adequately with its local metastases.

Malignancies of the oral cavity that have suspected or proven lymph node involvement are candidates for composite resection in which the lesion, surrounding tissues, and lymph nodes of the neck are totally removed. This procedure may produce large defects of the jaws and extensive loss of soft tissues, which make functional and esthetic rehabilitation a long, involved process.

Surgical Management of Benign Lesions in Oral Soft Tissues

Superficial soft tissue lesions of the oral mucosa are usually benign and in most instances lend themselves to simple surgical removal



• **Fig. 23.12** Local excision of lip carcinoma. (A–E) Full-thickness V-shaped excision of the lip. Local excision of lip carcinoma.

using biopsy techniques (see Chapter 22). These lesions include fibromas, pyogenic granulomas, papillomas, peripheral giant cell granulomas, verruca vulgaris, mucoceles (i.e., mucous extravasation phenomena), and epulis fissurata. All of these lesions are overgrowths of the normally present histologic elements in the oral mucosa and submucosa. The principles of removal are the same as those outlined previously and include the use of elliptical, wedge type of incisions during removal. In the case of lesions that appear associated with the dentition (i.e., pyogenic granuloma), the associated tooth or teeth should be thoroughly curetted and polished to remove any plaque, calculus, or foreign material that may have played a role in the development of the lesion and that may cause a recurrence if not removed.

Reconstruction of Jaw After Removal of Oral Tumors

Osseous defects may occur after removal of oral tumors. These defects may range from loss of alveolar bone to loss of major portions of the jaw and may cause the patient concern on a functional or cosmetic basis. The treatment of oral pathologic entities should always include immediate or future plans for reconstruction that have been made before the surgical procedure to remove the lesion to afford the patient optimal reconstructive results.

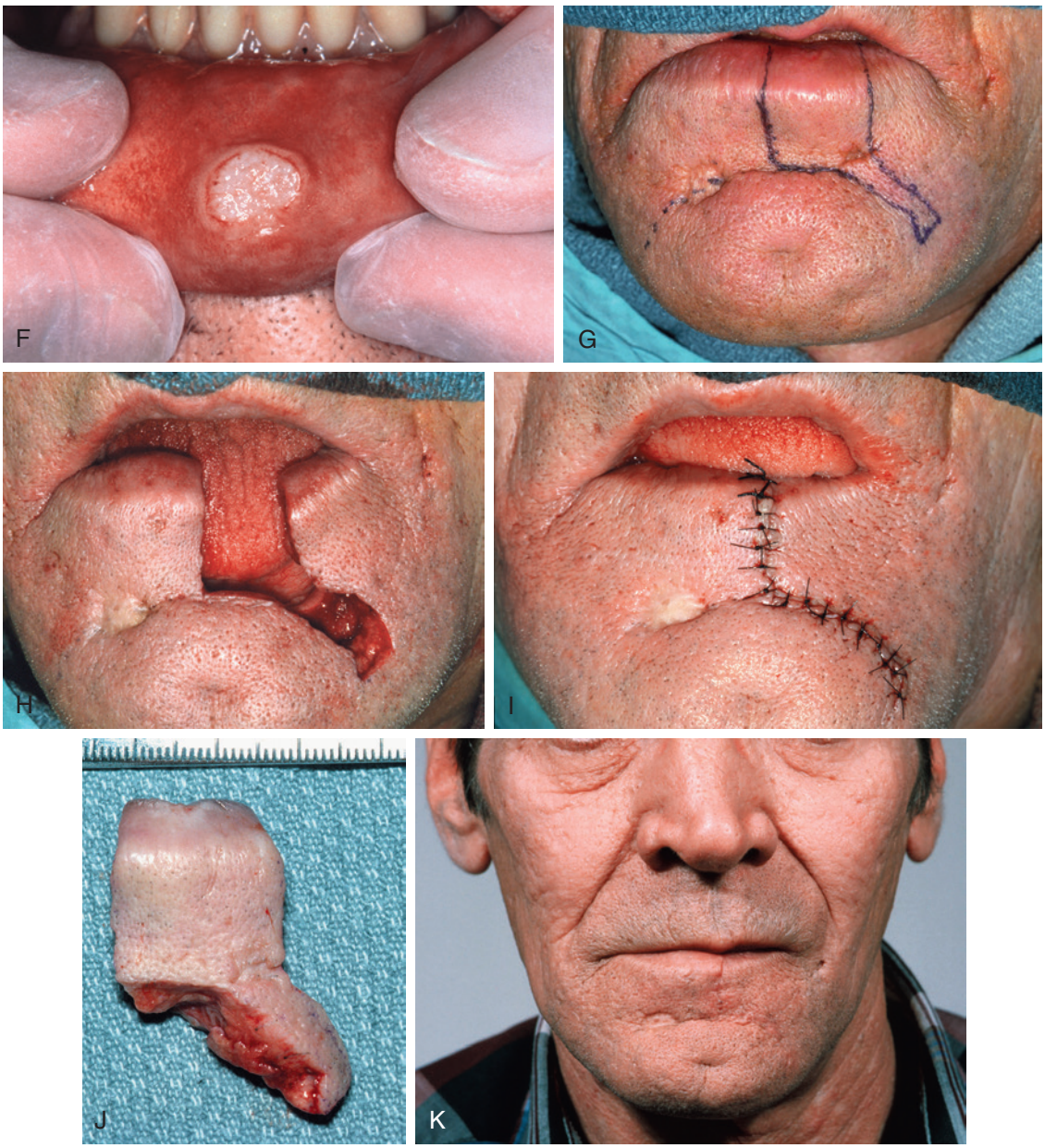
The general dentist plays a crucial role in the functional and cosmetic rehabilitation of the patient by providing dental replacements for teeth that have been surgically removed. However, before dental rehabilitation is pursued, the underlying skeleton of the jaws should be reconstructed, if necessary. Frequently surgical removal of a lesion involves removal of a portion of the alveolus, which presents the dentist with an obvious problem: Any bridge across the site or any complete or partial denture will have no osseous base on which to rest. In these cases, the patient would be well served to undergo ridge augmentation before dental restorative treatment. This augmentation can be in the form of bone grafts, synthetic bone grafts, or a combination of these materials. Optimal dental restorations can then be completed.

The reconstruction of a defect caused by resection of the mandible or a portion thereof can be performed immediately (i.e., at the time of the surgical removal of the lesion) or may be delayed until a later date.

Several surgeons delay reconstruction of defects caused by the removal of benign tumors. They suggest that the presence of simultaneous intraoral and extraoral defects, which frequently is a determining factor for removal of the tumor, contraindicates an immediate reconstruction of the mandible. Instead, a space-maintaining device is placed at the time of resection, and a secondary reconstruction is performed weeks to months later.[6,7]

When a decision for delayed reconstruction is made, consideration should be given to maintaining the residual mandibular fragments in their normal anatomic relationship with intermaxillary fixation, external pin fixation, splints, internal fixation, or a combination of these modalities. This technique prevents cicatricial and muscular deformation and displacement of the segments, and simplifies secondary reconstructive efforts.

Clinical results have shown that immediate reconstruction is a viable option and has the advantages of requiring a single surgical



• **Fig. 23.12, cont'd** (F) Carcinoma of the lower lip. (G) Surgical incisions outlined. (H) Lip after excision of specimen. (I) Closure. (J) Specimen. (K) Appearance after healing.

procedure and having an early return to function with a minimal compromise to facial esthetics.[6] A possible disadvantage is loss of the graft because of infection. The risk of infection may be higher when a graft is placed transorally or in an extraoral wound that was orally contaminated during the ablative surgery. Because the recurrence rate is substantial in some tumors, prudent planning and meticulous surgery are mandatory before reconstruction is attempted. These measures minimize the risk of failure as a result of recurrence. Three choices for immediate reconstruction are possible:

1. The entire surgical procedure is performed intraorally by first removing the tumor and then grafting the defect.
2. The tumor is removed via a combination of the intraoral and extraoral routes. A watertight oral closure is obtained, which is followed immediately by grafting the defect through the extraoral incision.
3. When the tumor has not destroyed alveolar crestal bone and when no extension of the tumor into oral soft tissues has occurred, the involved teeth are extracted. A waiting period of 6 to 8 weeks is allowed for healing of the gingival tissues. The tumor is then removed and the defect is grafted through an extraoral incision, with care taken to avoid perforation of the oral soft tissues. This procedure is the only type of immediate reconstruction by which oral contamination can be avoided.

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PART VI

Oral and Maxillofacial Trauma

One of the most demanding, yet rewarding, aspects of dental and surgical practice is the management of the patient who has sustained oral or facial trauma. The abruptness of the injury can cause intense emotional distress, even when only minor injuries are present. The perception of the injury by the patient or family and their reaction to the trauma may seem out of proportion to the degree of injury. The patient and family may be anxious and fearful, and they depend heavily on the clinician to make an accurate diagnosis, communicate that diagnosis to them, offer hope for a successful outcome, and perform the treatment necessary to repair the injury and restore function and esthetics. Therefore the clinician must effectively deal with the patient's physical injuries as well as the emotional state. Few conditions in clinical practice demand such compassion, competence, and attention to detail.

Whenever a maxillofacial injury is sustained, the patient goes abruptly from a normal state to one of tissue disruption. Patients usually expect that the treatment of the injury will make them appear and function as they did before the trauma. Unfortunately, this is often difficult to achieve. The most the clinician can do is provide the individual with the most favorable physical circumstances for optimal healing. The clinician accomplishes this by cleansing, debriding, and replacing tissues into their former positions. The resulting appearance thus depends on the site, type, and degree of injury; the ability of the clinician performing tissue repair; and the ability of the patient's tissues to heal the wounds. The dentist's approach with the patient should be hopeful yet realistic.

The next two chapters discuss the diagnosis and management of injuries to the maxillofacial region. In Chapter 24, the injuries that dentists see with some frequency are discussed in detail. These include injuries to the teeth, alveolar process, and surrounding soft tissues. Chapter 25 presents an overview of the management of more severe maxillofacial injuries and discusses various management approaches.

24

Soft Tissue and Dentoalveolar Injuries

EDWARD ELLIS III

CHAPTER OUTLINE

Soft Tissue Injuries

The types of soft tissue injuries the dentist may see in practice vary considerably. However, it is fair to assume that given the current availability of other health care providers, the dentist will probably not be involved in the management of severe soft tissue injuries around the face. Those injuries seen with some frequency are the ones associated with concomitant dentoalveolar trauma or those that the dentist may inadvertently cause in practice.

While studying the following descriptions of the wounds the dentist may see in practice and their management, it must be kept in mind that patients may have combinations of these injuries; thus management may be more complicated.

Abrasion

An *abrasion* is a wound caused by friction between an object and the surface of the soft tissue. This wound is usually superficial, denudes the epithelium, and occasionally involves deeper layers. Because abrasions involve the terminal endings of many nerve fibers, they are painful. Bleeding is usually minor because it is from capillaries and responds well to application of gentle pressure.

The types of abrasions most commonly seen by laypersons are the scrapes that children sustain on their elbows and knees from rough play. If the abrasion is not particularly deep, re-epithelialization occurs without scarring. When the abrasion extends into the deeper layers of the dermis, healing of the deeper tissues occurs with the formation of scar tissue, and some permanent deformity can be expected.

The dentist may see abrasions on the tip of the nose, lips, cheeks, and chin in patients who have sustained dentoalveolar trauma (Fig. 24.1). The abraded areas should be thoroughly cleansed to remove foreign material. Surgical hand soap and copious saline irrigation are useful for this purpose. All particles of foreign matter must be removed. If these particles are allowed to remain within the tissue, a permanent "tattoo" that is difficult to treat results. In deep abrasions that are contaminated with dirt or other material, it may be necessary to anesthetize the area and use a surgical scrub brush (or toothbrush) to remove the debris completely.

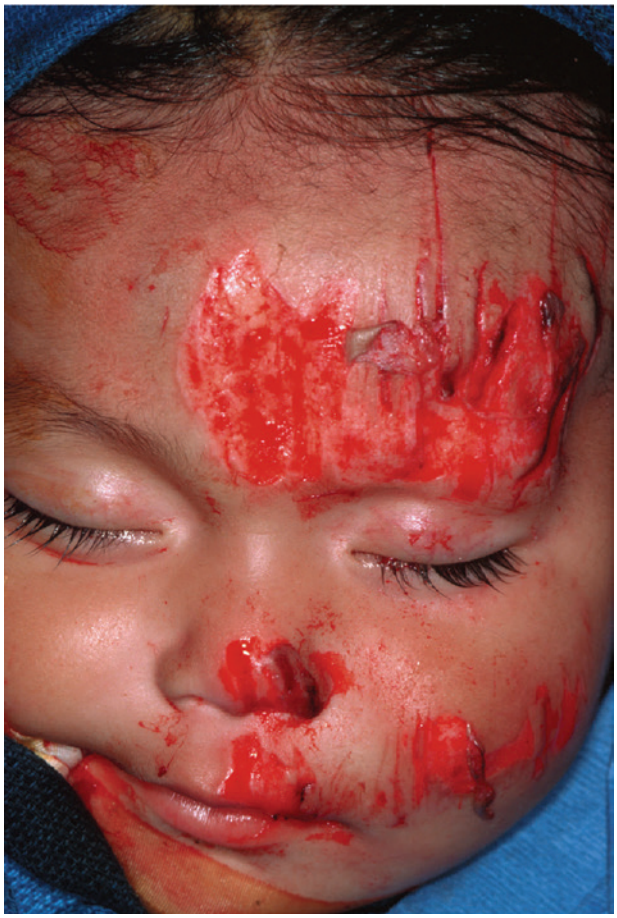
Once the wound is free of debris, topical application of an antibiotic ointment is adequate treatment. A loose bandage can be applied if the abrasion is deep but is unnecessary in superficial abrasions. Systemic antibiotics are not usually indicated. Over the next week, reepithelialization will occur under the eschar, which is a crust of dried blood and serum that develops after an injury to soft tissue (e.g., a scab). The eschar will then drop off.

If a deep abrasion on the skin surface is discovered after wound cleansing, referral to an oral-maxillofacial surgeon is indicated because skin grafting may be necessary to prevent excessive amounts of scar formation.

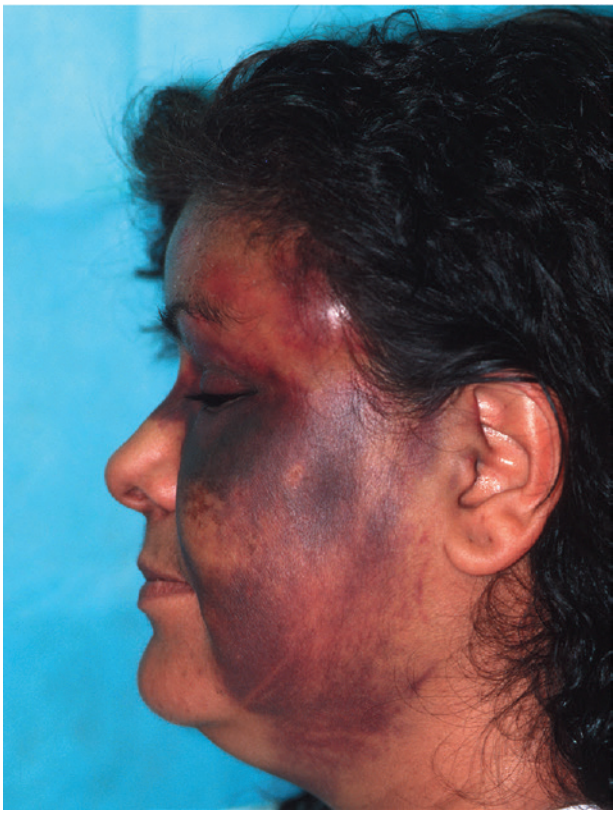
The dentist may create abrasions iatrogenically, as occurs when the shank of a rotating burr touches the oral mucosa or when a gauze pack or other fabric (e.g., absorbent triangular pads) abrades the mucosa during removal from the mouth. Fortunately, the oral epithelium regenerates rapidly, and no treatment other than routine oral hygiene is indicated.

Contusion

A *contusion* is more commonly called a *bruise* and indicates that some amount of tissue disruption has occurred within the tissues,



• **Fig. 24.1** Patient with abrasions to the tip of the nose, cheek, and forehead. Some of the abrasions are superficial, and some are deeper with peeling off of the epithelium.



• **Fig. 24.2** Soft tissue contusions caused by blunt injury with no underlying facial fractures.

that resulted in subcutaneous or submucosal hemorrhage without a break in the soft tissue surface (Fig. 24.2).

Contusions are usually caused by trauma inflicted with a blunt object but are also frequently found with concomitant dentoalveolar injuries or facial bone fractures. In this instance, the trauma to the deeper tissues (e.g., floor of mouth or labial vestibule) has occurred from the disrupting effect of the fractured bones. The importance of contusions from a diagnostic point of view is that when they occur, one should search for osseous fractures.

A contusion generally requires no surgical treatment. Once the hydrostatic pressure within the soft tissues equals the pressure within the blood vessels (usually capillaries), bleeding ceases. If a contusion is seen early, application of ice or pressure dressings may help constrict blood vessels and thereby decrease the amount of hematoma that forms. If a contusion does not stop expanding, a hemorrhaging artery within the wound is likely. The hematoma may require surgical exploration and ligation of the vessel.

Because there has been no disruption of soft tissue surfaces, over time, the body resorbs the hemorrhage formed within a contusion, and the normal contour is reestablished. In the next several days, however, the patient can expect areas of ecchymosis (i.e., purplish discoloration caused by extravasation of blood into the skin or mucosa; a "black and blue mark"), which turn a variety of colors (e.g., blue, green, yellow) before fading. These areas may extend down below the clavicles and cause alarm, but they are innocuous.

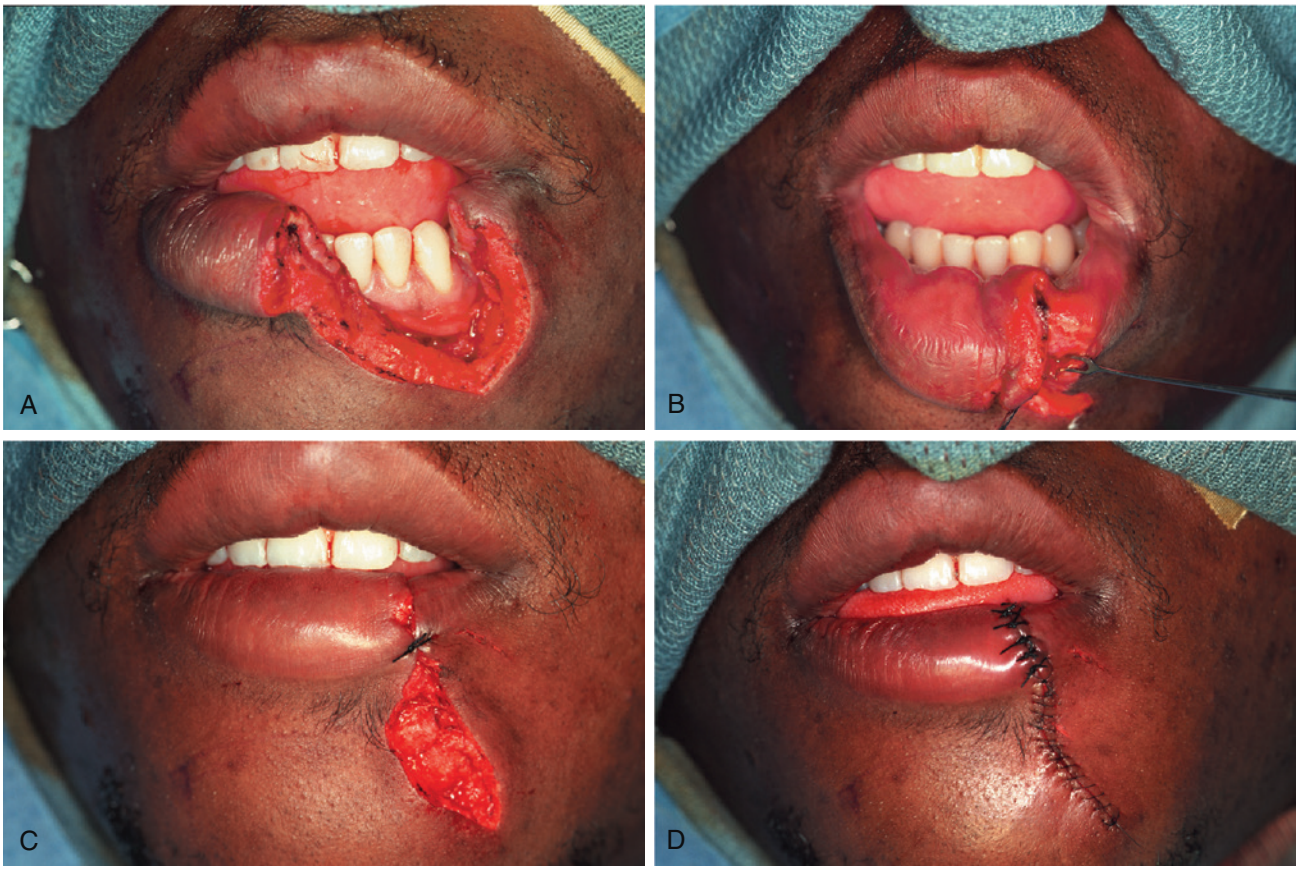
When no break has occurred in the surface of soft tissue, infection is unlikely, so systemic antibiotics are not indicated. If, however, the contusion results from dentoalveolar trauma, it is likely that communication may exist between the oral cavity and the submucosal hematoma. In this case, systemic antibiotics are warranted because coagulated blood represents an ideal culture medium.

Laceration

A *laceration* is a tear in the epithelial and subepithelial tissues. A laceration is perhaps the most frequent type of soft tissue injury and is caused most commonly by a sharp object such as a knife or a piece of glass. If the object is not sharp, the lacerations created may be jagged because the tissue is literally torn by the force of the blow (Fig. 24.3). As with abrasions, the depth of a laceration can vary. Some lacerations involve the external surface only, but others extend deep into tissue, disrupting nerves, blood vessels, muscle, and other major anatomic cavities and structures.

The dentist frequently encounters lacerations of the lips, floor of mouth, tongue, labial mucosa, buccolabial vestibule, and gingiva caused by trauma. One should explore the oral cavity thoroughly to identify ones that are not gaping. For instance, lacerations within the vestibule can be overlooked unless the lips are retracted, allowing a laceration to gape. Lip lacerations are commonly seen with dentoalveolar trauma, but in many instances of trauma, teeth are uninjured because soft tissue has absorbed the force of the blow.

Soft tissue wounds associated with dentoalveolar trauma are always treated after the management of the hard tissue injury. Suturing soft tissue first is a waste of time because the sutures are likely to be stressed too much and pulled out of the tissue during



• **Fig. 24.3** Repair of a full-thickness laceration of the lower lip. (A) Tissues have been cleaned and hemostasis has been obtained. (B) Muscle has been closed with interrupted 3-0 chromic catgut sutures. These sutures are the ones that primarily pull the tissues back together. The sutures should make it possible to close the skin without any tension. (C) A 4-0 silk suture is placed at the mucocutaneous junction. This suture is critical because it aligns the vermilion border. If not done carefully, after healing a noticeable step or notch will show from misalignment. (D) Skin and mucosal sutures are placed. Silk sutures were used to close the vermilion of the lip while nylon sutures were used to close the skin surface.

intraoral manipulation, which is necessary to replant an avulsed tooth or treat a dentoalveolar fracture. Furthermore, once sutures have been pulled out of the tissue, it will be more difficult to close the tissue on the second attempt.

After adequate anesthesia is provided, the surgical management of lacerations involves four major steps: (1) cleansing, (2) debridement, (3) hemostasis, and (4) closure. These steps apply to lacerations anywhere in the body, including the oral cavity and perioral areas.

Cleansing of Wound

Mechanical cleansing of the wound is necessary to prevent any remaining debris. Cleansing can be performed with surgical soap and may necessitate the use of a brush. An anesthetic is usually necessary. Copious saline irrigation is then used to remove all water-soluble material and to flush out particulate matter. Pulsed irrigation has been shown to be more effective in removing debris than a constant flow of irrigation.

Debridement of Wound

Debridement refers to the removal of contused and devitalized tissue from a wound and the removal of jagged pieces of surface tissue to enable linear closure. In the maxillofacial region, which has a rich blood supply, the amount of debridement should be kept to a minimum. Only tissue that is obviously not vital is excised. For most of the lacerations a dentist encounters, no debridement is necessary, except for minor salivary gland tissue (discussed later).

Hemostasis in Wound

Before closure, hemostasis must be achieved. Continued bleeding might jeopardize the repair by creating a hematoma within the tissues that can break the tissues open once they are sutured closed. If any bleeding vessels are identified, they should be clamped and tied with ligatures or cauterized with an electrocoagulation unit. The largest vessel the dentist will probably encounter is the labial artery, which runs horizontally across the lip just beneath the labial mucosa. Because of its position, the labial artery is frequently involved in vertical lip lacerations. This artery is approximately 1 mm in diameter and usually can be clamped and tied or clamped and cauterized.

Closure of Wound

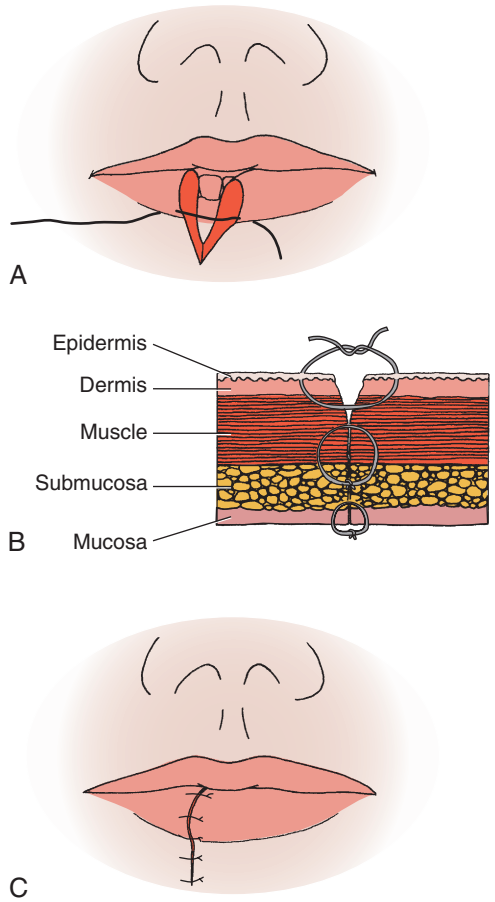
Once the wound has been cleansed and debrided and hemostasis achieved, the laceration is ready to be closed with sutures. However, not every laceration in the oral cavity must be closed with sutures. For example, a small laceration in the palatal mucosa caused by falling on an object extending from the mouth need not be closed. Similarly, a small laceration on the inner aspect of the lip or tongue

caused by entrapment between teeth during a fall usually does not require closure. These small wounds heal well by secondary intention and are best left to do so.

If closure of a laceration is deemed appropriate, the goal during closure is proper positioning of all tissue layers. The manner in which closure proceeds depends totally on the location and depth of the laceration.

Lacerations of the gingiva and alveolar mucosa (or floor of mouth) are simply closed in one layer. If a patient has a laceration of the tongue or lip that involves muscle, resorbable sutures should be placed to close the muscle layer or layers, after which the mucosa is sutured. Minor salivary gland tissue protruding into a wound can be judiciously trimmed to allow for a more favorable closure.

For lacerations extending through the entire thickness of the lip, a triple-layered closure is necessary (Fig. 24.4). If the laceration involves the vermilion border, the first suture placed should be at the mucocutaneous junction. Perfect alignment of this junction of skin and mucosa is imperative, or it can result in a noticeable deformity that can be seen from a distance. Once this suture is placed, the wound is closed in layers from the inside out. The oral mucosa is first closed with silk or resorbable suture. The orbicularis oris muscle is then sutured with interrupted resorbable sutures.



• **Fig. 24.4** Closure of a lip laceration or incision. (A) A critical suture is placed at the mucocutaneous junction. Realignment of the mucocutaneous junction is critical; otherwise, cosmetic deformity will be noticeable. (B and C) The lip is closed in three layers: (1) oral mucosa, (2) muscle, and (3) dermal surface. The choice of suture for oral and dermal surfaces varies with surgeon; however, the muscle layer should be closed with chromic or plain catgut (resorbable) suture.

Finally, the dermal surface of the lip is sutured with 5-0 or 6-0 nylon sutures. The wound will look as good at the completion of suturing as it ever will. If the alignment of tissues appears poor, consideration should be given to removing the sutures and replacing them in a more favorable manner. The dermal surface should then be covered with an antibiotic ointment.

Once a laceration is closed, the clinician must consider what supportive therapy can be instituted to bring about uneventful healing. Systemic antibiotics (e.g., penicillin) should be considered whenever a laceration extends through the full substance of the lip. In superficial lacerations, antibiotics are not indicated. The patient's tetanus status should be ascertained; if in doubt, patients should be referred to their general physicians. Patients should also be instructed in postsurgical diet and wound care.

In general, facial skin sutures should be removed 4 to 6 days postoperatively. When removing a suture, it should be cut and then pulled in a direction that does not cause the wound to gape. Adhesive strips can be placed at the time of suture removal to give external support to the healing wound.

Dentoalveolar Injuries

Dentoalveolar and perioral soft tissue injuries are frequently caused by many types of trauma. The most common causes are falls, motor vehicle accidents, sports injuries, altercations, child abuse, and playground accidents. Falling, which causes many injuries, starts when a child begins to walk, and the incidence peaks just before school age.[1] The dentist is likely to be called by a frantic parent whose child has just fallen and is bleeding from the mouth. Dentists must be familiar with dentoalveolar injuries so that they can effectively manage them when they are encountered.

A force directly on a tooth or an indirect force, most commonly transmitted through overlying soft tissue (e.g., the lip), may cause dentoalveolar injuries. Injuries of surrounding soft tissue almost always accompany injuries to the dentoalveolus. For example, gingival tissues may be torn; the lower lip may have been caught between teeth during the injury, creating a full-thickness laceration; or the floor of the mouth may be lacerated. Knowledge of management techniques for injuries to the dentoalveolus and soft tissue is necessary to allow the dentist to treat these injuries effectively.

Management of Dentoalveolar Injuries

Injuries to teeth and the alveolar process are common and should be considered emergency conditions because a successful outcome depends on prompt attention to the injury. Because proper treatment can be given only after an accurate diagnosis, the diagnostic process should commence immediately.

History

The first step in any diagnostic process should be to obtain an accurate history. A comprehensive history of the injury should be obtained from the patient, incorporating information on who, when, where, and how. The dentist must ask the following questions of the patient, parent, or a reliable respondent:

1. *Who is the patient?* The patient's name, age, address, telephone number, and other pertinent demographic data should be included in the answer. It is imperative that these data be obtained quickly and no time wasted.
2. *When did the injury occur?* This is one of the most important questions to ask because studies have shown that the sooner

an avulsed tooth can be repositioned, the better the prognosis.[2] Similarly, the results of treating displaced teeth, crown fractures (with and without exposed dental pulps), and alveolar fractures may be influenced by any delay in treatment.[1,3]

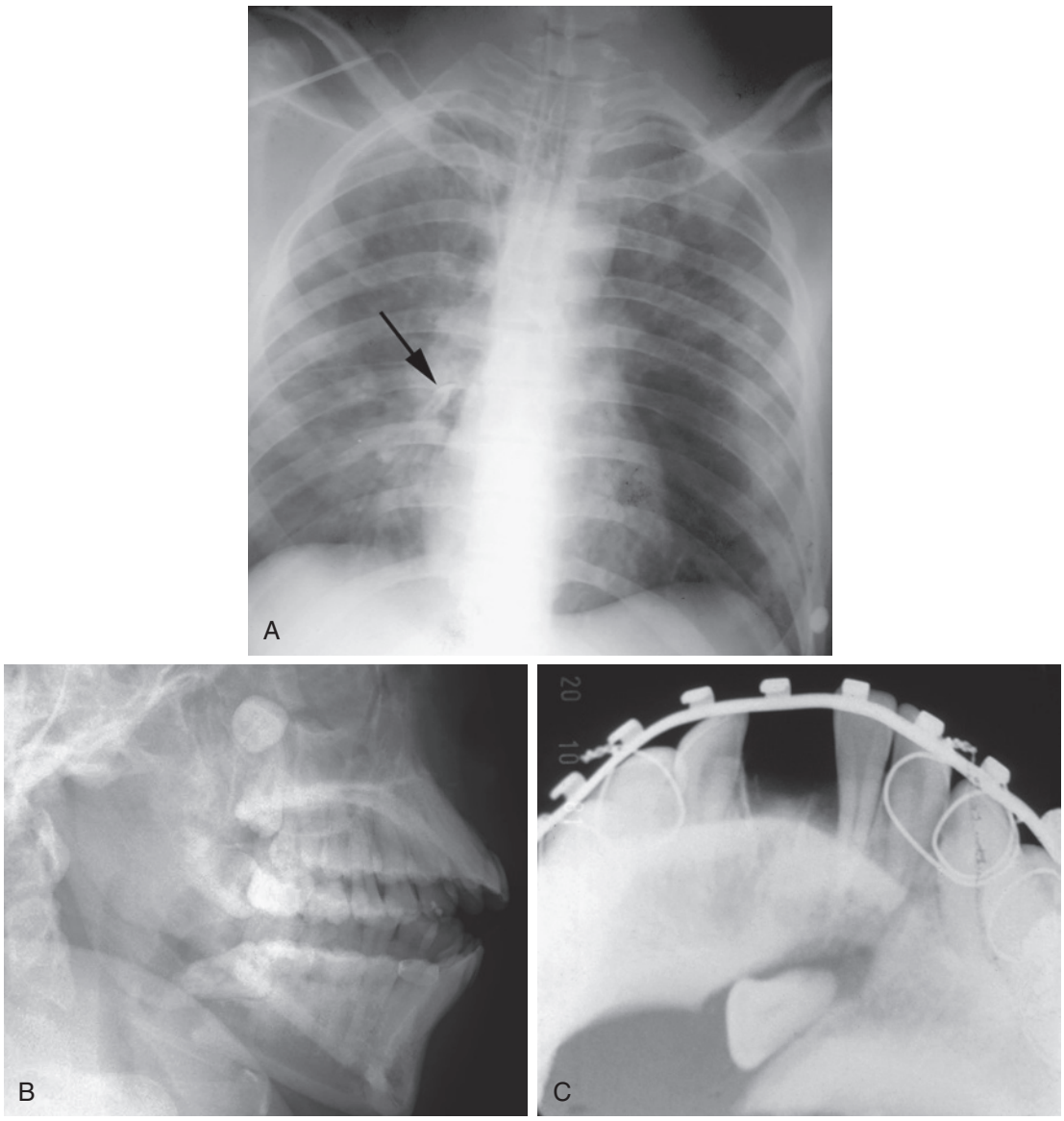
3. *Where did the injury occur?* This question may be important because the possibility and degree of bacterial or chemical contamination should be ascertained. For example, if a child falls on the playground and gets dirt in the wound, a tetanus prophylaxis history should be carefully established. However, if an injury occurs from a clean object held in the mouth, gross bacterial contamination from external sources is not expected.
4. *How did the injury occur?* The nature of the trauma provides valuable insight into what the resultant tissue injury is likely to be. For example, an unrestrained car passenger who is thrown forward into the dashboard with sufficient force to damage several teeth may also have sustained occult injuries to the neck. The manner in which the injury occurred is valuable information and should make the clinician investigate the possibility of further injuries. Additional information that can be gained from this question may relate to the cause of the injury. If a patient cannot remember what happened, a preexisting medical condition such as a seizure disorder may have caused the accident producing the injury. Injuries caused by possible negligence by others are open for litigation. These considerations should caution the clinician to document the findings carefully and word any discussions with the patient thoughtfully. Child abuse is another factor that must be kept in the clinician's mind when examining children whose injuries do not seem to be a likely result of the injury described by the parent.

   Unfortunately, child abuse has become more prevalent in recent years, and a high degree of suspicion may be the only manner by which it can be discovered by health care providers.
5. *What treatment has been provided since the injury (if any)?* This question elicits important information regarding the original condition of the injured area. Did the patient or parent replant a partially avulsed tooth? How was the avulsed tooth stored before presentation to the dentist?
6. *Did anyone note teeth or pieces of teeth at the site of the accident?* Before an accurate diagnosis and treatment plan are made, it is imperative to account for each tooth the patient had before the accident. If during the clinical examination a tooth or crown is found missing and no history suggests that it was lost at the scene, radiographic examination of the perioral soft tissues, the chest, and the abdominal region is necessary to rule out the presence of the missing piece within tissues or other body cavities (Fig. 24.5).
7. *What is the general health of the patient?* A succinct medical history is essential; it should not be ignored in the dentist's haste to replant an avulsed tooth. History taking, however, can be performed concomitantly with treatment or immediately thereafter. History with regard to drug allergy, heart murmur, bleeding disorder, other systemic disease, and current medications should be taken before treatment because the existence of these factors affects the treatment the dentist will provide.
8. *Did the patient have nausea, vomiting, unconsciousness, amnesia, headache, visual disturbances, or confusion after the accident?* An affirmative answer to any of these questions may indicate intracranial injury and direct the dentist to obtain medical consultation immediately after completing treatment. Immediate referral should be made if the patient is still having any of the symptoms or if the patient does not feel or look well. The patient's life should not be jeopardized merely to save an avulsed tooth.
9. *Is there a disturbance in the bite?* An affirmative answer to this question may indicate tooth displacement or dentoalveolar or jaw fracture.

Clinical Examination

The clinical examination is perhaps the most important part of the diagnostic process. A thorough examination of a patient who has had injury to the dentoalveolar structures should not focus only on that structure. Concomitant injuries may also be present; the history may direct the dentist to examine other areas for signs of injury. Vital signs such as pulse rate, blood pressure, and respiration should be measured. Such tests can usually be obtained during history taking. The mental state of the patient is also assessed throughout history taking and while performing the clinical examination by observation of the manner in which the patient reacts to the examination and responds to the questioning. During the clinical examination, the following areas should be examined routinely:

1. *Extraoral soft tissue wounds.* Lacerations, abrasions, and contusions of the skin are common with dentoalveolar injuries and should be noted. If a laceration is present, the depth of it should also be determined. Does the laceration extend through the entire thickness of the lip or cheek? Are there any vital structures such as the parotid duct or facial nerve crossing the line of the laceration? An oral-maxillofacial surgeon best treats major lacerations such as these.
2. *Intraoral soft tissue wounds.* Injuries to oral soft tissues are commonly associated with dentoalveolar injuries. Before a thorough examination, it may be necessary to remove blood clots, irrigate the area with sterile saline, and cleanse the oral cavity. Areas of bleeding usually respond to pressure applied through gauze sponges. Soft tissue injuries should be noted, and an examination should ascertain whether any foreign bodies such as tooth crowns or teeth remain within the substance of the lips, floor of mouth, cheeks, or other areas. The dentist should also note areas of extensive loss of soft tissue; blood supply to a segment of tissue may thereby be lost.
3. *Fractures of the jaws or alveolar process.* Fractures of the jaws are most readily found on palpation. However, because pain may be severe after the injury, examination may be difficult. Bleeding into the floor of the mouth or into the labial vestibule may indicate a fracture of the jaw. Segments of alveolar process that have been fractured are readily detected by visual examination and palpation.
4. *Examination of the tooth crowns for the presence of fractures or pulp exposure.* For adequate examination, teeth should be cleansed of blood. Any fractures should be noted. The depth of the fracture is an important point to note. Does it extend into dentin or into the pulp?
5. *Displacement of teeth.* Teeth can be displaced in any direction. Most commonly, they are displaced in a buccolingual direction, but they may also be extruded or intruded. In the most severe type of displacement, teeth are avulsed—that is, totally displaced out of the alveolar process. Observation of the dental occlusion may provide assistance in determining minimal degrees of tooth displacement.
6. *Mobility of teeth.* All teeth should be checked for mobility in the horizontal and vertical directions. A tooth that does not appear to be displaced but that has considerable mobility may have sustained a root fracture. If adjacent teeth move with the tooth being tested, a dentoalveolar fracture (in which a segment



• **Fig. 24.5** Teeth displaced into abnormal locations. (A) Chest radiograph showing maxillary canine tooth in right main stem bronchus after traumatic displacement. (B) Molar displaced into maxillary sinus from maxillary fracture. (C) Incisor tooth in line of fracture preventing anatomic reduction.

of alveolar bone and teeth are separated from the remainder of the jaw) should be suspected.

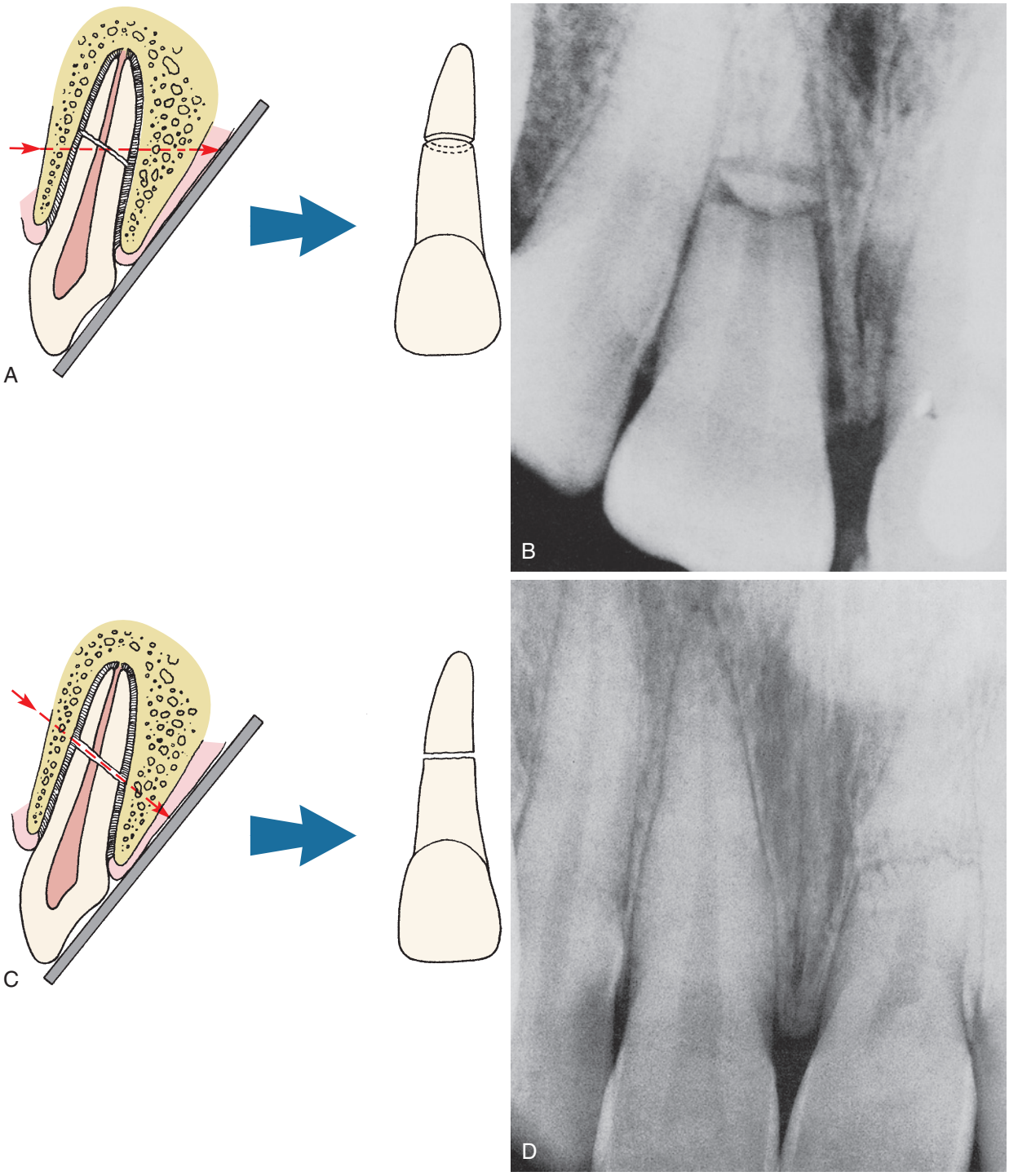
7. *Percussion of teeth.* When a tooth does not appear to be displaced but pain is felt in the region, percussion determines whether the periodontal ligament has undergone some injury.
8. *Pulp testing of teeth.* Although rarely used in acute injuries, vitality tests (which induce a reaction from teeth) may direct the type of treatment provided once the injury has healed. False-negative results may occur, so teeth should be retested several weeks later and before endodontic therapy is performed.

Radiographic Examination

A host of radiographic techniques are available to evaluate dentoalveolar trauma. Most techniques can be readily performed in the dental office with available equipment. Most commonly a combination of occlusal and periapical radiographs is used. The radiographic examination should provide the following information[4]:

1. Presence of root fracture
2. Degree of extrusion or intrusion
3. Presence of preexisting periapical disease
4. Extent of root development
5. Size of the pulp chamber and root canal
6. Presence of jaw fractures
7. Tooth fragments and foreign bodies lodged in soft tissues

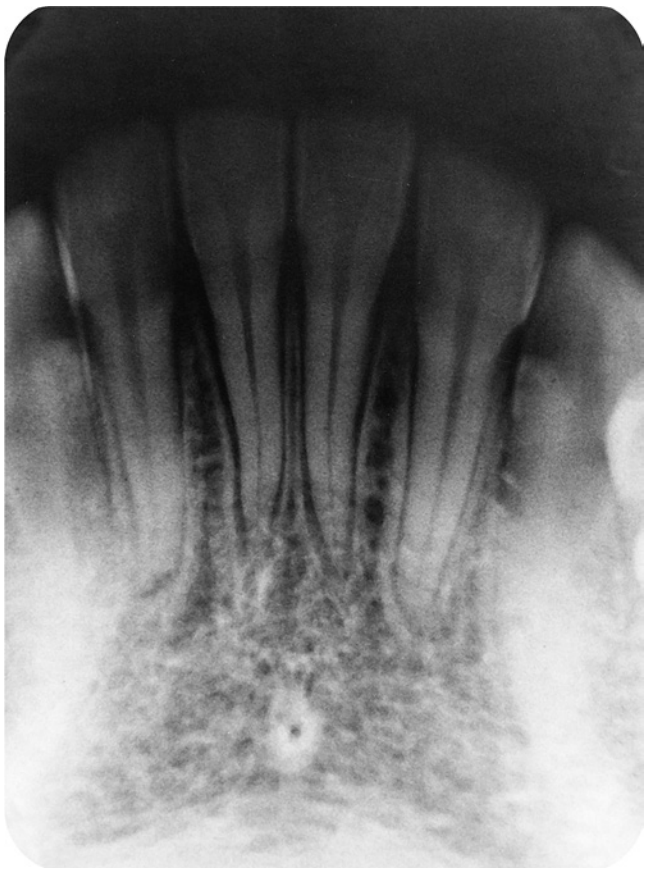
A single radiograph may not be sufficient to demonstrate a root fracture.[1] For a radiograph to demonstrate a fractured root, the central beam of the x-ray device must be parallel to the line of fracture; otherwise the fracture may not be clearly seen (Fig. 24.6). Multiple views with differing vertical and horizontal angulations of the central ray may be necessary.



• **Fig. 24.6** Effect of vertical angulation of central x-ray beam on the detection of horizontal root fracture. When the central ray is not parallel to the fracture (A), either a double fracture (B) or no fracture at all may be observed on radiograph. When the central ray is parallel to the fracture (C), the fracture appears on the radiograph (D).

Displaced teeth may show a widening of the periodontal ligament space or displacement of the lamina dura. Extruded teeth may demonstrate a conical periapical radiolucency (Fig. 24.7). Intruded teeth may show minimal radiographic findings because of the continued close adaptation of the lamina dura and the root surface. Frequently, however, intruded teeth show an absence of the periodontal ligament space.

Radiographic evaluations for foreign bodies within the soft tissues of the lips or cheeks are taken with the radiographic film placed inside the soft tissues to be examined, labial to the alveolus (Fig. 24.8A). A reduced radiographic exposure time is used (approximately one-third of normal). Foreign bodies in the floor of the mouth are viewed with cross-sectioned occlusal radiographs and with reduced radiographic exposure time (see Fig. 24.8B).



• **Fig. 24.7** Radiograph showing widened periodontal ligament spaces around several teeth that are displaced coronally.

Classification of Traumatic Injuries to Teeth and Supporting Structures

Many systems are used for the description of dentoalveolar injuries, all of which have advantages and disadvantages. A relatively simple yet useful classification was presented by Sanders et al. (Box 24.1).[4] Their method is based entirely on a description of the injury sustained during the traumatic episode, describing the tooth structures involved, the type of displacement, and the direction of crown or root fracture.

Treatment of Dentoalveolar Injuries[a]

After conducting a thorough history and clinical and radiologic examinations, the dentist should be able to determine whether the treatment plan for the patient's type of injury is within the clinician's range of expertise. Several circumstances may render an otherwise minor injury untreatable by the dentist alone. A problem the dentist frequently encounters is the uncooperative patient, most commonly a child. The combination of the traumatic episode and the child's fear of the dentist may render a simple surgical procedure impossible without general anesthesia. Another difficulty is the patient with multiple medical problems. When it is felt that it would not be possible to effectively manage a patient because of surgical difficulty, anesthesia requirement, concomitant medical problems, or other reasons, an oral-maxillofacial surgeon should immediately be consulted for assistance with treatment.

The goal in the treatment of dentoalveolar injuries is re-establishing normal form and function of the masticatory apparatus. When the pulp is directly involved, treatment differs from that of tooth injuries in which the pulp is not involved. Because of the training in operative dentistry and endodontics, a dentist has the knowledge, the instruments, and the medications routinely available to manage cases of tooth fracture. Therefore the treatment regimen for these injuries is outlined only briefly here. More severe injuries such as tooth dislocations, avulsions, or dentoalveolar fractures are areas in which the dentist may have had little training; these are presented in greater detail.

[a]For a comprehensive website on this topic, go to: http://dentaltraumaguide.com.

• BOX 24.1 Classification of Dentoalveolar Injuries

Crown Craze or Crack (i.e., Infraction; see Fig. 24.9**)**
- Crack or incomplete fracture of the enamel without a loss of tooth structure

Horizontal or Vertical Crown Fracture (see Fig. 24.10)
- Confined to enamel
- Enamel and dentin involved
- Enamel, dentin, and exposed pulp involved
- Horizontal or vertical
- Oblique (involving the mesioincisal or distoincisal angle)

Crown-Root Fracture (see Fig. 24.11)
- No pulp involvement

Horizontal Root Fracture (see Fig. 24.12)
- Involving apical third
- Involving middle third
- Involving cervical third
- Horizontal or vertical

Sensitivity (i.e., Concussion)
- Injury to the tooth-supporting structure, resulting in sensitivity to touch or percussion but without mobility or displacement of the tooth

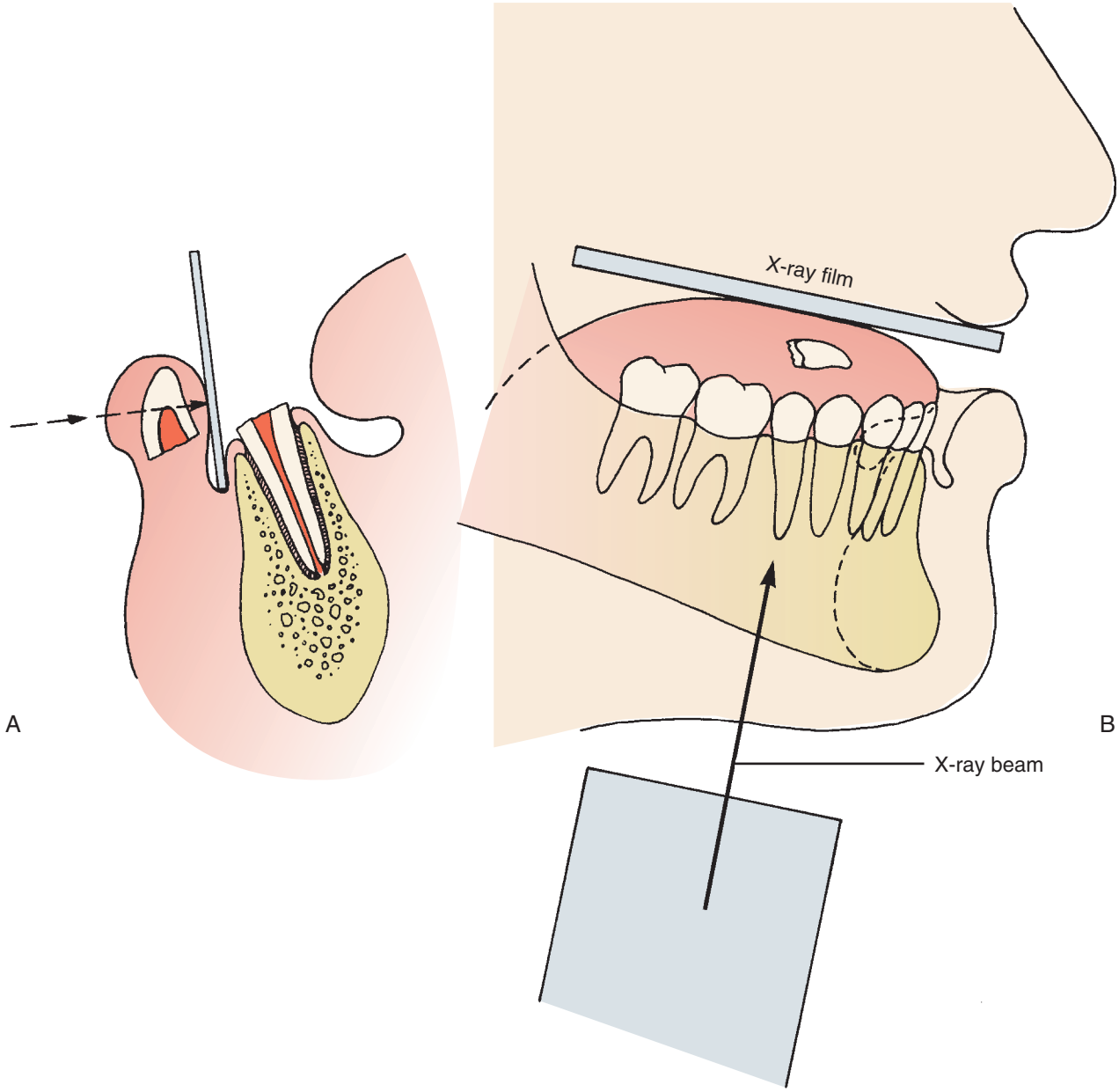
Mobility (i.e., Subluxation or Looseness)
- Injury to the tooth-supporting structure, resulting in tooth mobility but without tooth displacement

Tooth Displacement (see Fig. 24.13)
- Intrusion (displacement of tooth into its socket—usually associated with compression fracture of socket)
- Extrusion (partial displacement of tooth out of its socket—possibly no concomitant fracture of alveolar bone)
- Labial displacement (alveolar wall fractures probable)
- Lingual displacement (alveolar wall fractures probable)
- Lateral displacement (displacement of tooth in mesial or distal direction, usually into a missing tooth space—alveolar wall fractures probable)

Avulsion
- Complete displacement of tooth from its socket (may be associated with alveolar wall fractures)

Alveolar Process Fracture
- Fracture of alveolar bone in the presence or absence of a tooth or teeth

Data from Sanders B, Brady FA, Johnson R. Injuries. In: Sanders B, ed. Pediatric Oral and Maxillofacial Surgery. *St Louis: Mosby; 1979.*



• **Fig. 24.8** Radiographic technique to detect foreign bodies within lip (A) and tongue (B). The clinician should use one half to one third of normal exposure for soft tissue radiography.

Primary teeth that have been injured are generally treated in a manner similar to that for permanent teeth. However, in many instances, the lack of cooperation by an injured child results in treatment compromises and, frequently, extraction of the damaged tooth. If this occurs, the dentist should consider space maintenance measures in the near future, where indicated.

Crown Craze or Crack

Because the cracks are limited to the enamel (i.e., enamel infraction) and usually stop before reaching the dentinoenamel junction, no treatment is usually indicated. However, periodic follow-up examinations are valuable, as any force to the tooth can result in injury to the pulp and periodontal tissues (Fig. 24.9). Multiple cracks may be sealed with an unfilled resin to prevent their becoming stained.

Crown Fracture

The depth of tooth tissue involvement determines the treatment of crown fractures.[5] For fractures that are only through the enamel or those with minimal amounts of dentin involvement, no acute treatment other than smoothing off the sharp edges is warranted. If reshaping of teeth would leave a noticeable deformity, replacement of the missing enamel by acid-etched composite resin techniques is indicated. The sooner teeth are treated, the better the prognosis, because the risk of inflammatory hyperemia of the pulp is decreased. Periodic follow-up examinations are necessary to monitor pulp and periodontal health (Fig. 24.10).

If a considerable amount of dentin is exposed, the pulp must be protected. Measures to seal the dentinal tubules and promote secondary dentin deposition by the pulp can be undertaken. Calcium

hydroxide has been the traditional material applied to exposed dentin before the fractured part is covered with a suitable restoration, most commonly a composite with or without acid etching. Current recommendations are the placement of a dentin-bonding agent or glass ionomer cement over exposed dentin, followed by the placement of a resin composite restoration.[6] Glass ionomer cements chemically bind to dentin, facilitating placement and restoration. The status of pulp vitality at periodic follow-up visits dictates what the final treatment plan will be. If the pulp and periodontal health are satisfactory, no more intervention is necessary other than for esthetic reasons.

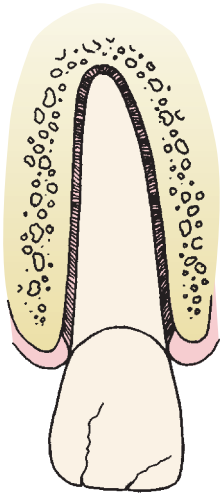
If the pulp is exposed, the aim of treatment is to preserve it in a vital, healthy state. This can usually be accomplished by pulp capping if five conditions are present: (1) the exposure is small; (2) the patient is seen soon after injury; (3) the patient had no root fractures; (4) the tooth has not been displaced; and (5) no large or deep fillings exist that might indicate chronic inflammation within the pulp. The most common injury for which pulp capping is instituted is in a tooth in which a single pulp horn was exposed with a crown fracture.

The more apically immature the tooth, the more favorable the response the dentist can expect from pulp capping. As with any operative procedure on the dental pulp, isolation with a rubber dam is recommended. After application of calcium hydroxide on the exposed pulp, glass ionomer cement is placed over the exposed dentin and a watertight acid-etch composite restoration is placed (Fig. 24.11).

A pulpotomy involves aseptic removal of damaged and inflamed pulp tissue to the level of clinically healthy pulp, after which calcium hydroxide is applied. A pulpotomy is usually implemented in larger exposures in which the apex is not closed. In these instances, a pulpotomy should be only a temporary measure to maintain the vitality of the radicular pulp until the apex is closed. Endodontic therapy should then be instituted.

Periodic follow-up examinations are mandatory after any pulpal procedure. The final restorative decision is based on the pulpal health of the tooth. Because the prognosis is guarded, endodontic treatment may be necessary if the pulp degenerates.

Another technique that can be used to restore the tooth is replacement of the original fractured tooth fragment by using the acid-etch technique or with the newer enamel and dentin adhesives.[7] This technique is particularly useful for treating large fractures.

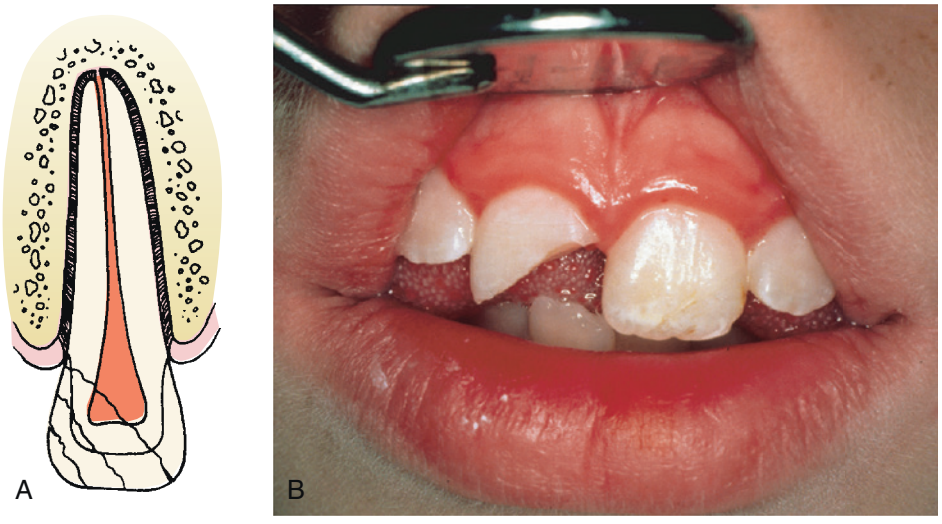


• **Fig. 24.9** Crown cracks or crazes. These injuries usually extend only into enamel.

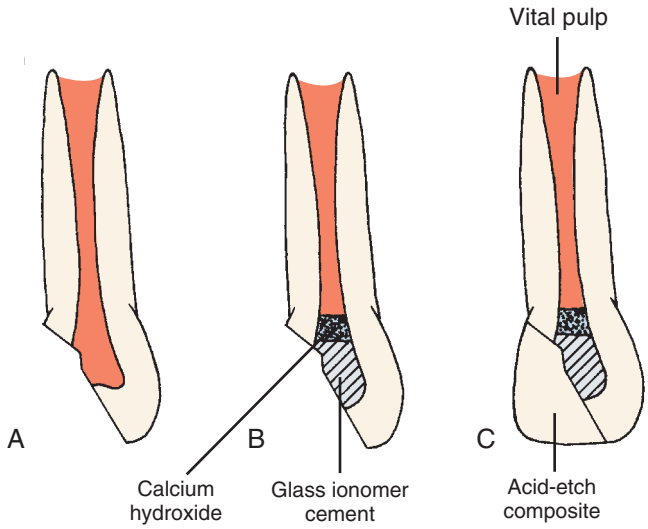
Crown-Root Fracture

The treatment of crown-root fractures depends on the location of the fracture and local anatomic variance. If the coronal fragment is still in place, it must be removed to assess the depth to which the fracture has gone. If the fracture does not descend too far apically (and the tooth is therefore restorable) and if the pulp has not been exposed, the tooth is treated as already discussed for crown fracture.

Depending on the apical extent of the fracture, it may be necessary to perform periodontal procedures to make the apical margin of the fracture accessible for restorative procedures. Alternatively, orthodontic extrusion of the root can make it accessible for restorative procedures. If the pulp is involved and the tooth is restorable, endodontic treatment is implemented. If, however, the tooth is not restorable, removal is indicated. If a concomitant



• **Fig. 24.10** (A) Coronal fractures involving enamel, dentin, and pulp. (B) A coronal fracture that involved enamel and dentin.



• **Fig. 24.11** Pulpotomy technique. (A) Apically immature tooth with coronal fracture involving pulp. (B) The coronal pulp is removed aseptically, after which calcium hydroxide solution is applied over exposed pulp. (C) Glass ionomer cement can then be used to fill the remainder of the coronal pulp chamber, and temporary or permanent (i.e., composite) filling is placed.

alveolar fracture is found, the extraction may be delayed for several weeks to permit the fracture to heal and thus prevent undue loss of alveolar bone at the time of extraction (Fig. 24.12).

Horizontal Root Fracture

When a horizontal or oblique fracture of the root occurs, the main factor in determining the prognosis, and therefore in directing treatment, is the position of the fracture in relation to the gingival crevice. If the fracture is above or close to the gingival crevice, the tooth should be removed or the coronal fragment should be removed and endodontic treatment performed on the root. The root can then be restored with a post and core restoration. Fractures in the middle to apical third of the root have a good prognosis for survival of the pulp and healing of the root fragments to one another. These fractures should be treated with repositioning (if any mobility is detectable) and firm immobilization for 2 to 3 months (these techniques are described later). During this time, bridging of the fracture with calcified tissue usually occurs, and the tooth remains vital (Fig. 24.13; see Fig. 24.6).

Sensitivity

No acute treatment is recommended for sensitivity (i.e., concussion) other than symptomatic relief, such as relieving the tooth from occlusal contact. This is easiest to perform by grinding the occlusal contacts from the opposing tooth. Follow-up examinations should be instituted to monitor periodontal and pulpal health.

Mobility

If the tooth is only mildly mobile, relieving the occlusal contact is effective treatment. Most mobile teeth stabilize (i.e., "tighten up") with time. If the tooth is extremely mobile, splinting it to adjacent teeth is recommended (described later). Periodic observation is then necessary.

Intrusion

Traumatic intrusion of teeth indicates that the alveolar socket has sustained a compression fracture to permit the new tooth position. On percussion, the tooth emits a metallic sound similar to that by an ankylosed tooth, distinguishing it from a partially erupted or unerupted tooth. The intrusion may be so severe that the tooth actually appears to be missing on clinical examination. Traumatic tooth intrusion is less frequent than lateral displacements; when seen, intrusion usually involves maxillary teeth. This type of nonavulsive tooth displacement has the worst prognosis (Fig. 24.14).

The treatment of intruded teeth is controversial. Some clinicians favor surgically repositioning and splinting these teeth; however, this treatment has resulted in serious periodontal and pulpal consequences. Others think that, if left alone, many intruded teeth will reerupt. Others use orthodontic forces to assist reeruption (Fig. 24.15).

When orthodontic-assisted eruption is used, the tooth should be extruded slowly, over a 3- to 4-week period. Once the tooth is in position within the dental arch, it is splinted for 2 to 3 months. Recent evidence suggests that immediate application of orthodontic force is necessary to prevent ankylosis in the intruded position.[8] The decision to perform endodontic treatment is based on the follow-up findings of each case.

However, if the intrusion occurred in an apically mature tooth, pulpal degeneration is likely and endodontic treatment should be performed as described later.

If a deciduous tooth has been intruded to the point that it is touching the follicle of a succedaneous tooth, the deciduous tooth should be removed as atraumatically as possible. If the deciduous tooth is not in direct proximity to the succedaneous tooth, a period of observation should follow because reeruption is common. If the dentist is in doubt about the position of a deciduous tooth, removal is a sound prophylactic approach that helps ensure the health of the succedaneous tooth.

Extrusion

An extruded tooth can usually be manually seated back into its socket if the injury was recent. After replacement of the tooth within the socket, splinting for 1 to 3 weeks is usually necessary, as is endodontic treatment (discussed later; Fig. 24.16; see also Fig. 24.13B).

Lateral Displacement

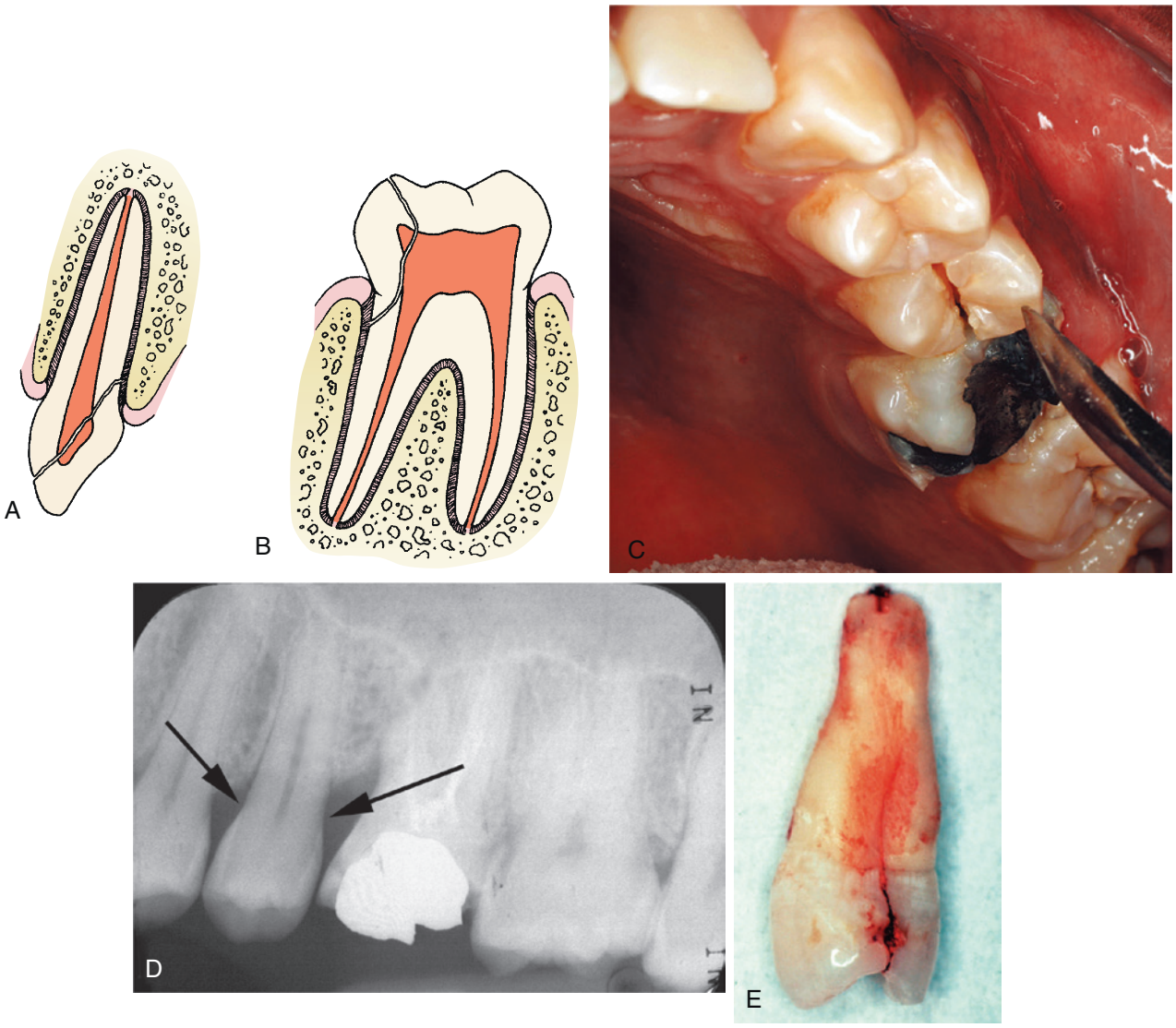
If a tooth is minimally displaced, the accompanying alveolar wall fractures may not be grossly displaced. In this case, manual repositioning of the tooth and splinting for several weeks is indicated. When substantial tooth displacement has occurred, displaced alveolar bone fractures have also been sustained (see Fig. 24.13C–D). Gingival lacerations frequently accompany this type of injury. The tooth and alveolar bone must be manually repositioned, the tooth splinted, and soft tissue sutured (Fig. 24.17).

Postsurgical follow-up examinations will determine the state of the pulp and periodontal damage.

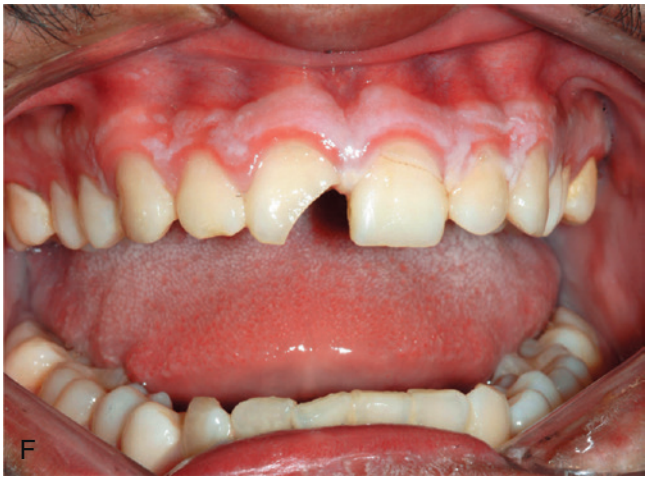
Avulsion

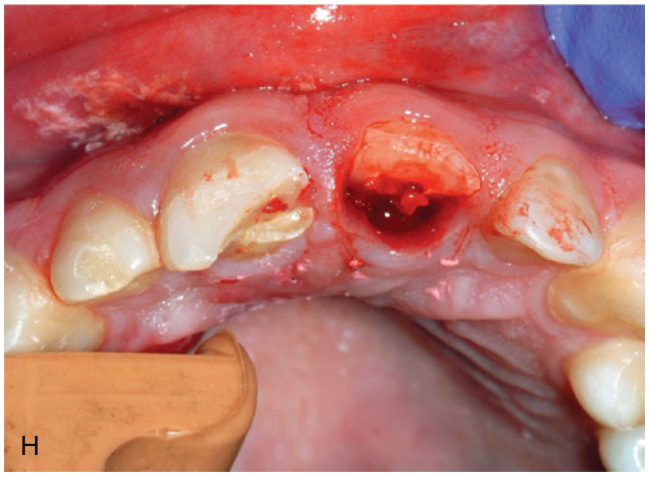
Total avulsion from its socket is the gravest situation for a tooth because the health of the pulp and periodontal tissues is in severe jeopardy. The factors most important for determining how successful treatment measures will be are the length of time the tooth has been out of the socket, the state of the tooth and periodontal tissues, and the manner in which the tooth was preserved before replantation. The sooner the tooth can be replanted, the better the prognosis.[2]

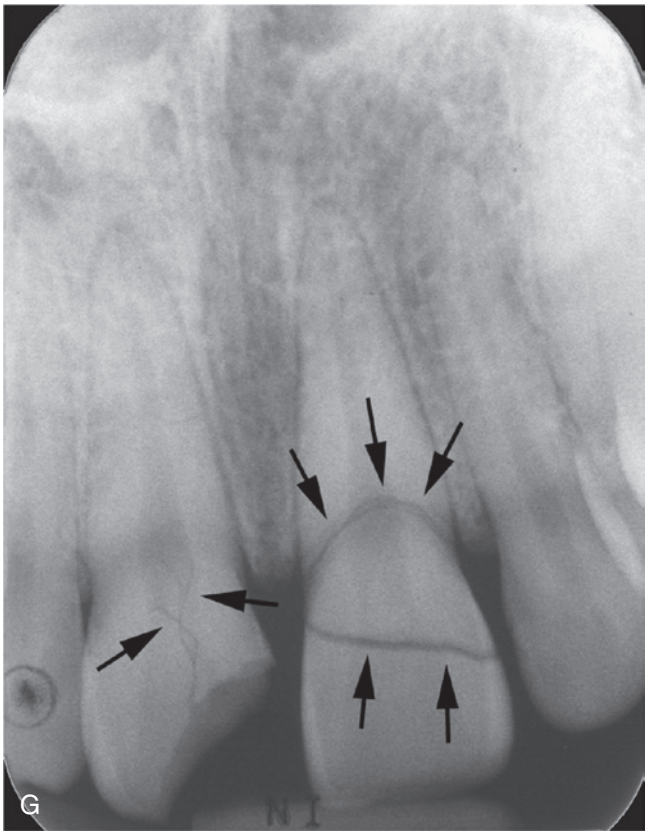
Therefore when the dentist receives a call from a patient, parent, teacher, or other responsible person regarding a totally avulsed



• **Fig. 24.12** Crown-root fractures. (A–B) Crown-root fractures in incisor and molar, respectively. The fractures extend below the alveolar crest of bone. (C) Clinical image of crown-root fracture in premolar. This tooth is commonly fractured in this manner, especially when a restoration extends across the occlusal surface (i.e., mesio-occluso-distal). (D) Radiograph of this premolar showing no obvious fracture because the fracture is in the mesiodistal direction. (E) Tooth after extraction showing the fracture extending apically. Crown-root fractures.

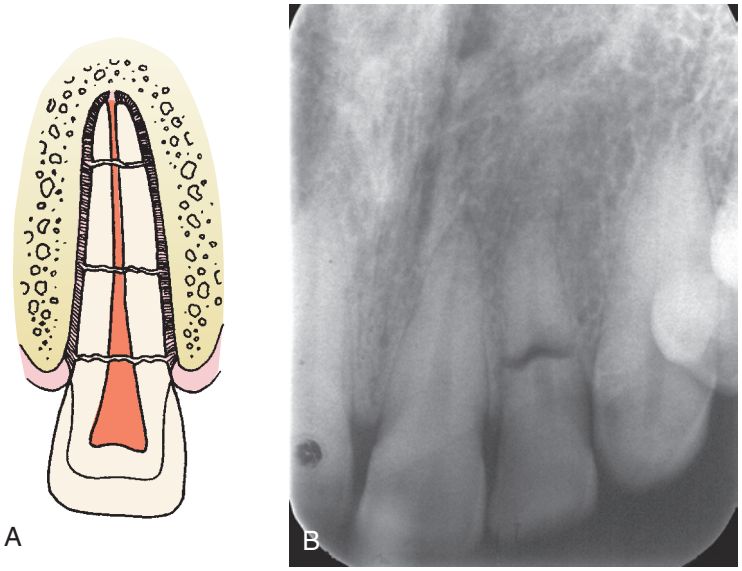




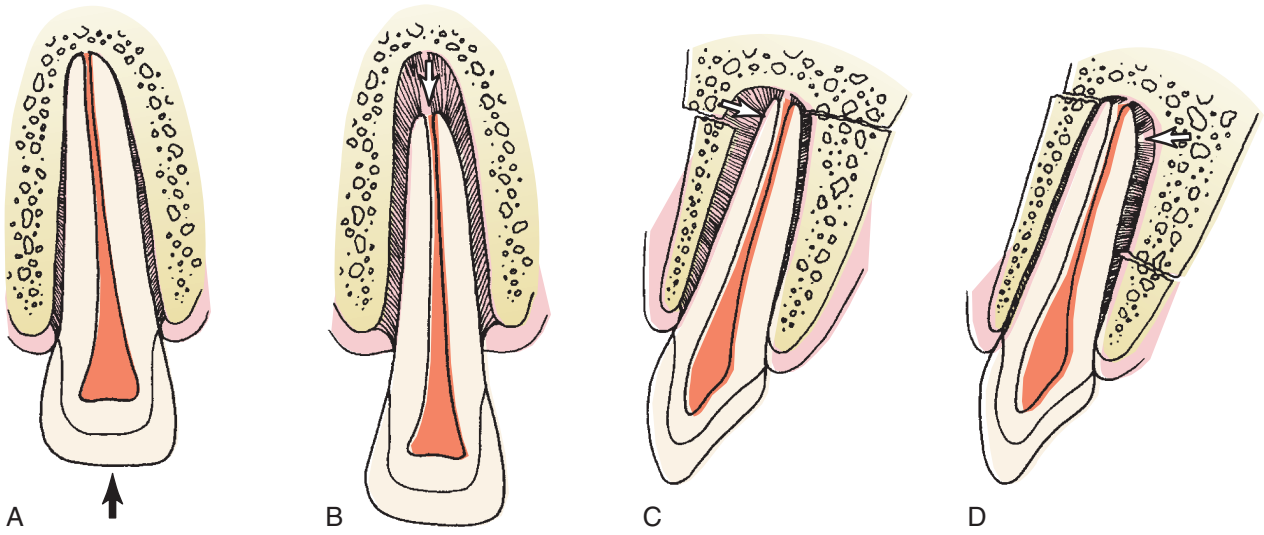


• **Fig. 24.12, cont'd** (F) Clinical image of two incisors with crown-root fractures. Tooth #8 appears to have only a fracture of the crown. (G) The radiograph shows fracture lines extending into the root. Similarly, the clinical examination does not reveal the depth of the fracture on tooth #9, but the radiograph shows it extending apical to the cementoenamel junction. (H) After the loose crown portion was removed, the fracture was found to involve the pulp and to extend well above the cementoenamel junction. Both teeth were removed and replaced with dental implants.

tooth, the dentist should direct the caller to rinse the tooth immediately with the patient's saliva, tap water, or saline solution and to replant the tooth. The patient should hold the tooth by the crown, while trying to not touch the root, and then hold the tooth in place and go immediately to the dentist. If the patient cannot replace the tooth, it should be placed into an appropriate medium until care can be delivered by a dentist. Many storage mediums have been recommended, including water, the vestibule of the mouth, physiologic saline, milk, and cell culture media in specialized containers. Water is the least desirable because it is hypotonic and causes cell lysis. Saliva keeps the tooth moist but is not ideal because of incompatible osmolality and pH and the presence of bacteria. The most ideal storage medium is Hanks balanced salt solution, which can be purchased as part of a commercial tooth-preserving system (Save-A-Tooth, Phoenix-Lazerus Inc.). Many schools, sporting venues, and ambulances have these kits on hand for use in cases of tooth avulsion. If this solution is not available, milk is considered the best alternative storage medium because it is readily available at or near an accident site, it has a pH and osmolarity compatible with vital cells, and it is relatively



• **Fig. 24.13** (A) Horizontal root fractures at apical, middle, and coronal levels of root *(top, middle,* and *bottom,* respectively). (B) Radiograph of a horizontal root fracture at the junction of the coronal and middle thirds. This tooth was extremely mobile, so it was removed and replaced with an immediate dental implant. Fig. 24.6B shows a radiograph of a horizontal root fracture at the junction of the apical and middle thirds. This tooth had slight mobility but was stabilized, and it healed.

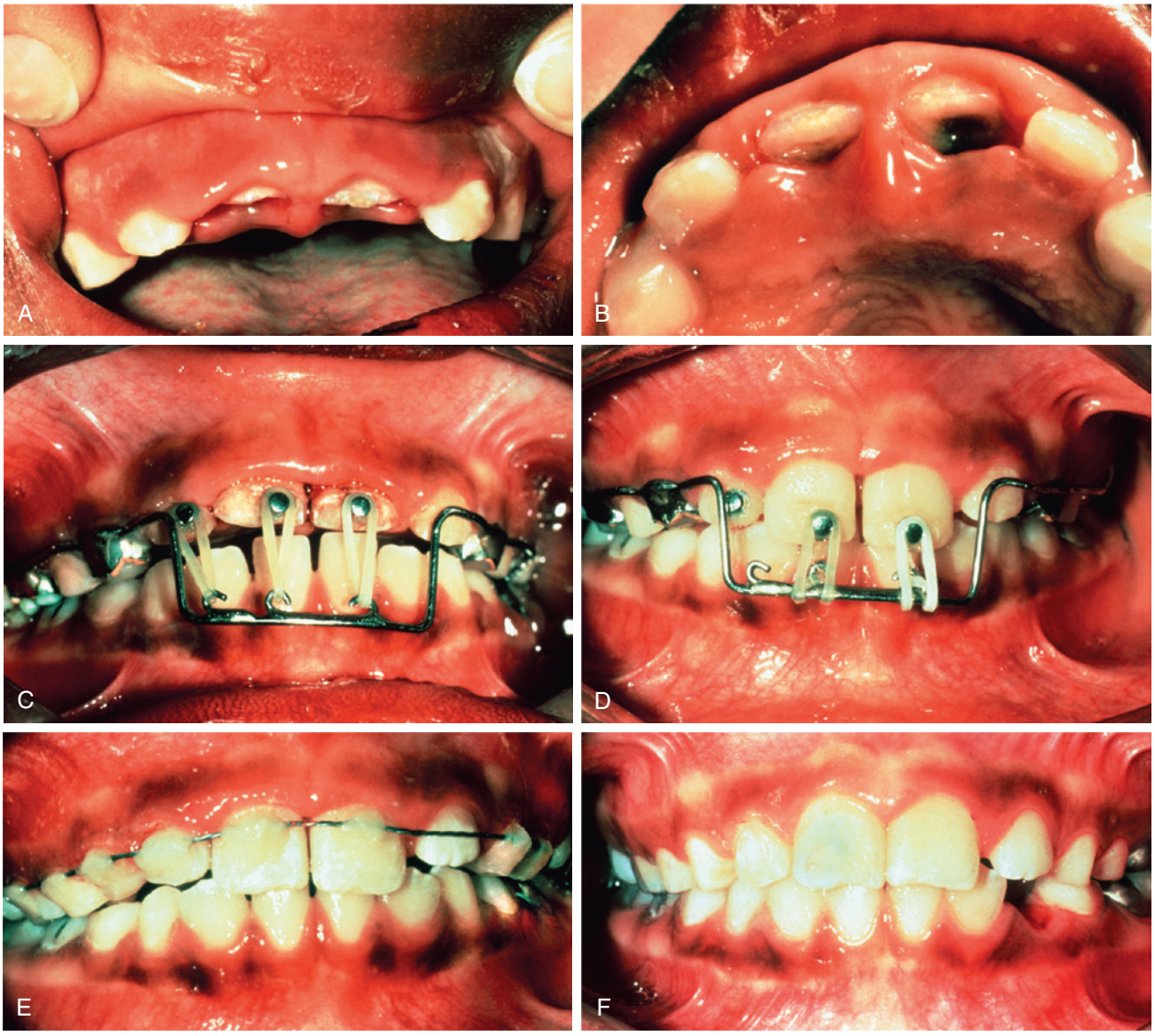


• **Fig. 24.14** Tooth displacement. (A) Intruded tooth. The absence of periodontal ligament space along apex is demonstrated. (B) Tooth displaced from its socket in coronal direction (i.e., extruded). (C–D) Displacement of incisor tooth crown buccally and lingually, respectively. Associated alveolar wall fractures, which are frequently present, are visualized.

free of bacteria. Milk has been shown effectively to maintain the vitality of periodontal ligament cells.[9]

When the patient gets to the dentist's office, the dentist must decide whether the tooth is salvageable. If the tooth has already been replanted and seems to be in good position, it should be radiographed and then splinted for 7 to 10 days. If the tooth is carried into the office and it has been out of its socket less than 20 minutes, it should be immediately rinsed in saline and replanted by the dentist. Removal of all of the blood clot from within the socket is not necessary; however, careful suctioning and gentle irrigation with sterile saline will remove the bulk of the clot. The root surface and tooth socket should never be scraped, "sterilized," or manipulated before replantation, because this destroys viable periodontal tissue.

If the tooth has been out of the socket for more than 20 minutes, it should not be replanted until after it has been placed into Hanks balanced salt solution for 30 minutes and then in doxycycline (1 mg/20 mL saline) for 5 minutes. The tooth should then be replanted and splinted. Soaking the tooth in Hanks solution seems to reduce the incidence of ankylosis by improving the survival of periodontal cells on the root. The solution also helps cleanse debris from the root and dilutes bacteria. The doxycycline helps inhibit bacteria in the pulpal lumen, which reduces a major obstacle to revascularization. Even teeth that



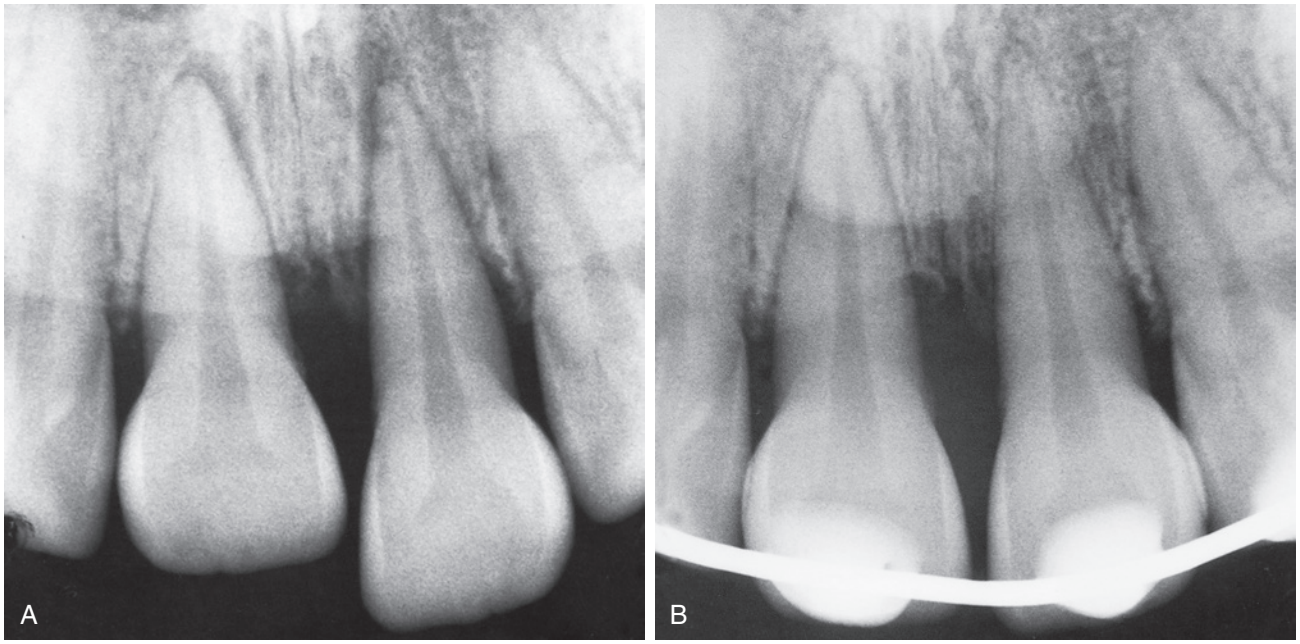
• **Fig. 24.15** Treatment of intruded maxillary incisors with immature apices. (A–B) Buccal and palatal views of intruded maxillary incisor teeth. (C) Orthodontic traction instituted to extrude teeth a few weeks after traumatic episode. (D) Appearance after 6 weeks of traction. (E) Stabilization of teeth after orthodontic-guided reeruption with acid-etch technique for 11 weeks. (F) Appearance after 1 year. This patient had calcium hydroxide pulpectomies and apexification during period of orthodontic extrusion and subsequently had root canals. (From Spalding PM, Fields HW Jr, Torney D, et al. The changing role of endodontics and orthodontics in the management of traumatically intruded permanent incisors. *Pediatr Dent.* 1985;7:104.)

were stored in milk or saline should undergo this regimen before replantation.

Stabilization of an avulsed tooth can be achieved using a variety of materials such as wires, arch bars, and splints. However, several factors must be considered: The stabilizing device should be as hygienic as possible and should be positioned away from the gingiva and tooth roots, if possible. During the healing response, inflammation must be kept to a minimum or inflammatory root resorption will be favored, which is one of the drawbacks to interdental wiring and cold-cured acrylic splints. Patients have difficulty cleansing teeth that are covered with wires or splints. Furthermore, wire can slip apically around the cervical aspect and damage cementum. The stabilization applied to the tooth need not be absolutely rigid,

TABLE 24.1 Stabilization Periods for Dentoalveolar Injuries

Injury	Duration of Immobilization
Mobile tooth	7–10 days
Tooth displacement	2–3 weeks
Root fracture	2–4 months
Replanted tooth (mature)	7–10 days
Replanted tooth (immature)	3–4 weeks



• **Fig. 24.16** Radiographs of extruded tooth before (A) and after (B) repositioning and stabilization with acid-etch composite technique.

because this may predispose to ankylosis and external root resorption. Physiologic movements of the tooth are thought by some to promote fibrous (i.e., desired) attachment instead of osseous (i.e., tending toward ankylosis) attachment of the root to alveolar bone. The stabilization device should also be easy to apply and remove with readily available instruments.

A technique that serves admirably for the stabilization of avulsed teeth is the use of an acid-etched composite system (Fig. 24.18; see also Fig. 24.17). A wire of moderate stiffness but that still has some flexibility (e.g., braided orthodontic wire) is adapted to the facial surfaces of one or two teeth on each side of the avulsed tooth. More physiologic movement can be imparted to the replanted tooth during function if fewer teeth are required to stabilize the avulsed tooth. If braided orthodontic wire is unavailable, any wire—even a paper clip—will suffice. The facial surfaces of the avulsed and the adjacent teeth are acid etched, and the wire is cemented to them with composite. This technique makes cleansing teeth easy because the wire is away from the gingiva. The wire can be readily removed, and most dentists have the necessary supplies and instrumentation available for its use.

The duration of stabilization (Table 24.1) should be as short a time as necessary for the tooth to become reattached, usually 7 to 10 days. Studies have shown that the more rigid and the longer the stabilization, the better would be the root resorption.[1,10]

On removal of the stabilization device, the tooth will still be mobile. Therefore it is important that the stabilization device be removed with great care and that the patient be instructed to avoid this region during mastication. If, however, the apical foramen is wide open, pulp may survive and revascularize. To promote this possibility, the tooth is usually stabilized for 3 to 4 weeks instead of the shorter time for apically mature teeth.

Patients who have no recollection of a tetanus booster within the past 5 to 10 years should be referred to their general physician for one. The use of antibiotics (e.g., penicillin) for 7 to 10 days is appropriate.

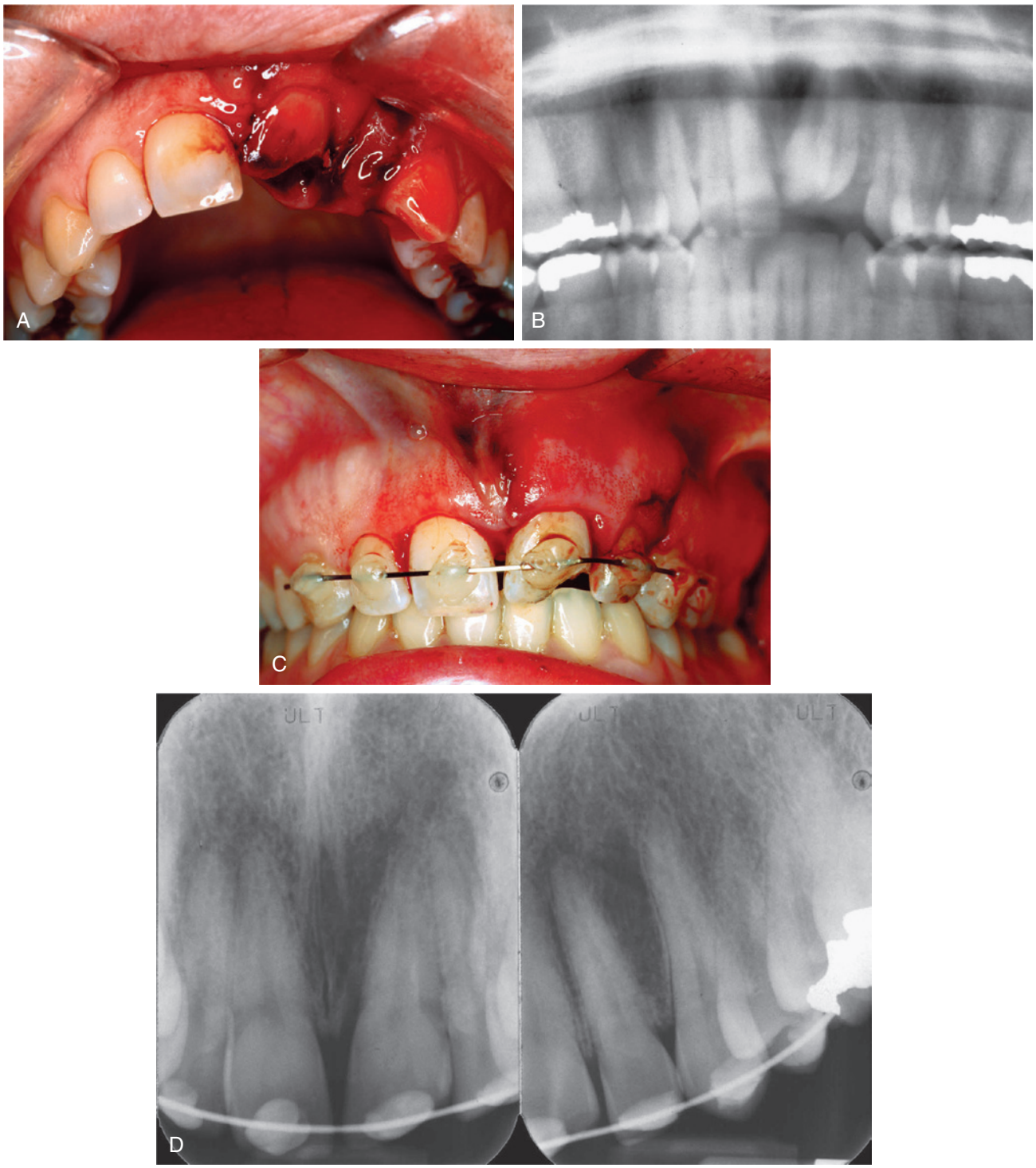
The patient should be told that several outcomes are possible after replantation. The best result to be expected is a relatively normal, functional tooth that in most instances will require endodontic therapy (described later). However, varying amounts of root resorption and ankylosis may occur. The development of these signs determines the prognosis of the tooth. Although acute dental infection is rare, it can lead to loss of the replanted tooth. These patients must be followed carefully at regular and frequent intervals for some time after replantation. Andreasen and Hjorting-Hansen list the following five factors to be considered before replanting avulsed teeth[3]:

1. The avulsed tooth should have no advanced periodontal disease.
2. The alveolar socket should be reasonably intact to provide a seat for the avulsed tooth.
3. No orthodontic contraindications such as significant crowding of teeth should exist.
4. The extraalveolar period should be considered; periods exceeding 2 hours are usually associated with poor results. If the tooth is replanted within the first 30 minutes, excellent results can be expected.
5. The stage of root development should be evaluated. Survival of the pulp is possible in teeth with incomplete root formation if replantation is accomplished within 2 hours after injury.

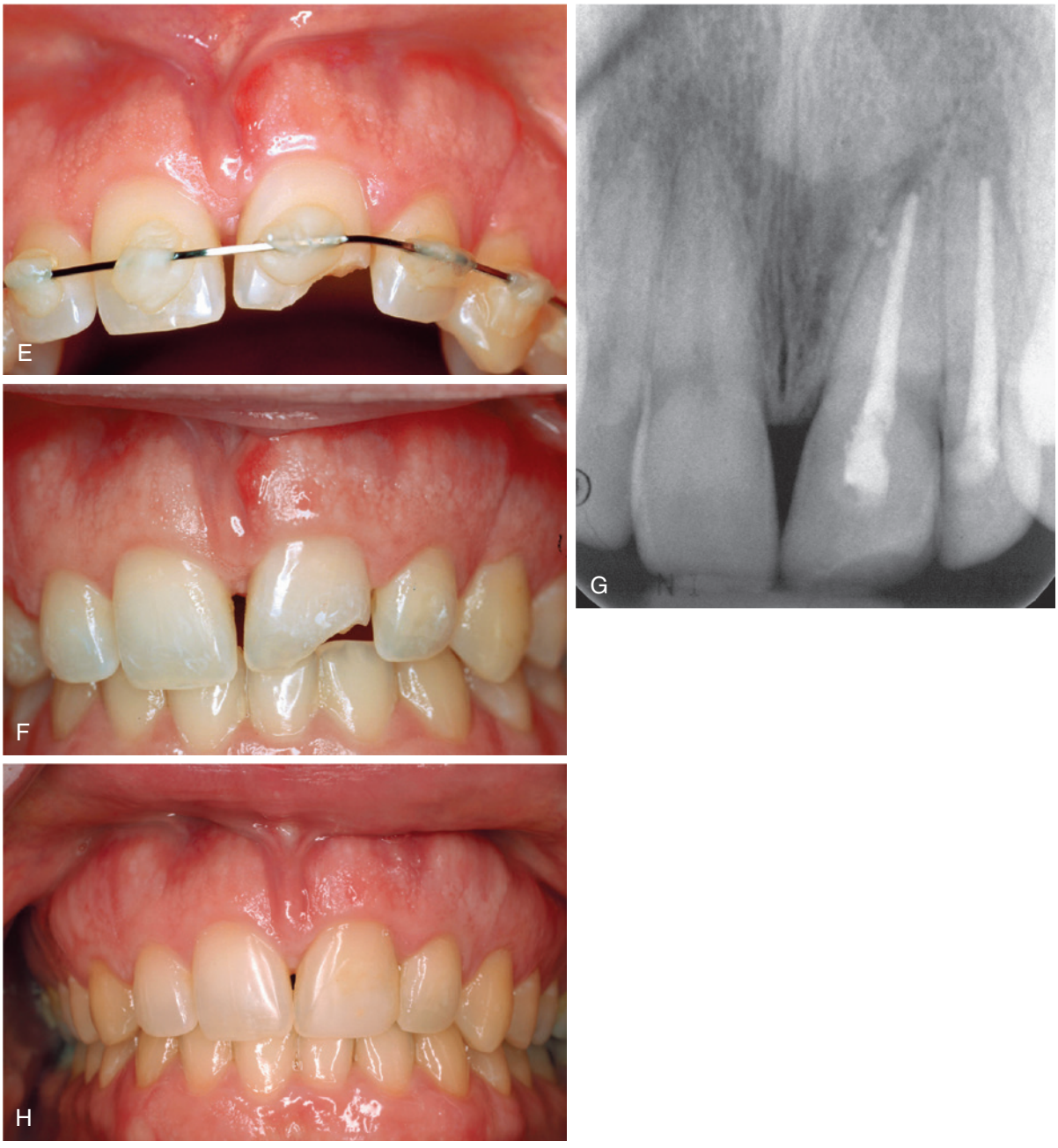
If the tooth to be replanted is not favorable for replantation, as determined by these factors, the patient should be made aware that the prognosis will be worse. The alternatives to replantation must be considered in cases where the factors involved are unfavorable, for example, teeth with existing periodontal disease, large restorations, alveolar disruption, and long extraalveolar duration. Today, the use of dental implants can offer patients who suffered tooth avulsion an option that was not available in the past. In hopeless cases, one might elect to defer tooth replantation for placement of a dental implant once the alveolus has healed.

Alveolar Fractures

Small fractures through the alveolar process, as mentioned previously, frequently accompany injuries to teeth. However, injuries to the alveolar process often occur independently and can be challenging



• **Fig. 24.17** Treatment of lingually displaced central and lateral incisors in apically mature tooth. (A) Appearance on presentation. (B) Radiograph showing position of the teeth and the lack of root fracture(s). (C) Position of teeth after digital reduction and stabilization with an arch wire bonded to the teeth with composite resin. (D) Immediate postreduction radiograph showing teeth replaced into their sockets. Treatment of lingually displaced central and lateral incisors in apically mature tooth.



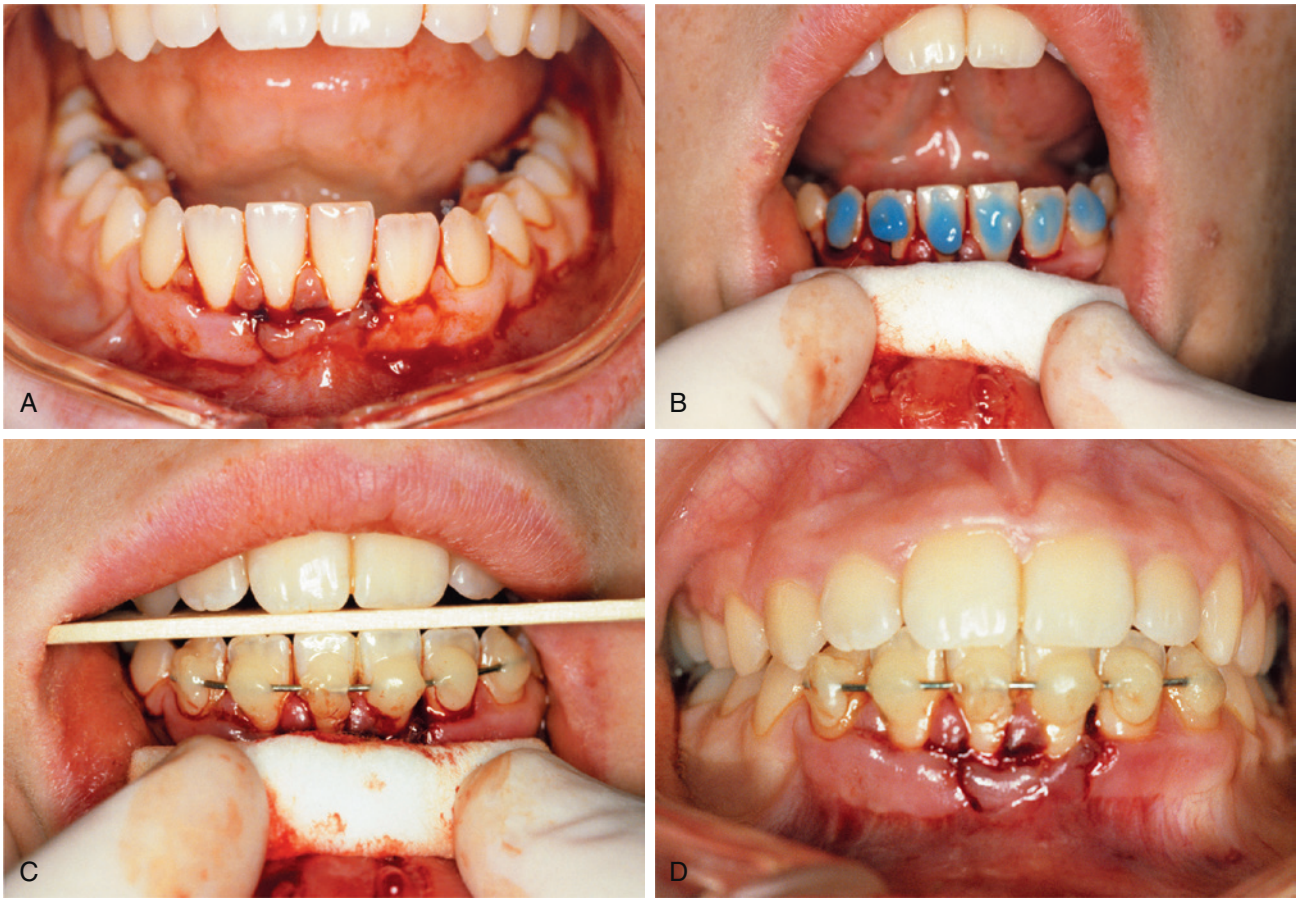
• **Fig. 24.17, cont'd** (E) Clinical appearance at 3 weeks just before the arch wire was removed. (F) Clinical appearance 1 week after arch wire was removed. (G) The patient was sent for endodontic therapy. (H) Composite was used to reconstruct the missing portion of the crown of tooth #9.

to manage. In most instances, the segment of bone contains at least one tooth but more frequently several teeth.

Concomitant injuries such as crown fractures, root fractures, and soft tissue injuries may have occurred. These injuries may best be managed by referral to an oral-maxillofacial surgeon because management may involve open surgical treatment to reposition the bony segments.

The treatment of this type of injury, as for any fracture, is first to place the segment into its proper position and then to stabilize it until osseous healing occurs. This procedure may be simply performed with digital pressure applied after an appropriate anesthetic is administered (Fig. 24.19). Frequently, however, splintering of the dento-osseous segment margins makes repositioning difficult, and open surgical treatment might then be required.

Teeth with root apices that are denuded within a dentoalveolar fracture should undergo endodontic treatment within 1 to 2 weeks to help prevent inflammatory root resorption and infection. The dento-osseous segment must be stabilized for approximately 4 weeks to allow osseous healing. Several acceptable methods can be used to stabilize the segment. The simplest is to ligate an arch bar to the teeth both mesial and distal to the segment and within the fractured alveolar segment. Teeth immediately adjacent to the fracture are frequently not wired to the arch bar, so these teeth are more amenable to oral hygienic measures. Not wiring them also helps prevent their loosening from the forces placed by the



• **Fig. 24.18** Technique of acid-etch composite stabilization of displaced teeth. (A) Lower incisor teeth displaced lingually. (B) After digital repositioning, acid is applied to facial surfaces of displaced incisors and one or two teeth on each side after isolation and drying. (C) Composite material and wire applied. (D) Occlusion checked during and after stabilization.

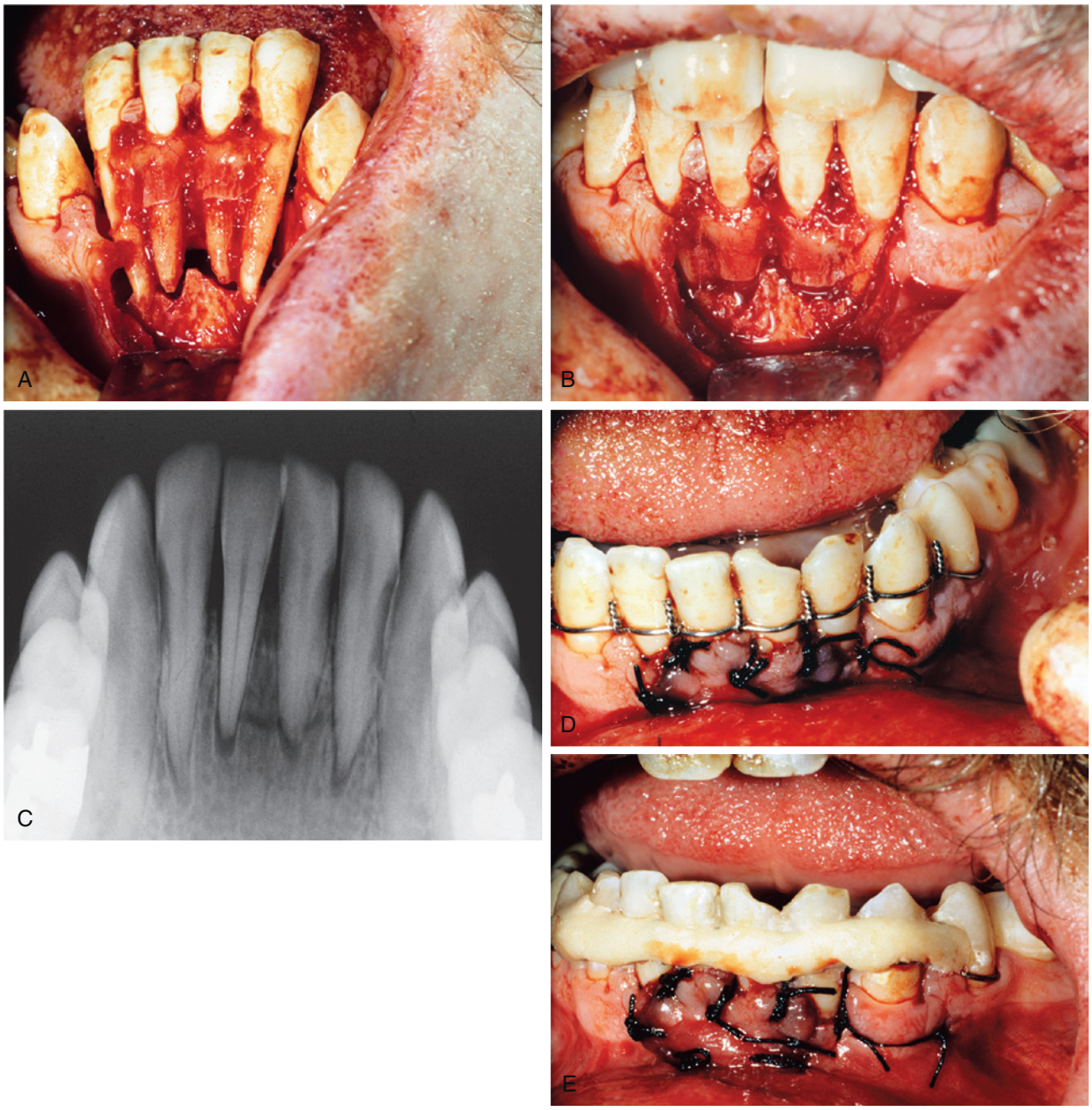
wire. The use of an acid-etched arch wire, as just described, is also acceptable. A cold-cured acrylic splint can be made in situ or on casts obtained by taking an impression immediately after repositioning the alveolar segment. The splint can be wired to adjacent teeth and to teeth within the fractured segment.

Treatment of Pulp

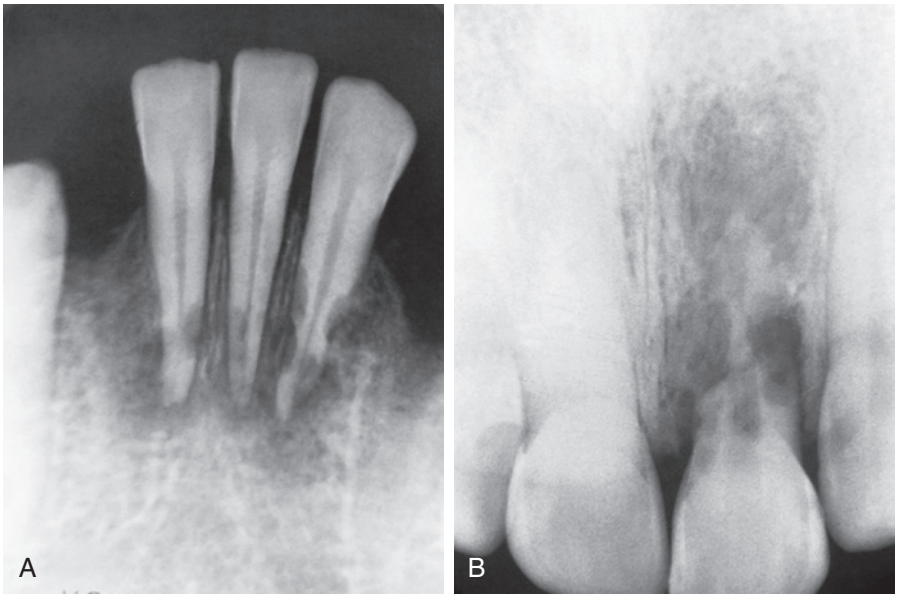
The dental pulp may be damaged during any of the tooth injuries just described, as a result of direct exposure, the inflammatory response of near exposure, concussive effects, or disruption of the nutrient artery of the pulp. In any injury to the tooth, the possibility for pulpal degeneration is real, and early detection is imperative. If a pulp degenerates, an inflammatory response occurs and leads to tooth resorption and ankylosis (Fig. 24.20). Therefore, for all injuries described, the status of the pulp must be ascertained. Because it is difficult to establish the health status of the pulp immediately after injury, the dentist must assume that if the apex of a mature tooth has moved more than 1 mm in any direction, pulpal degeneration will occur.

Root canal treatment should not be performed at the time of tooth repositioning or replantation because the extra time necessary to perform this treatment is not warranted and exposes the tooth to more chance of external damage. However, in all teeth with closed apical foramina, endodontic treatment should be instituted after approximately 2 weeks. This treatment helps minimize inflammatory root resorption by eliminating nonvital tissue from the pulp. A standard biomechanical preparation of the root canal system is then performed. However, instead of filling the root canal with gutta-percha, the clinician treats the canal in a manner similar to an apexification technique—that is, a 1:1 mixture of calcium hydroxide and barium sulfate is placed within the canal for 6 to 12 months. The barium sulfate allows radiographic evaluation of the amount of calcium hydroxide present because it slowly dissipates within the root canal after placement. Periodic radiographic evaluations should be performed, and the calcium hydroxide should be replaced every 3 months if noted to be absent from the root canal system. A conventional root canal can be performed when successive radiographs indicate no further root resorption. This regimen should be used instead of placing a permanent endodontic filling soon after biomechanical preparation because it appears to minimize inflammatory root resorption.

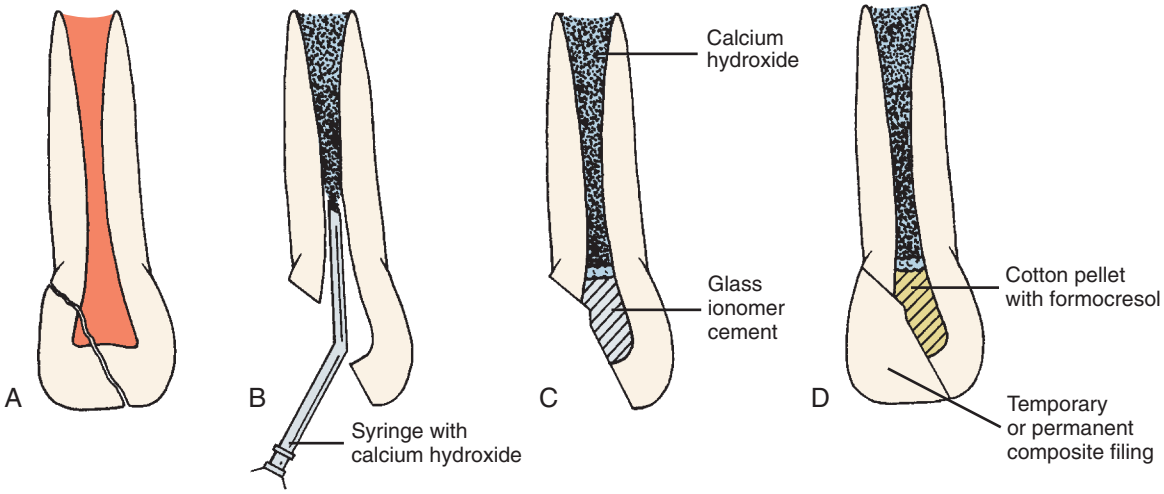
In teeth with apical foramina that are wide open, endodontic treatment may be delayed for several weeks while careful follow-up examinations, including pulp vitality tests, determine its necessity. When the apices are open, it is likely that revascularization of the root canal system will occur. If root canal therapy appears necessary, apexification procedures with the use of calcium hydroxide can be used before filling of the root canal system with a permanent filling material. The technique of apexification is illustrated in Fig. 24.21.



• **Fig. 24.19** Treatment of dentoalveolar fracture. (A) Clinical appearance of fracture involving four mandibular incisors. These teeth are apically mature and have minimal bone around lateral and apical areas. (B) Clinical appearance after digital reduction of fracture. The occlusal relationship is verified before stabilization of these teeth. (C) Radiographic appearance of teeth after digital reduction. (D) Appearance after application of Essig wire and suturing of mucosa. (E) Cold-curing acrylic added for rigidity. (Note: Bonding an arch wire to the teeth with the acid-etch composite technique demonstrated in Fig. 24.18 would be preferable.) Because of maturity of apices, root canal treatment should be performed on these teeth in 1 to 2 weeks after trauma. (B, Courtesy Dr. Stephen Feinberg, University of Michigan, Ann Arbor, MI.)



• **Fig. 24.20** Two cases of inflammatory root resorption that occurred several months after dentoalveolar trauma without root canal treatment.



• **Fig. 24.21** Apexification procedure. (A) Coronal fracture involving pulp of apically immature tooth. (B) Removal of entire pulp and filling with calcium hydroxide solution. Calcium hydroxide can be injected from the syringe or spun in with a spiral on rotating instrument. (C) A cotton pledget (with or without formocresol) is then placed, after which coronal pulp chamber is filled with glass ionomer cement. (D) Temporary or permanent composite filling is then placed. Calcium hydroxide solution may require replacing every 3 months until apex is closed.

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25

Management of Facial Fractures

MARK W. OCHS, MYRON R. TUCKER, AND RICHARD E. BAUER

CHAPTER OUTLINE

Trauma to the facial region frequently results in injuries to soft tissue, teeth, and major skeletal components of the face, including the mandible, maxilla, zygoma, naso-orbital-ethmoid (NOE) complex, and supraorbital structures. In addition, these injuries frequently occur in combination with injuries to other areas of the body.[1] Participation in the treatment and rehabilitation of the patient with facial trauma involves a thorough understanding of the types of, principles of, evaluation for, and surgical treatment of facial injuries. This chapter outlines the fundamental principles for treatment of the patient with facial trauma.

Evaluation of Patients With Facial Trauma

Immediate Assessment

Before completing a detailed history and physical evaluation of the facial area, critical injuries that may be life threatening must be addressed. The first step in evaluating a trauma patient is to assess the patient's cardiopulmonary stability by ensuring that the patient has a patent airway and that the lungs are adequately ventilated. Vital signs, including respiratory and pulse rates and blood pressure, should be taken and recorded. During this initial assessment (i.e., primary survey), other potentially life-threatening problems such as excessive bleeding should also be addressed. Immediate measures such as pressure dressings, packing, and clamping of briskly bleeding vessels should be accomplished as quickly as possible. An assessment of the patient's neurologic status and an evaluation of the cervical spine should be completed next. Forces severe enough to cause fractures of the facial skeleton are often transmitted to the cervical spine. The neck should be temporarily immobilized until neck injuries have been ruled out. Careful palpation of the neck to assess possible areas of tenderness and a cervical spine radiographic series should be completed as soon as possible.

Treatment of head and neck injuries generally should be deferred until a thorough evaluation, assessment, and stabilization of the patient has been accomplished. However, some initial treatment is often necessary to stabilize the patient. Management of the patient's airway is of vital importance. Frequently, fractures of the facial bones severely compromise the patient's ability to maintain the airway, particularly when the patient is unconscious or completely supine. Severe mandible fractures, especially bilateral or comminuted fractures, could cause posterior displacement of the mandible and the tongue, which results in obstruction of the upper airway (Fig. 25.1).

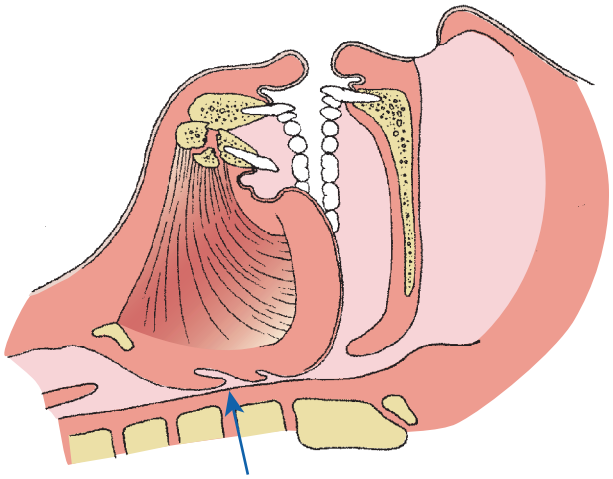
Simply grasping, repositioning, and stabilizing the mandible into a more anterior position may alleviate this obstruction. Placement of a nasopharyngeal or an oropharyngeal airway may also be sufficient to temporarily maintain a patent airway. In some cases, endotracheal intubation may be necessary. Any prosthetic devices, avulsed teeth, pieces of completely avulsed bone, or other debris may also contribute to airway occlusion and must be removed immediately. Any areas of bleeding should be quickly examined and managed with packing, pressure dressings, or clamping. All excess saliva and blood must be suctioned from the pharynx to avoid aspiration and laryngospasm.

Injuries to the facial region may involve not only bones of the face but also soft tissue such as the tongue or upper neck areas, or they may be associated with injuries such as a fractured larynx.[2] In some cases, an emergency tracheostomy may be necessary to provide an adequate airway. In trauma patients who have complete upper airway obstruction, a cricothyrotomy is the most rapid way to access the trachea (Fig. 25.2).

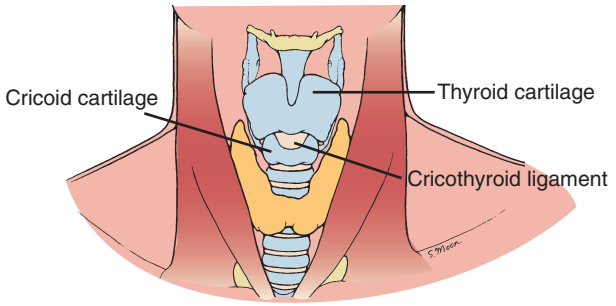
History and Physical Examination

After the patient has been initially stabilized, as complete a history as possible should be obtained. This history should be obtained from the patient; however, because of loss of consciousness or impaired neurologic status, information must often be obtained from witnesses or accompanying family members. Five important questions should be considered:

1. How did the accident occur?
2. When did the accident occur?
3. What are the specifics of the injury, including the type of object contacted, the direction from which contact was made, and similar logistic considerations?



• **Fig. 25.1** Posterior displacement of tongue and occlusion of upper airway resulting from bilateral mandibular fractures.



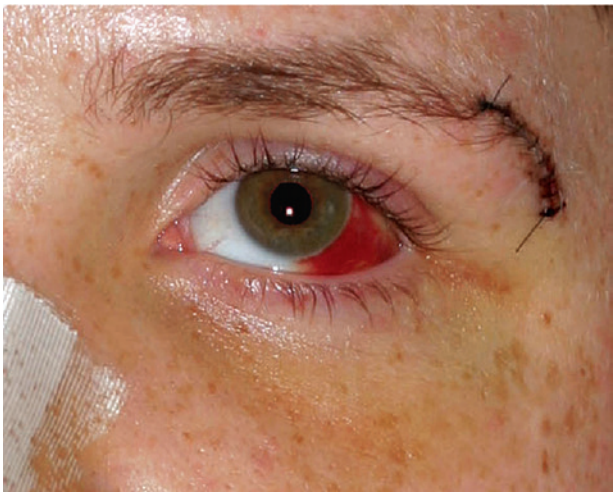
• **Fig. 25.2** Tracheostomy and cricothyrotomy sites with landmarks for emergency surgical airway access.

4. Did loss of consciousness occur?
5. What symptoms are now being experienced by the patient, including pain, altered sensation, visual changes, and malocclusion?

A complete review of systems, including information about allergies, medications, and previous tetanus immunization, medical conditions, and prior surgeries should be obtained.

Physical evaluation of the facial structures should be completed only after an overall physical assessment that addresses cardiopulmonary and neurologic functions and other areas of potential trauma, including the chest, abdomen, and pelvic areas. Because patients with multiple severe injuries frequently require evaluation and treatment by several specialists, trauma teams have become standard in the emergency departments of major hospitals. These teams usually include general surgeons and specialists in cardiothoracic surgery, vascular surgery, orthopedic surgery, neurosurgery, and anesthesiology; these specialists are on call to provide immediate attention to emergency department patients. Other trauma team specialists include oral-maxillofacial surgeons, ophthalmologists, otolaryngologists, plastic surgeons, and urologists. The combined efforts of these specialists are frequently required to assess and treat the patient's injuries properly.

Evaluation of the facial area should be performed in an organized and sequential fashion. The face and cranium should be carefully inspected for evidence of trauma, including lacerations, abrasions, contusions, areas of edema or hematoma formation, and possible contour defects. Areas of ecchymosis should be carefully evaluated.



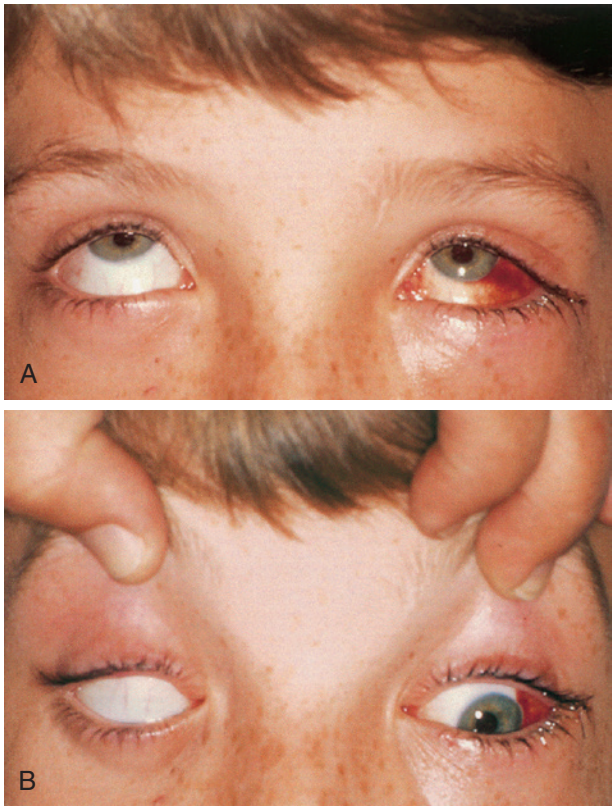
• **Fig. 25.3** Periorbital ecchymosis and lateral subconjunctival hemorrhage associated with zygomatic complex fracture.

Periorbital ecchymosis, especially with subconjunctival hemorrhage, is often indicative of orbital rim or zygomatic complex fractures (Fig. 25.3). Bruises behind the ear, or the Battle sign, suggest a basilar skull fracture. Ecchymosis in the floor of the mouth usually indicates an anterior mandibular fracture.

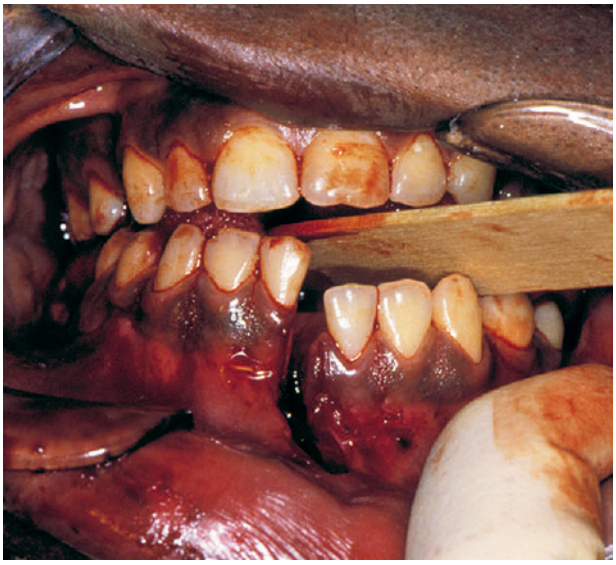
A neurologic examination of the face should include careful evaluation of all cranial nerves. Vision, extraocular movements, and pupillary reaction to light should be carefully evaluated. Visual acuity or pupillary changes may suggest intracranial (cranial nerve [CN] II or III dysfunction) or direct orbital trauma. Uneven pupils (anisocoria) in a lethargic patient suggest an intracranial bleed (subdural or epidural hematoma or intraparenchymal bleed) or injury. An asymmetric or irregular (not round) pupil is most likely caused by a globe (eyeball) perforation. Abnormalities of ocular movements may also indicate central neurologic problems (CN III, IV, or VI) or mechanical restriction of the movements of the eye muscles resulting from fractures of the orbital complex (Fig. 25.4). Motor function of the facial muscles (CN VII) and muscles of mastication (CN V) and sensation over the facial area (CN V) should be evaluated. Any lacerations should be carefully cleaned and evaluated for possible transection of major nerves or ducts, such as the facial nerve or the Stensen duct.

The mandible should be carefully evaluated by extraorally palpating all areas of the inferior and lateral borders and the temporomandibular joint, paying particular attention to areas of point tenderness. The occlusion should be examined, and step deformities along the occlusal plane and lacerations of gingival areas should be assessed (Fig. 25.5). Bimanual palpation of the suspected fracture area should be performed by placing firm pressure over the mandible posterior and anterior to the fracture area in an attempt to manipulate and elicit mobility in this area. The occlusion should be reexamined after this maneuver. Mobility of the teeth in the area of a possible fracture should also be noted.

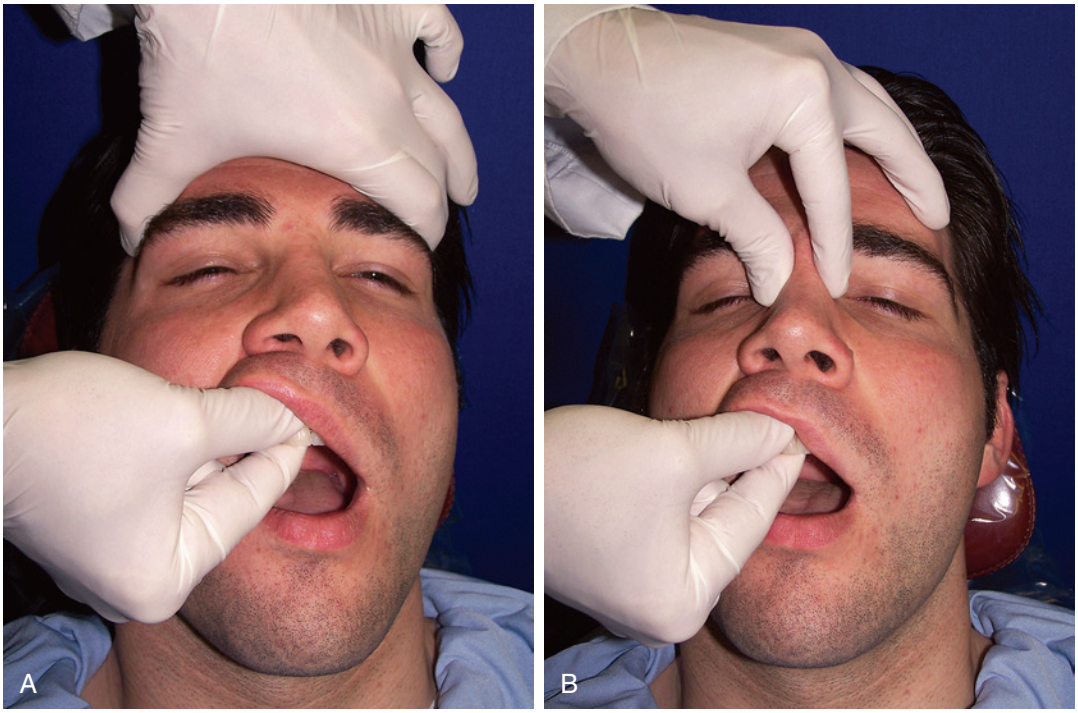
The evaluation of the midface begins with an assessment of the mobility of the maxilla as an isolated structure or in combination with the zygoma or nasal bones. To assess maxillary mobility, the patient's head should be stabilized by using pressure over the forehead with one hand. With the thumb and forefinger of the other hand, the maxilla is grasped; firm pressure should be used to elicit maxillary mobility (Fig. 25.6).



• **Fig. 25.4** (A) A 14-year-old patient with a left orbital floor fracture in upward gaze. (B) Entrapment of inferior rectus muscle is the result of impingement in area of linear orbital floor fracture. In the down gaze, the patient is unable to rotate the left eye inferiorly, whereas the right eye is fully rotated inferiorly.



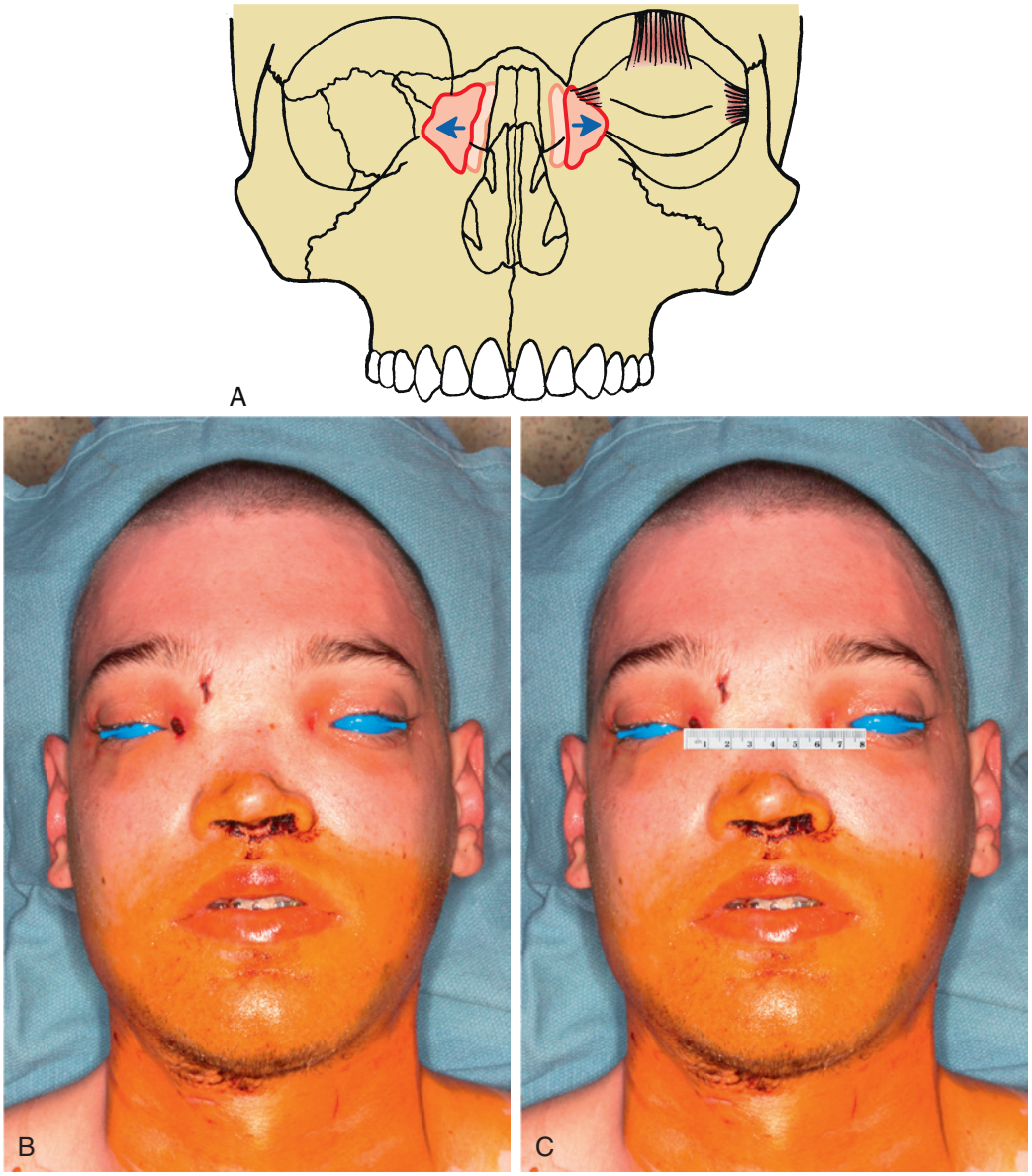
• **Fig. 25.5** Irregularity of plane of occlusion and laceration in gingiva and mucosa between the mandibular central incisors, indicating a likelihood of mandibular fracture in this area.



• **Fig. 25.6** Examination of maxilla for mobility. (A) Firm pressure on the forehead is used to stabilize the patient's head. Pressure is placed on the maxilla in an attempt to elicit mobility. (B) A stabilizing hand can also evaluate mobility in the area of nasal bones.

The upper facial and midfacial regions should be palpated for step deformities in the forehead, orbital rim, or nasal or zygoma areas. Firm digital pressure over these areas is used to carefully evaluate the bony contours and may be difficult when these areas are grossly edematous. In checking for a zygomatic complex or arch fracture, an index finger can be inserted in the maxillary vestibule adjacent to the molars while palpating and applying pressure superolaterally. Bony crepitus (the ability to feel the vibration as fractured bone edges are rubbed against one another) or extreme tenderness warrants a further workup. An evaluation of the nose and paranasal structures includes measurement of the intercanthal distance between the innermost portions of the left and right medial canthus. Frequently, NOE injuries cause spreading of the nasal bones and displacement of the medial canthal ligaments, resulting in traumatic telecanthus (widening of the medial intercanthal distance; Fig. 25.7). Normally the medial intercanthal distance should equal the alar base width. The nose should also be evaluated for symmetry. The bony anatomy of the nose should be evaluated by palpation. A nasal speculum is used to visualize the internal aspects of the nose to locate excessive bleeding or hematoma formation, particularly in the area of the nasal septum.

Intraoral inspection should include an evaluation of areas of mucosal laceration or ecchymosis in the buccal vestibule or along the palate and an examination of the occlusion and areas of loose or missing teeth. These areas should be assessed before, during, and after manual manipulation of the mandible and the midface. Unilateral occlusal prematurity with a contralateral open bite should raise suspicion for some type of jaw fracture.



• **Fig. 25.7** Injury to naso-orbital-ethmoid complex, which resulted in the displacement of medial canthal ligaments and a widening of the intercanthal distance (i.e., traumatic telecanthus). (A) Diagram of bony fractures and medial canthal ligament displacement. (B) Clinical image of traumatic telecanthus. (C) Clinical image of traumatic telecanthus with ruler to demonstrate widening in millimeters.

Radiographic Evaluation

After a careful clinical assessment of the facial area, radiographs should be taken to provide additional information about facial injuries.[3] In cases of severe facial trauma, cervical spine injuries should be ruled out with a complete cervical spine series (i.e., cross-table, odontoid, and oblique views) before any manipulation of the neck. The facial radiographic examination should depend, to some degree, on clinical findings and the suspected injury. Haphazard or excessive radiographic examination is generally not warranted. In the patient with facial trauma, the purpose of radiographs should be to confirm the suspected clinical diagnosis, obtain information that may not be clear from the clinical examination, and more accurately determine the extent of the injury. Radiographic examination should also document fractures from different angles or perspectives.

Radiographic evaluation of the mandible can require two or more of the following four radiographic views: (1) panoramic view, (2) open-mouth Towne view, (3) posteroanterior view, and (4) lateral oblique views (Fig. 25.8). Occasionally even these radiographs do not provide adequate information; therefore, supplemental radiographs, including occlusal or periapical views, may be helpful.[3] Computed tomography (CT) scans, axial views without intravenous contrast medium, may provide information not obtainable from plain radiographs or when cervical spine precautions or other injuries do not permit standard facial films. CT scanning is used to rule out neurologic injury in many patients with facial trauma, and this scan can also be used to supplement the radiographic evaluation. More commonly, these CT images are being obtained as the primary radiographic analysis for patients with facial fractures, therefore eliminating the plain film analysis altogether. In addition, the widespread availability of cone-beam CT in the outpatient setting has allowed for three-dimensional analysis at relatively low radiation doses, therefore replacing multiple plain film analysis.

Evaluation of midface fractures historically has been supplemented with standard radiographic views, including Waters view, lateral skull view, posteroanterior skull view, and submental vertex view (Fig. 25.9). However, because of the difficulty of interpreting plain radiographs of the midface, more sophisticated techniques are currently used. CT is the most commonly used radiographic technique for the evaluation of midface trauma. The ability to evaluate fractures in several planes of space and to visualize the entire skull, midface, and mandible with three-dimensional reconstruction provides invaluable information for diagnosing and treating complex facial trauma (Fig. 25.10).[4]

Cause and Classification of Facial Fractures

Causes of Facial Fractures

The major causes of facial fractures include motor vehicle accidents and physical altercations. Other causes of injuries include falls, sports-related incidents, and work-related accidents.[5,6] Facial fractures resulting from motor vehicle accidents are far more frequent in persons who were not wearing restraints at the time of the accident.

Mandibular Fractures

Depending on the type of injury and the direction and force of the trauma, fractures of the mandible commonly occur in several locations. One classification of fractures describes mandibular fractures by anatomic location. Fractures are designated as occurring in the condylar, ramus, angle, body, symphyseal, alveolar, and, rarely, coronoid process areas. Fig. 25.11 illustrates the location and frequency of different types of mandibular fractures.[7]

Another system of classification of mandibular fractures categorizes the type of fracture as greenstick, simple, comminuted, and compound fractures (Fig. 25.12). These categories describe the condition of the bone fragments at the fracture site and possible communication with the external environment. *Greenstick fractures* are those involving incomplete fractures with flexible bone. Greenstick fractures generally exhibit minimal mobility when palpated and the fracture is incomplete. A *simple fracture* is a complete transection of the bone with minimal fragmentation at the fracture site. In a *comminuted fracture*, the fractured bone is left in multiple segments. Gunshot wounds, penetrating objects, and other high-impact injuries to the jaws frequently result in comminuted fractures. A *compound fracture* results in communication of the margin of the fractured bone with the external environment. In maxillofacial fractures, communication with the oral or external environment may result from mucosal tears, perforation through the gingival sulcus and periodontal ligament, communication with sinus linings, and lacerations in the overlying skin. By definition, any jaw fracture within a tooth-bearing segment is an open or compound fracture.

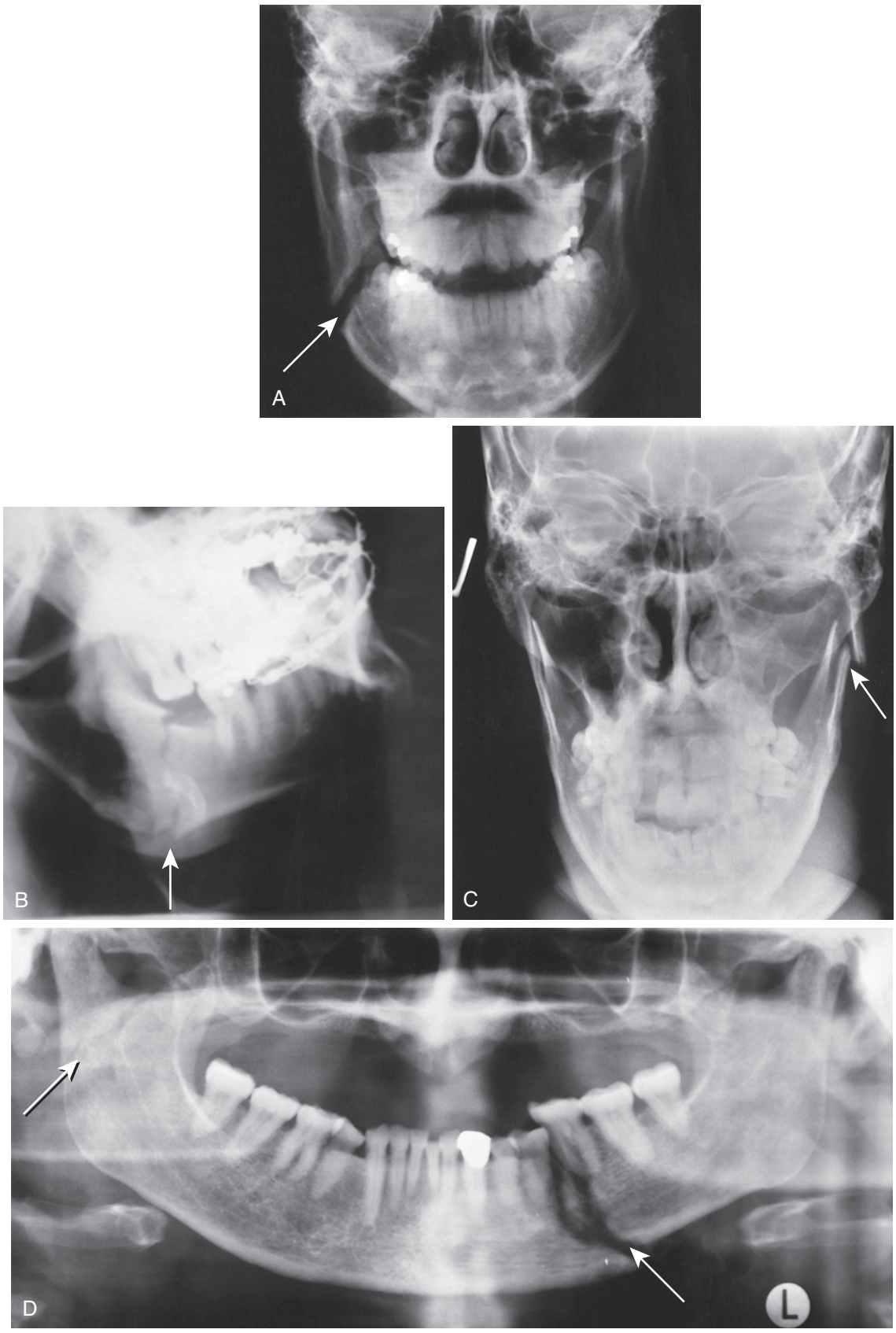
Fractures of the mandible could be *favorable* or *unfavorable*, depending on the angulation of the fracture and the force of the muscle pull proximal and distal to the fracture. In a favorable fracture, the fracture line and the muscle pull resist displacement of the fracture (Fig. 25.13). In an unfavorable fracture, the muscle pull results in displacement of the fractured segments.

Midface Fractures

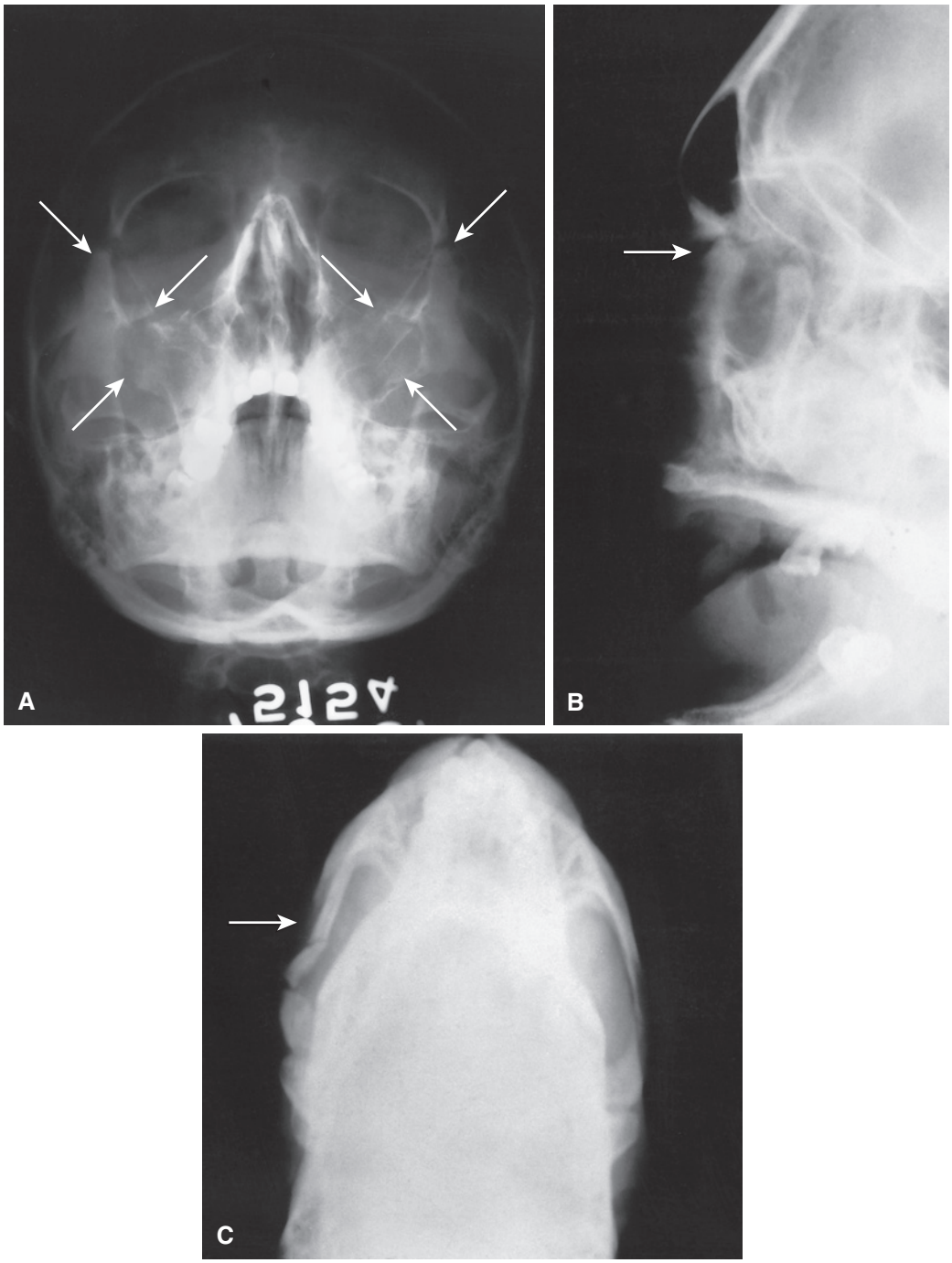
Midfacial fractures include fractures affecting the maxilla, the zygoma, and the NOE complex. Midfacial fractures can be classified as Le Fort I, II, or III fractures, zygomaticomaxillary complex fractures, zygomatic arch fractures, or NOE fractures. These injuries may be isolated or occur in combination.[8]

The Le Fort I fracture frequently results from the application of horizontal force to the maxilla, which fractures the maxilla through the maxillary sinus and along the floor of the nose. The fracture separates the maxilla from the pterygoid plates and nasal and zygomatic structures (Fig. 25.14A). This type of trauma may separate the maxilla in one piece from other structures, split the palate, or fragment the maxilla. Forces that are applied in a more superior direction frequently result in Le Fort II fractures, which is the separation of the maxilla and the attached nasal complex from the orbital and zygomatic structures (see Fig. 25.14B). A Le Fort III fracture results when horizontal forces are applied at a level superior enough to separate the NOE complex, the zygomas, and the maxilla from the cranial base, which results in a *craniofacial separation* (see Fig. 25.14C). Invariably, midfacial fractures are hybrids or combinations of the previously mentioned injuries.

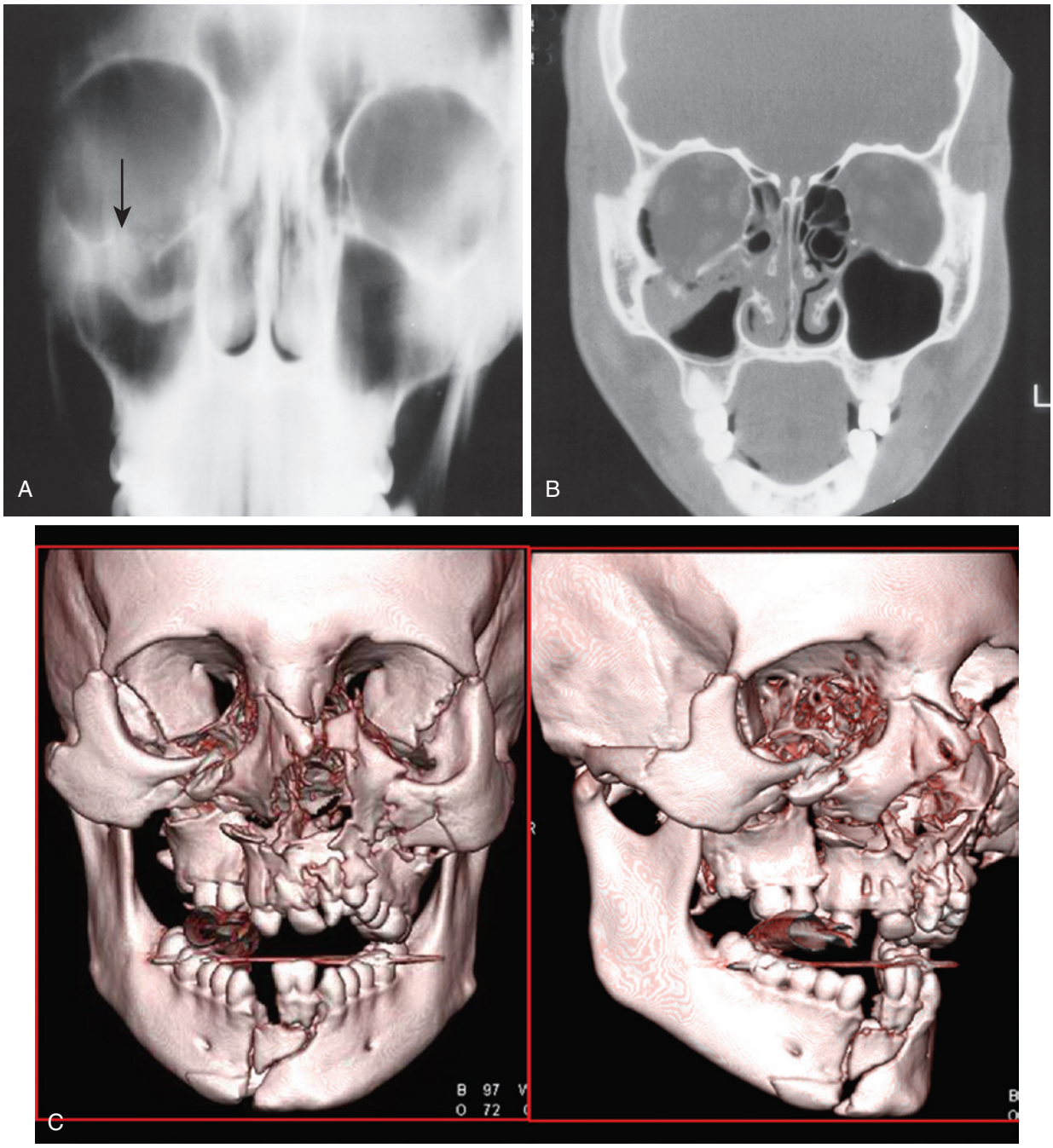
The most common type of midfacial fracture treated in the operating room setting is the zygomatic complex fracture (Fig. 25.15A). This type of fracture results when an object such as a fist or a baseball strikes the lateral aspect of the cheek. Similar trauma can also result in isolated fractures of the nasal bones, the orbital rim, or the orbital floor areas. Blunt trauma to the eye can result in compression of the globe and subsequent blow-out facture of



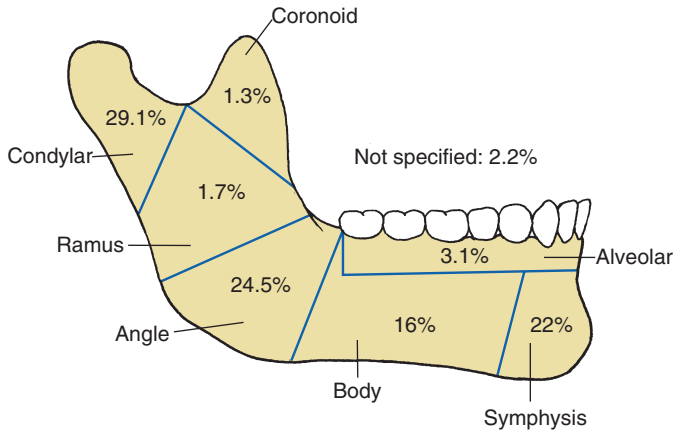
• **Fig. 25.8** (A) The posteroanterior view demonstrates a fracture in the angle area of the mandible *(arrow)*. (B) The lateral oblique view shows a fracture in the angle area *(arrow)*. (C) The Towne view shows a displacement of condylar fracture *(arrow)*. (D) The panoramic view shows a displaced fracture of the left mandibular body and a right subcondylar fracture *(arrows)*.



• **Fig. 25.9** (A) The Waters view shows fractures of orbital rim areas *(arrows)*. (B) The lateral skull view illustrates a Le Fort III fracture or craniofacial separation. The fracture line *(arrow)* separates the midface from the cranium. (C) The submental vertex demonstrates a zygomatic arch fracture *(arrow)*.



• **Fig. 25.10** (A) The tomographic view demonstrates a disruption of orbital floor *(arrow)*. (B) Computed tomography scan showing disruptions of the medial wall and floor of the right orbit. (C) Three-dimensional reconstruction of patient with multiple facial fractures. (C, Courtesy Dr. R. Bryan Bell.)



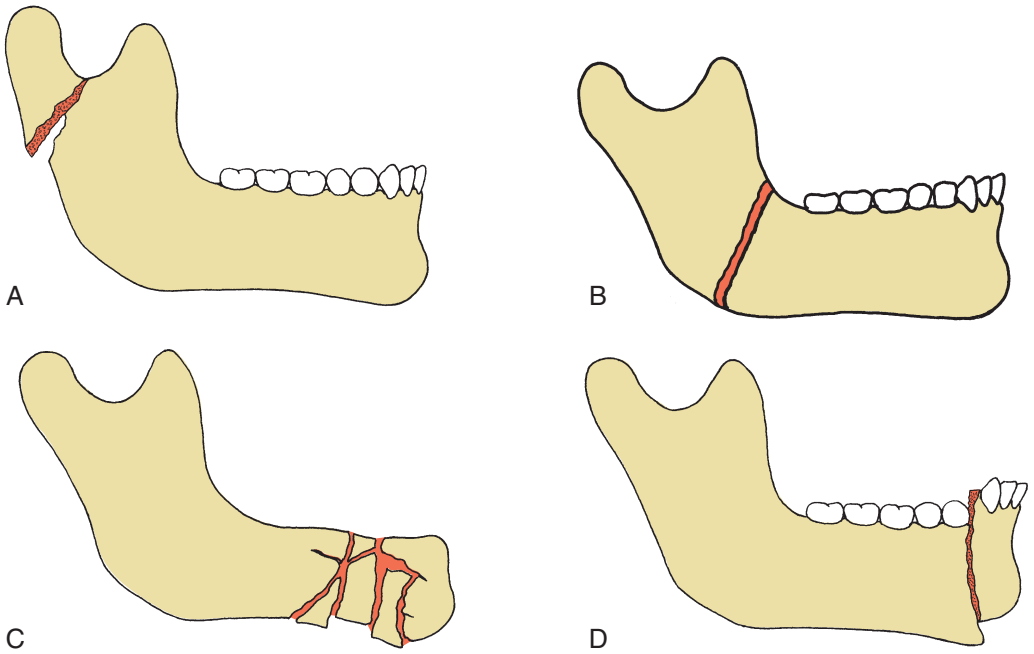
• **Fig. 25.11** Anatomic distribution of mandibular fractures. (Data from Olson RA, Fonseca RJ, Zeitler DL, Osbon DB. Fractures of the mandible: a review of 580 cases. *J Oral Maxillofac Surg.* 1982;40:23.)

the orbital floor (Fig. 25.16). The zygomatic arch may also be affected, alone or in combination with other injuries (see Fig. 25.15B–C).

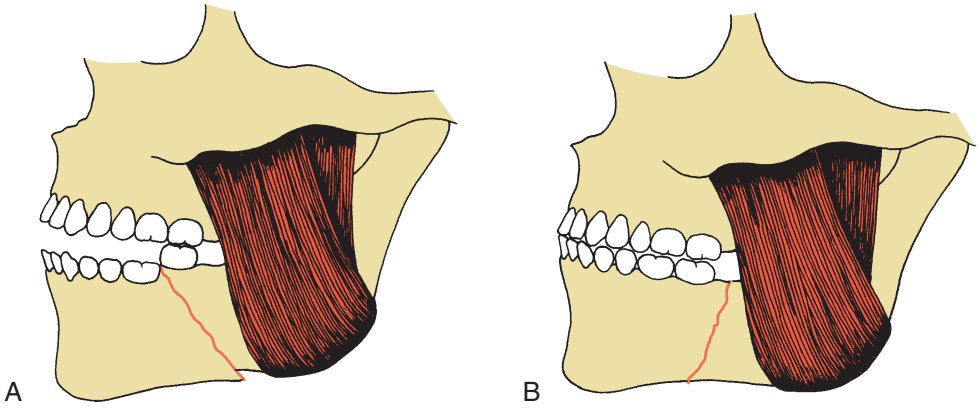
Treatment of Facial Fractures

Whenever facial structures are injured, treatment must be directed toward maximal rehabilitation of the patient. For facial fractures, treatment goals include rapid bone healing; return of normal ocular, masticatory, and nasal functions; restoration of speech; and an acceptable facial and dental esthetic result. During the treatment and healing phases, it is also important to minimize the adverse effect on the patient's nutritional status and achieve treatment goals with the least amount of discomfort and inconvenience possible.

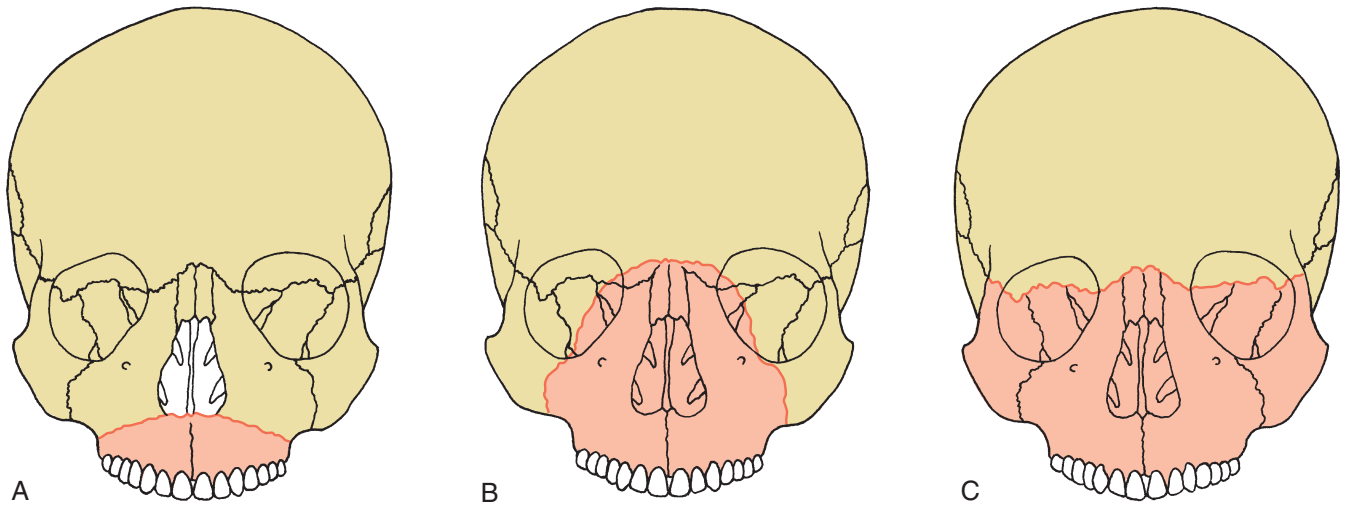
To achieve these goals, the following basic surgical principles should serve as a guide for treatment of facial fractures: reduction



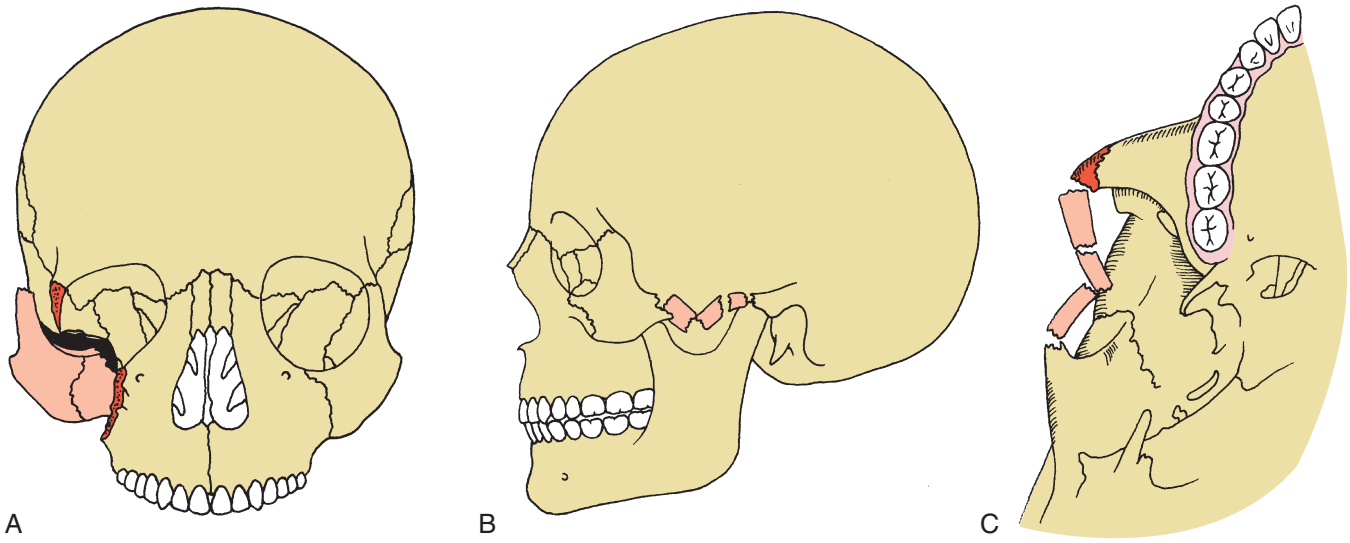
• **Fig. 25.12** Types of mandible fractures classified according to extent of injury in area of fracture site. (A) Greenstick. (B) Simple. (C) Comminuted. (D) Compound. Bone would be exposed through the mucosa near teeth.



• **Fig. 25.13** Favorable and unfavorable fractures of mandible. (A) Unfavorable fractures resulting in displacement at fracture site caused by pull of masseter muscle. (B) Favorable fracture in which direction of fracture and angulation of muscle pull resists displacement.



• **Fig. 25.14** Le Fort midfacial fractures. (A) Le Fort I fracture separating inferior portion of maxilla in horizontal fashion, extending from piriform aperture of nose to pterygoid maxillary suture area. (B) Le Fort II fracture involving separation of maxilla and nasal complex from cranial base, zygomatic orbital rim area, and pterygoid maxillary suture area. (C) Le Fort III fracture (i.e., craniofacial separation), which is a complete separation of midface at level of naso-orbital-ethmoid complex and zygomaticofrontal suture area. The fracture also extends through orbits bilaterally.



• **Fig. 25.15** (A) Zygomatic complex fracture. (B) Lateral view. Isolated zygomatic arch fracture. (C) Submental vertex view showing zygomatic arch fracture in different view. (A and C, Modified from Kruger E, Schilli W. *Oral and Maxillofacial Traumatology*, Vol 2. Chicago: Quintessence; 1986.)

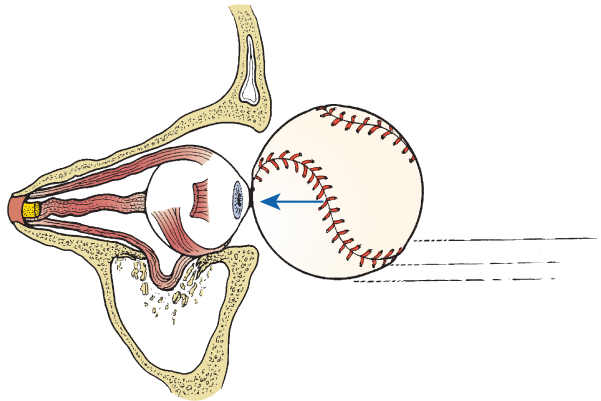
of the fracture (i.e., restoration of the bony segments to their proper anatomic location) and fixation of the bony segments to immobilize segments at the fracture site. In addition, the preoperative occlusion must be restored, and any infection in the area of the fracture must be eradicated or prevented.

The timing of treatment of facial fractures depends on many factors. In general, it is always better to treat an injury as soon as possible. Evidence shows that the longer open or compound wounds are left untreated, the greater the incidence of infection and malunion. In addition, a delay of several days or weeks makes an ideal anatomic reduction of the fracture difficult, if not impossible. In addition, edema progressively worsens over 2 to 3 days after an injury and frequently makes the treatment of a fracture more difficult.

However, treatment of facial fractures is often delayed for several reasons. In many cases, patients have other injuries that demand more immediate treatment. An injury such as severe neurologic trauma that precludes presurgical stabilization of the patient and increases anesthetic and surgical risks should obviously be managed before facial fractures. In some cases, a delay of 1 or 2 days results in the presence of tissue edema that makes a further wait of 3 to 4 days necessary for elimination of the edema and easier fracture treatment. Although treatments of maxillary and mandibular fractures frequently have many aspects in common, these types of

fractures are addressed separately in this chapter. Traditionally, the plan for treatment of most facial fractures was to begin with reduction of mandibular fractures and work superiorly through the midface. The rationale was that the mandible could be most easily stabilized, and the occlusion and remainder of the facial skeleton could be set to the reduced mandible. However, with the advent of and improvement in rigid fixation (plate and screw) techniques, facial fracture treatment may begin in the area where fractures can be most easily stabilized and progress to the most unstable fracture areas.

In approaching facial fractures, the surgeon attempts to rebuild the face on the basis of the concept that certain bony structures within the face provide the primary support in the vertical and anteroposterior directions. Three buttresses exist bilaterally that form the primary vertical supports of the face: (1) the nasomaxillary, (2) the zygomatic, and (3) the pterygomaxillary buttresses (Fig. 25.17).[9] The structures that support the facial projection in an anteroposterior direction include the frontal bar, zygomatic arch and zygoma complex, maxillary alveolus and palate, and the basal segment of the mandible.[10] Regardless of the type of facial fracture or the surgical approach used, the initial procedure should be to place the teeth in the proper occlusion and then appropriately reduce the bony fractures. Bony repair should also precede soft tissue repair.

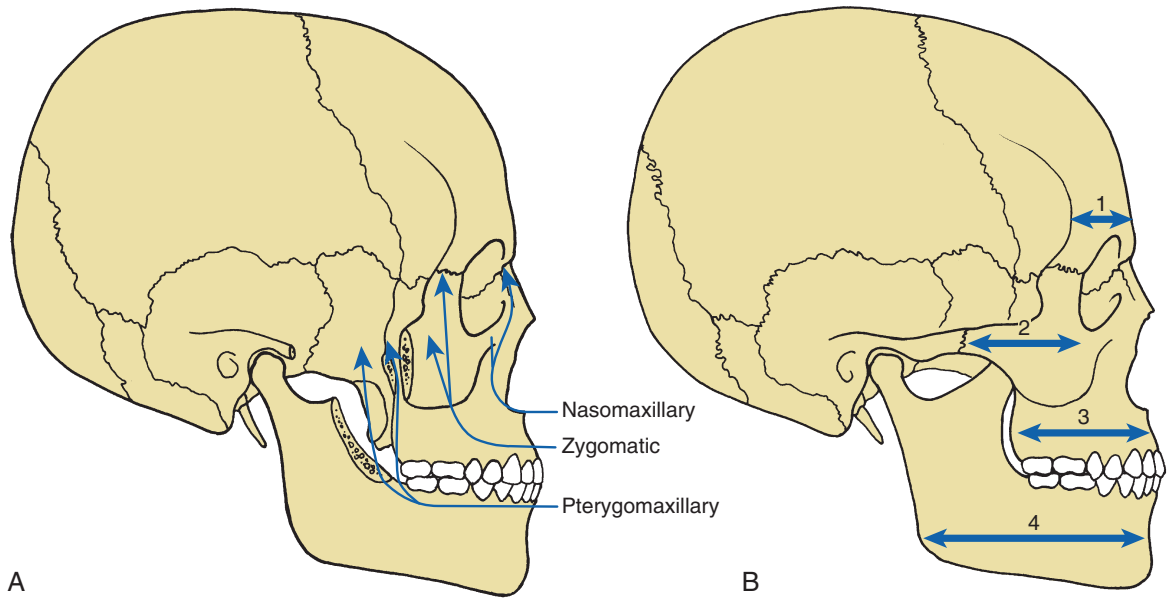


• **Fig. 25.16** Blunt-force trauma from a baseball, causing an orbital floor blowout fracture, with bone fragments and orbital contents sagging into the maxillary sinus below.

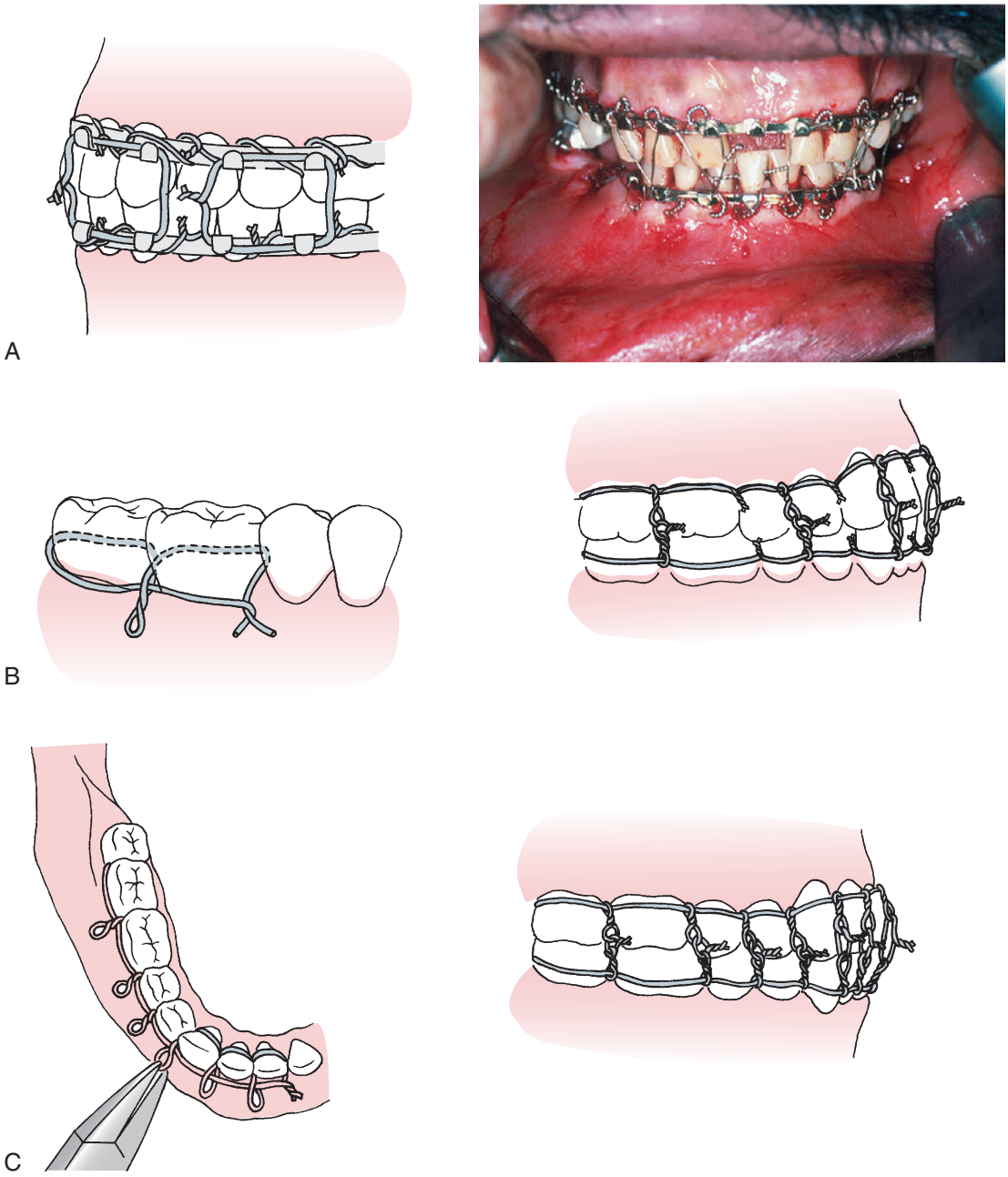
Mandibular Fractures

The first and most important aspect of surgical correction is to reduce the fracture properly or place the individual segments of the fracture into the proper relationship with each other. In the proper reduction of fractures of tooth-bearing bones, it is most important to place teeth into the preinjury occlusal relationship. Merely aligning and interdigitating the bony fragments at the fracture site without first establishing a proper occlusal relationship rarely results in satisfactory postoperative functional occlusion.

Establishing a proper occlusal relationship by wiring teeth together is termed *maxillomandibular fixation (MMF)* or *intermaxillary fixation*. Several techniques have been advocated for MMF (Fig. 25.18). The most common technique includes the use of a prefabricated arch bar that is adapted and circumdentally wired to teeth or acid-etch bonded in each arch; the maxillary arch bar is wired to the mandibular arch bar, thereby placing teeth in their proper relationship. This can be accomplished with traditional Erich-type arch bars or bone anchored arch bars (e.g. Stryker Hybrid MMF; see Fig. 25.18A) Other wiring techniques, such as Ivy loops or continuous loop wiring, have also been used for the same purpose. When fractures have not been treated for several days or are grossly displaced, it may be difficult to place the fractured segments immediately into their proper position and into adequate MMF. Heavy elastic traction can be used to pull the bony segments into their proper positions gradually over several hours or a few days (Fig. 25.19). Treatment of fractures using only MMF is called



• **Fig. 25.17** (A) Facial buttresses responsible for vertical support: nasomaxillary, zygomatic, and pterygomaxillary. (B) Anteroposterior buttresses: frontal (1), zygomatic (2), maxillary (3), and mandibular (4).



• **Fig. 25.18** Intermaxillary fixation wiring techniques. (A) Arch bar and bone anchored arch bar maxillomandibular fixation. (B) Ivy loop wiring technique. (C) Continuous loop wiring technique. (Modified from Kruger E, Schilli W. *Oral and Maxillofacial Traumatology*. Vol 1. Chicago: Quintessence; 1982.)

closed reduction because it does not involve direct opening, exposure, and manipulation of the fractured area.

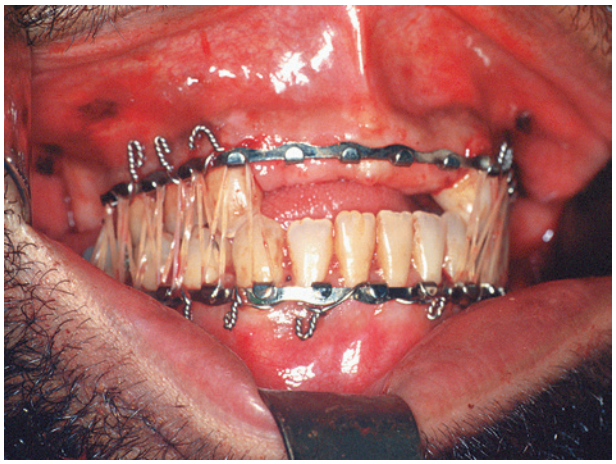
In the case of a fracture of an edentulous patient, the mandibular dentures can be wired to the mandible with circum-mandibular wiring, and the maxillary denture can be secured to the maxilla using wiring techniques or bone screws to hold the denture in place. The maxillary and mandibular dentures can then be wired together, which produces a type of MMF. In many instances, the totally edentulous fracture patient undergoes open reduction and internal fixation with anatomic alignment (Fig. 25.20). After an appropriate period of healing (minimum of 4 to 6 weeks), new dentures can be fabricated.

A splinting technique that can be used for dentate patients involves the use of a lingual or occlusal splint (Fig. 25.21). This technique is particularly useful in treatment of mandibular fractures in children in whom placement of arch bars and bone plates is difficult because of the configuration of the deciduous teeth and developing permanent teeth and because patient understanding and cooperation is difficult to obtain. After complete clinical and radiographic examinations, all fractures and soft tissue injuries should be identified and categorized. Then, with input from the patient and the patient's family, a treatment plan should be developed as to method and sequencing of surgery. Discussion regarding closed versus open reduction, any period of MMF, and

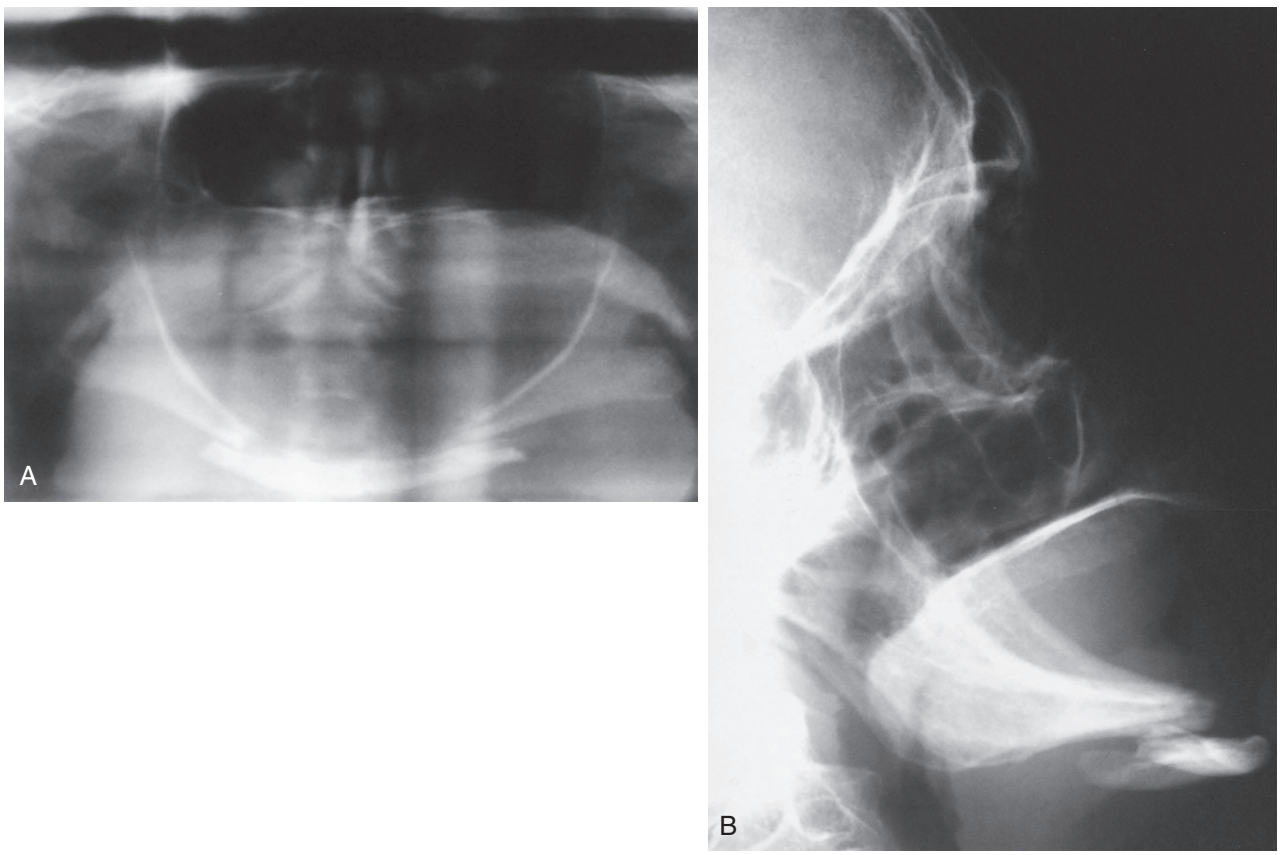
anticipated morbidity should lead to a decision, and surgical consent should be obtained.

After completing a closed reduction of the mandible and placing the dental component or alveolar process into the proper relationship with the maxilla, the necessity for an open reduction (i.e., direct exposure and reduction of the fracture through a surgical incision) must be determined. If adequate bony reduction has occurred, MMF may provide adequate stabilization during the initial bony healing phase of approximately 6 weeks. Indications for open reduction include continued displacement of the bony segments or an unfavorable fracture, as in an angle fracture (see Fig. 25.13) in which the pull of the masseter and medial pterygoid muscles can cause distraction of the proximal segment of the mandible. With rigid fixation techniques, patients can be allowed to heal without undergoing MMF or at least a decreased time of MMF. This alone may be an important factor in the decision to perform an open reduction. In most instances, patients opt to undergo open reduction and internal fixation, which allows an earlier return to more normal function without MMF.

In some cases, it is not necessary to achieve an ideal anatomic reduction of the fracture area. This is especially true of the condylar fracture. In this fracture, minimal or moderate displacement of the condylar segment generally results in adequate postoperative function and occlusion (but only if a proper occlusal relationship was established during the period of healing of the fracture site). In these cases, MMF is used for a maximum of 2 to 3 weeks in adults and 10 to 14 days in children, followed by a period of aggressive functional rehabilitation. Longer periods of MMF can lead to bony ankylosis or fibrosis and severe limited mouth opening. In case of significant anatomic displacement of the condylar segment, the outcome of treatment may be improved with open reduction and rigid fixation.[11]



• **Fig. 25.19** Arch bars used in combination with heavy elastic traction to pull bones gradually into proper alignment and to establish preinjury occlusion. Once the closed reduction had been achieved, maxillomandibular wires replace the elastics and are maintained for 6 weeks.



• **Fig. 25.20** (A) Panoramic radiograph demonstrating bilateral body fractures of an edentulous atrophic mandible. (B) Lateral cephalogram showing inferior displacement of the anterior mandibular segment as a result of the suprahyoid muscle pull.

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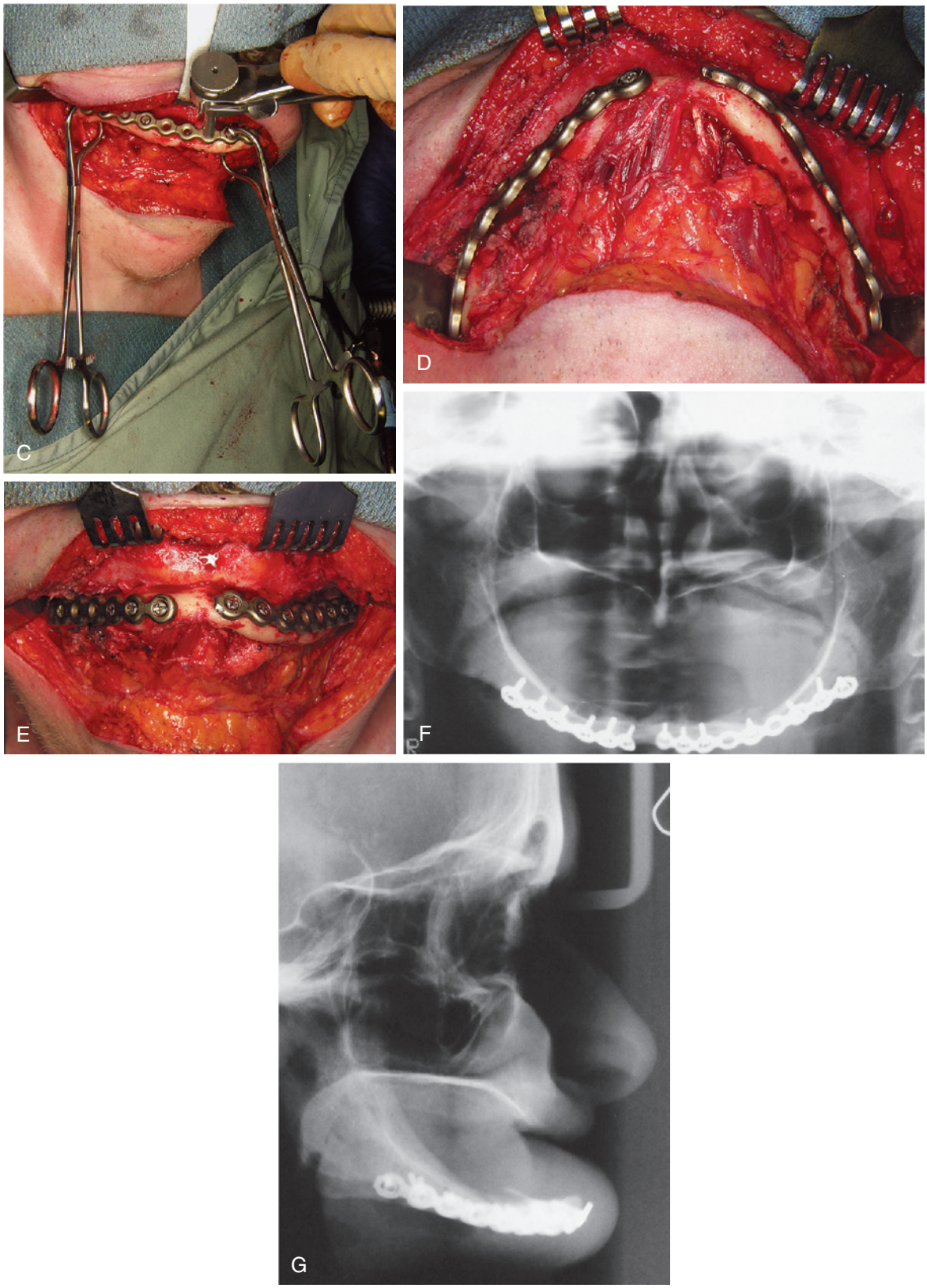
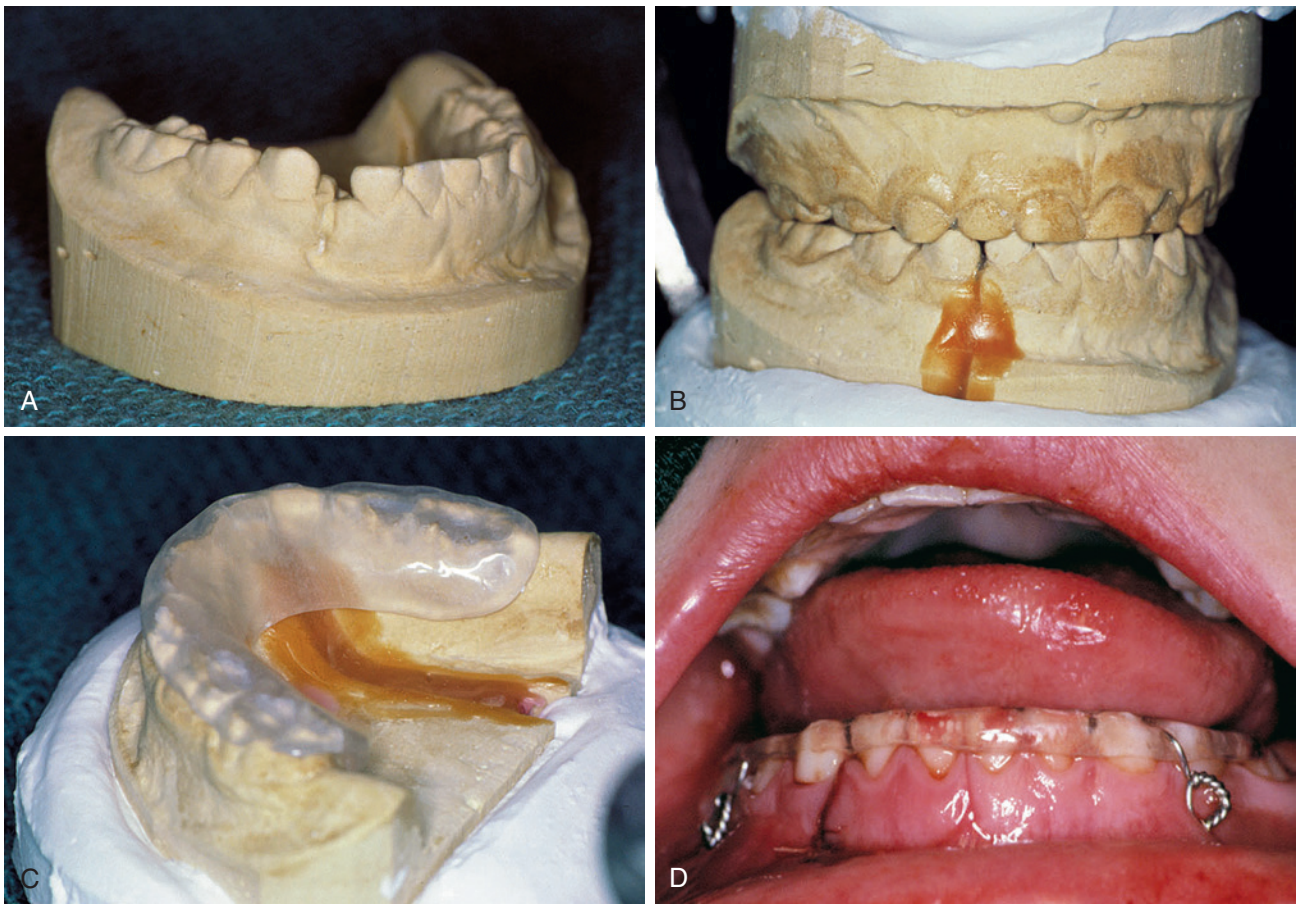


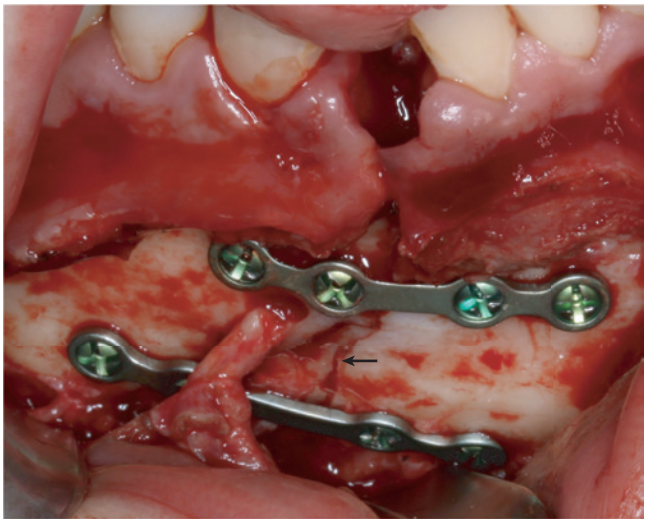
• **Fig. 25.20, cont'd** (C) Intraoperative appearance of the reduced right body fracture approached by a submandibular skin incision. Self-retaining bone clamps are used to hold the rigid fracture plate while a drill guide is used to ensure properly centered drilling within the plate holes. (D) Intraoperative submental view of separate rigid plate fixation of the bilateral body fractures. (E) Frontal view. (F) Postoperative panoramic radiograph. (G) Lateral cephalogram with restored anatomic alignment.



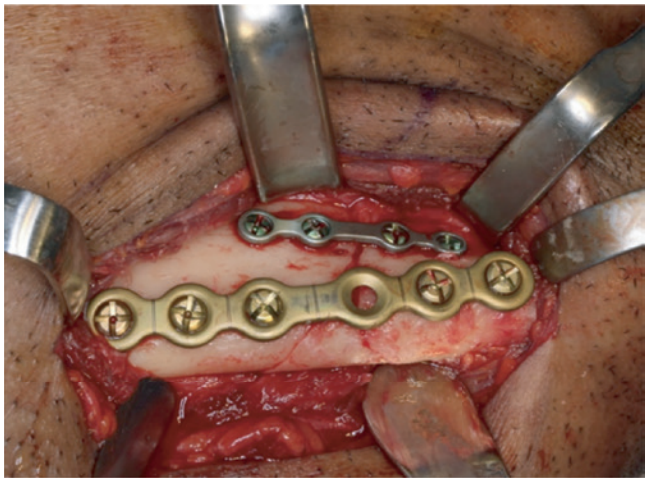
• **Fig. 25.21** A 5-year-old child with a right symphysis and bilateral intracapsular condyle fractures. (A) Mandibular dental cast shows the degree of displacement of the right symphysis fracture. (B) The lower cast is cut at the fracture site and reoriented into proper alignment by occluding with the maxillary cast. (C) An occlusal-lingual acrylic splint is fabricated on the mandibular cast. (D) Occlusal splint wired in place with circum-mandibular wires reducing and stabilizing the fractured mandible. Intermediate skeletal suspension wires were used to provide closed treatment (2 weeks) of the condylar fractures.

When open reduction is performed, direct surgical access to the area of the fracture must be obtained. This access can be accomplished through several surgical approaches, depending on the area of the mandible fractured. Both intraoral and extraoral approaches are possible. In general, the symphysis and anterior mandible areas can be easily approached through an intraoral incision (Fig. 25.22), whereas posterior angle or ramus and condylar fractures are more easily visualized and treated through an extraoral approach (Fig. 25.23). In some cases, posterior body and angle fractures can be treated through a combination approach using an intraoral incision combined with insertion of a small trocar and cannula through the skin to facilitate fracture reduction and fixation (Fig. 25.24). In either case, a surgical approach should avoid vital structures such as nerves, ducts, and blood vessels and should result in as little scarring as possible.

The traditional and still acceptable method of bone fixation after open reductions has been the placement of direct intraosseous wiring combined with a period of MMF ranging from 3 to 8 weeks. This method of fixation can be accomplished through a variety of wiring techniques (e.g., wire osteosynthesis) and is often sufficient to maintain the bony segments in the proper position during the time of healing (Fig. 25.25). If wire osteosynthesis



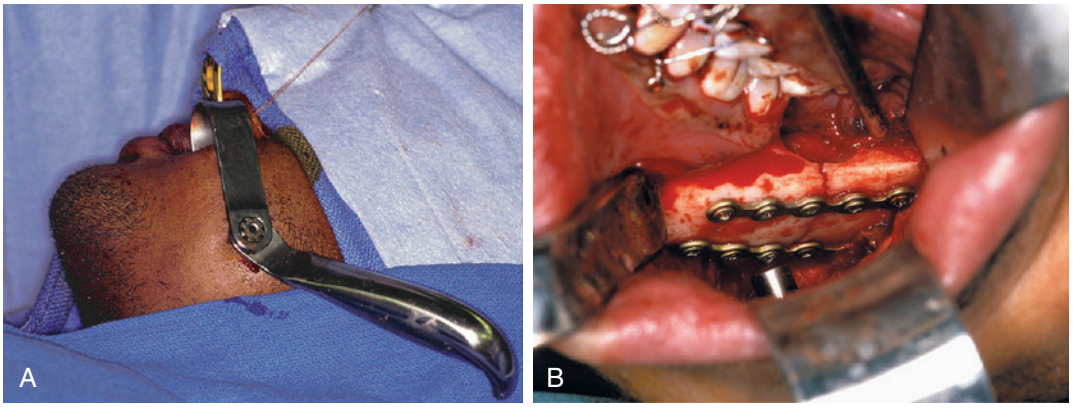
• **Fig. 25.22** Intraoral exposure of reduced and fixated fracture in the right anterior body of the mandible (*arrow* shows fracture line). Preservation of the mental nerve is demonstrated.



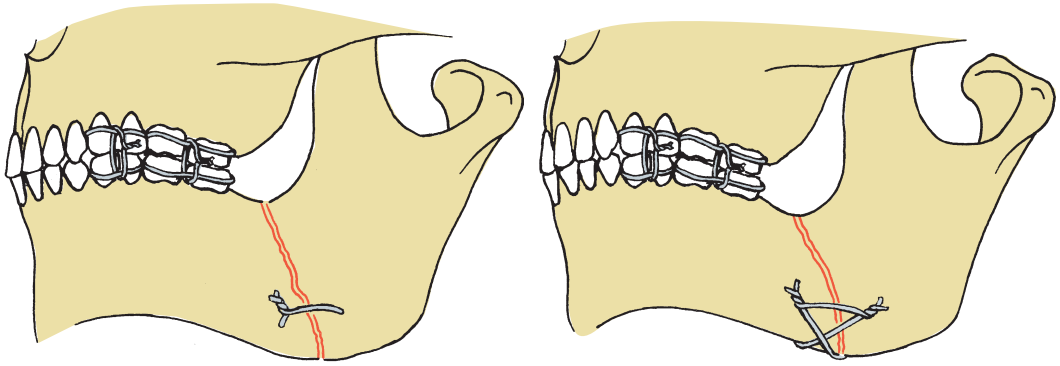
• **Fig. 25.23** Extraoral exposure and plating of right posterior body fracture of the mandible.

is used for fixation and stabilization of the fracture site, continued immobilization with MMF (generally 4 to 6 weeks) is required until adequate healing has occurred in the area of the fracture.

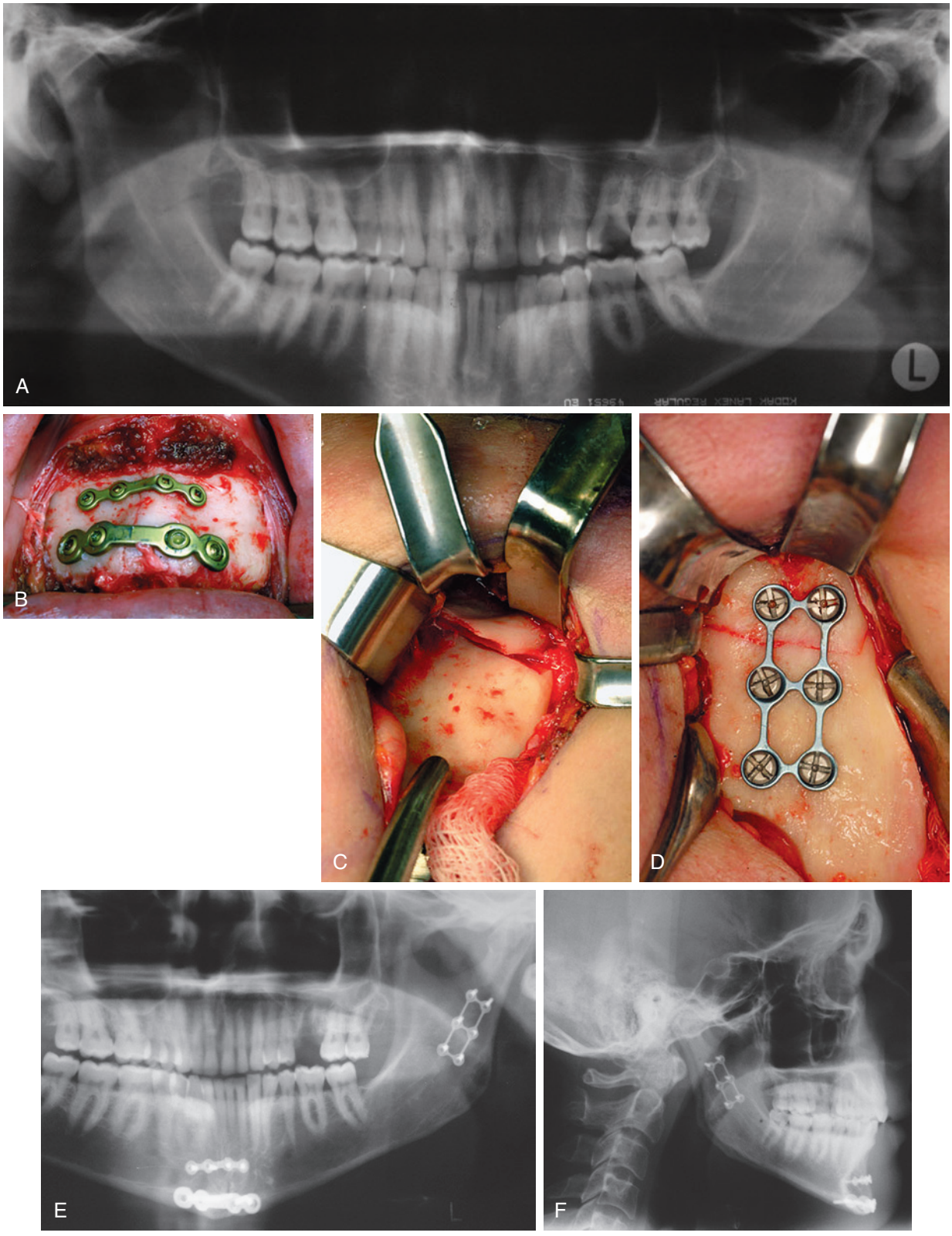
Currently techniques for rigid internal fixation are widely used for treatment of fractures.[12] These methods use bone plates, bone screws, or both to fix the fracture more rigidly and stabilize the bony segments during healing (Figs. 25.26 and 25.27). Even with rigid fixation, a proper occlusal relationship must be established before reduction and fixation of the bony segments. Advantages of rigid fixation techniques for treatment of mandibular fractures include decreased discomfort and inconvenience to the patient because MMF is eliminated or reduced, improved postoperative nutrition, improved postoperative hygiene, greater safety for patients with seizures, and, frequently, better postoperative management of patients with multiple injuries.



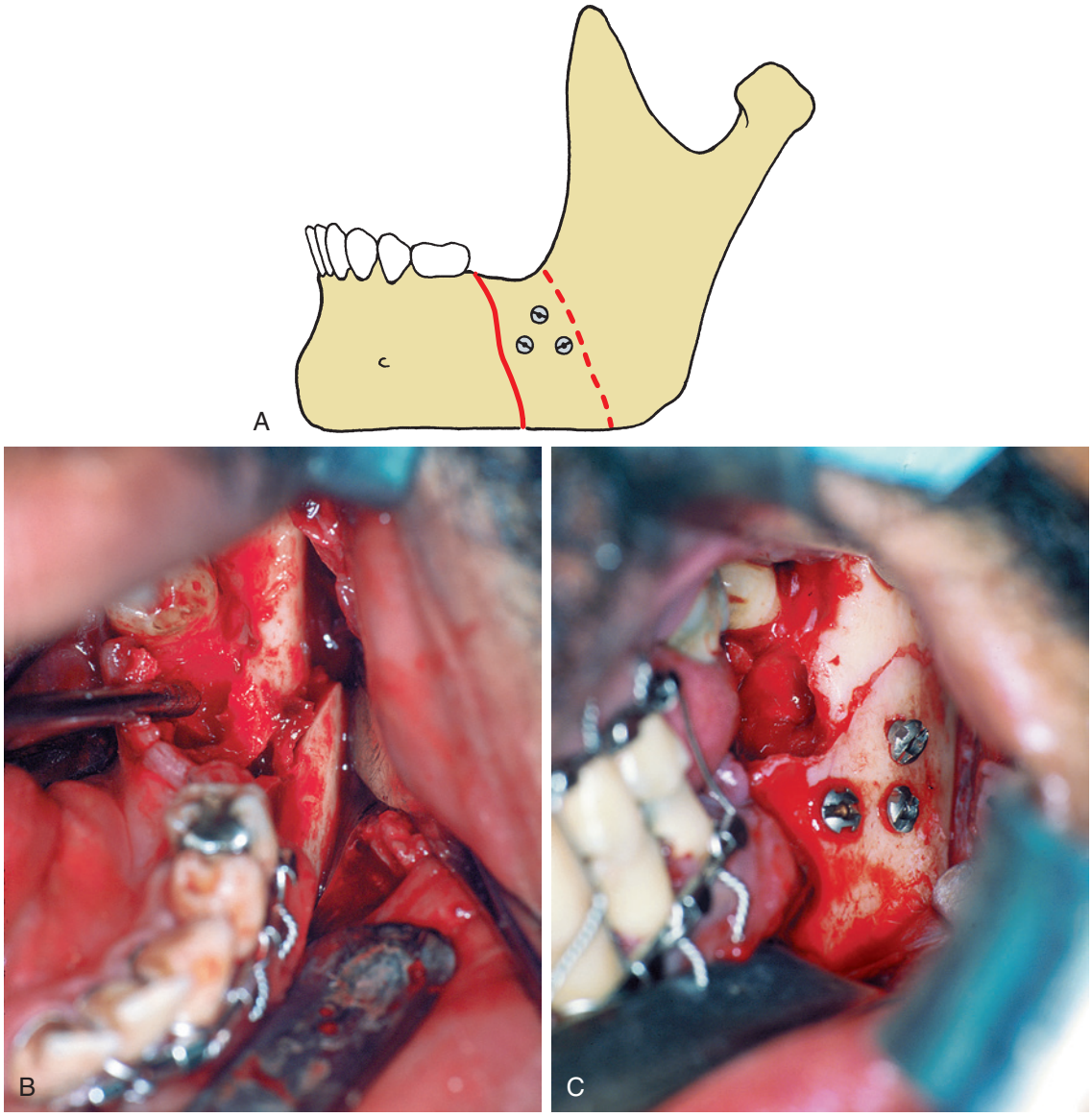
• **Fig. 25.24** Use of intraoral incision combined with percutaneous cannula placement for access to mandibular angle region. (A) View of left cheek with guarded cannula and handle in place. (B) Intraoral view of the left angle fracture plates being percutaneously fixated with screws that are perpendicular to the lateral bone surface. Note that the impacted third molar that was in the line of fracture has been removed.



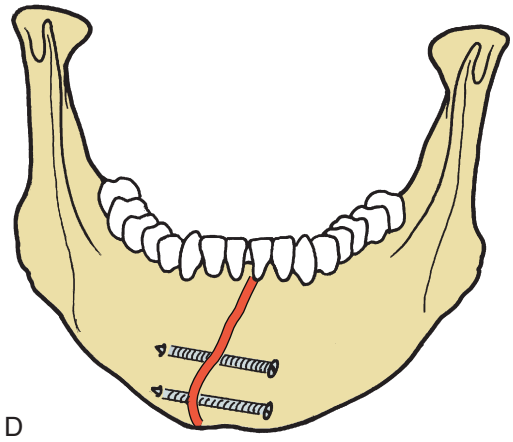
• **Fig. 25.25** Surgical wiring of fracture sites for reduction and stabilization of mandible fractures (with wire osteosynthesis of fracture sites, patients must be maintained in intermaxillary fixation during the healing period).

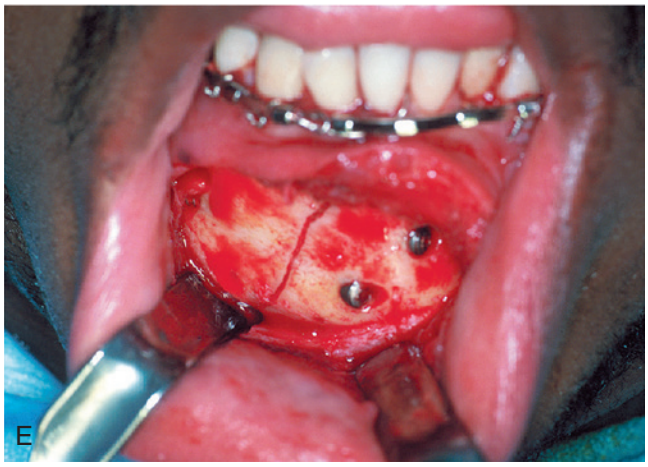


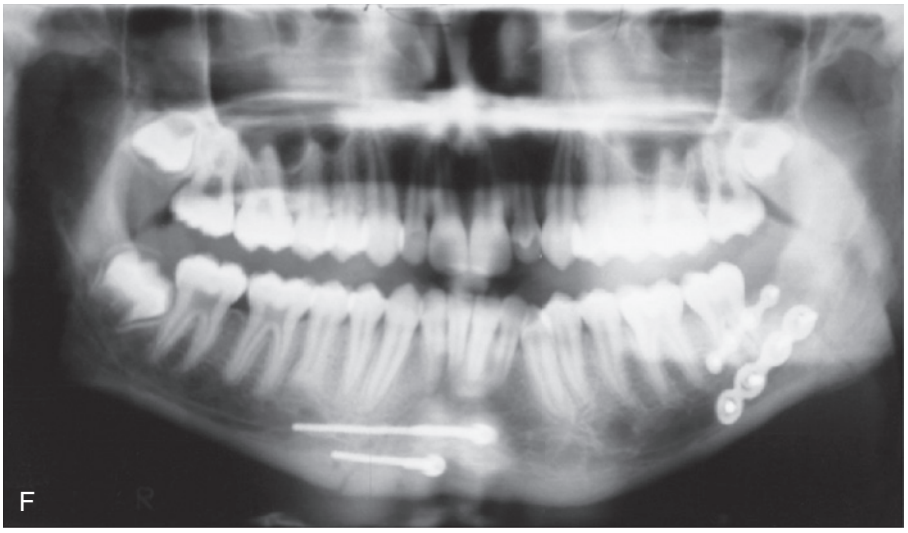
• **Fig. 25.26** (A) Preoperative panoramic radiograph with vertically displaced right symphysis and displaced and overlapped left condyle fractures. (B) Clinical photograph of superior monocortical tension band plate and inferior bicortical plate fixating the right symphysis fracture. (C) The left condyle fracture was approached extraorally and the displaced bony segments identified. (D) The condylar fracture was reduced and fixated with a monocortical plate. (E) Postoperative radiograph shows the fixated fractures and the removal of the nonsalvageable carious left maxillary first molar. (F) Postoperative lateral cephalogram shows re-establishment of proper vertical dimensions and occlusion.



• **Fig. 25.27** (A) Oblique fracture of mandible stabilized with three lag screws. (B) Clinical image of oblique fracture. (C) Clinical image of fixation.







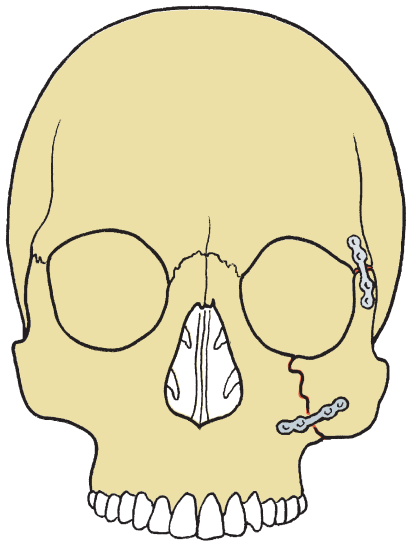
• **Fig. 25.27, cont'd** (D) Two screws placed tangentially across symphysis, stabilizing anterior mandible by engaging facial cortex on both sides of fracture and applying compression across fracture site with lag screws. (E) Clinical image of screw fixation. (F) Radiograph.

Midface Fractures

Treatment of fractures of the midface can be divided into those fractures that affect the occlusal relationship—such as Le Fort I, II, or III fractures—and those fractures that do not necessarily affect the occlusion, such as fractures of an isolated zygoma, the zygomatic arch, or the NOE complex.

In zygoma fractures, isolated zygomatic arch fractures, and NOE fractures, treatment is primarily aimed at the restoration of normal ocular, nasal, and masticatory function and facial esthetics. In an isolated zygoma fracture (the most common midfacial injury), an open reduction is generally performed through some combination of intraoral, lateral eyebrow, or infraorbital approaches. An instrument is used to elevate and place the zygoma into the proper position. If adequate stabilization is not possible by simple manual reduction, bone plating of the zygomaticomaxillary buttress, zygomaticofrontal area, and the inferior orbital rim area may be necessary (Fig. 25.28).

In a zygomatic arch fracture, an extraoral approach or an intraoral approach can be used to elevate the zygomatic arch and return it to its proper configuration. In addition to restoring adequate facial contour, this approach eliminates the impingement on the coronoid process of the mandible and the subsequent limitation of mandibular

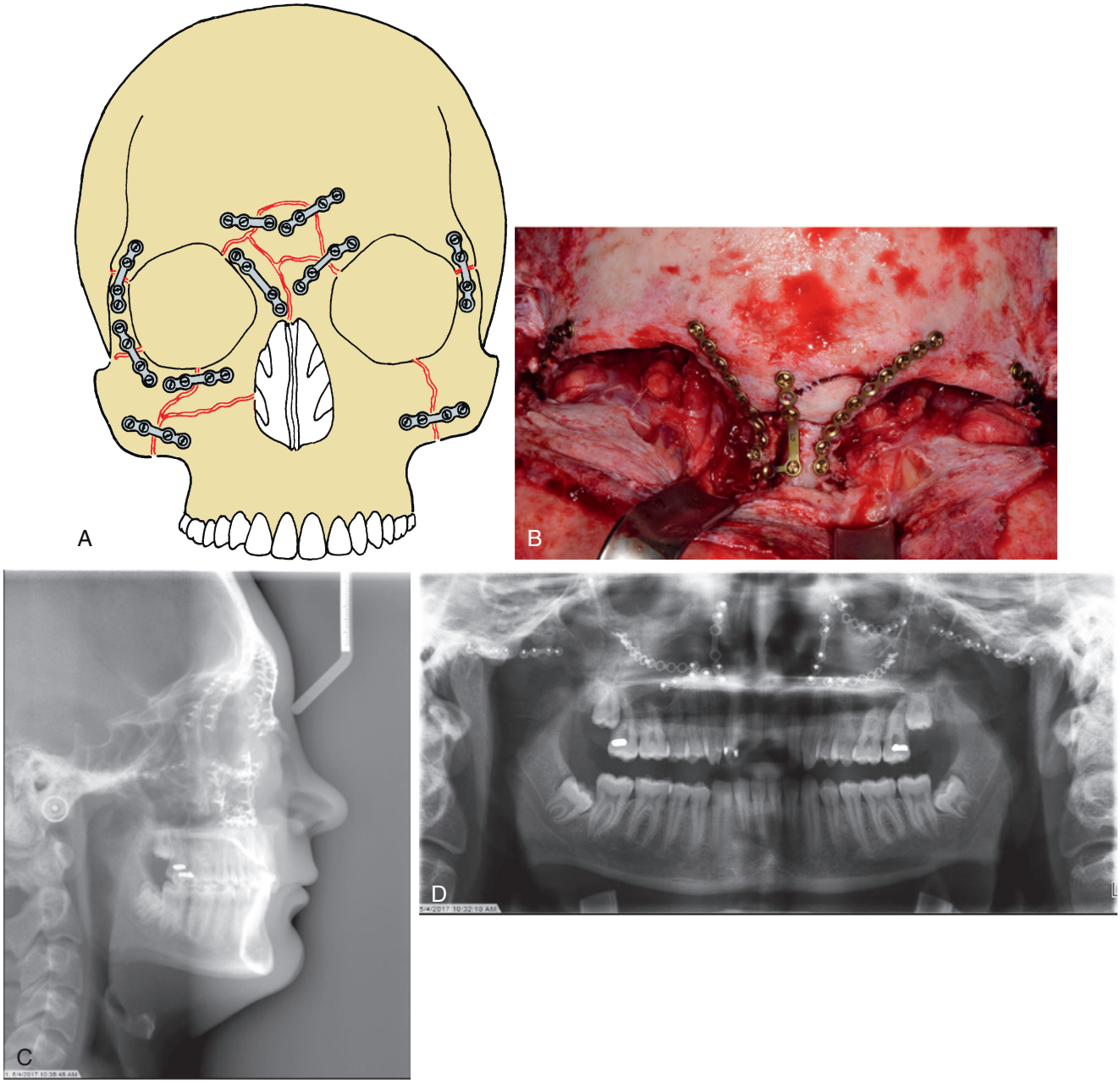


• **Fig. 25.28** Plate stabilization of zygomatic complex fracture. Plates stabilize the fractures at the zygomatic buttress and zygomaticofrontal suture area.

opening. Elevation and reduction of the zygomatic arch should be performed within several days of the injury. Longer delays make maintaining the arch in a stable supported configuration difficult, and it tends to collapse or drift to its injured position.

The goal of treatment for NOE fractures is to reproduce normal nasolacrimal and ocular function while repositioning nasal bones and medial canthal ligaments into an appropriate position to ensure normal postoperative esthetics. In these situations, open reduction of the NOE area is usually necessary. Wide exposure to the supraorbital rim and nasal, medial canthal, and infraorbital rim areas can be achieved through a variety of surgical approaches. The most popular approach currently in use is the coronal flap, which allows exposure of the entire upper facial and nasoethmoidal complex through a single incision that can be easily hidden in the hairline (Fig. 25.29).[13] Small bone plates and direct transnasal wiring appear to be most effective in stabilizing and maintaining bony segments in these types of injuries.

In midfacial fractures involving a component of the occlusion, as in mandibular fractures, it is important to reestablish a proper occlusal relationship by placing the maxilla into proper occlusion with the mandible. This step is accomplished by methods identical to the various types of intermaxillary fixation for mandibular fractures. However, as with mandibular fractures, reestablishing the occlusal relationship may not provide adequate reduction of the fractures in all areas. In addition to the need for anatomic reduction, additional stabilization of the fracture sites is often required.



• **Fig. 25.29** Plate stabilization of severe midface fracture. (A) Diagrammatic representation. (B) View of NOE and supraorbital area after stabilization of fragments with small bone plates. (C) Postoperative lateral cephalometric radiograph. (D) Postoperative Panorex radiograph.

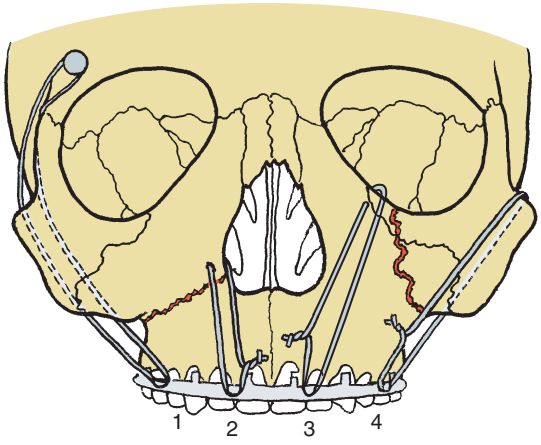
When adequate bony reduction occurs after MMF but the fracture remains unstable, direct wiring, suspension wiring techniques, or bone plates may be used to stabilize the fracture. An example of such a case is a Le Fort I, II, or III midfacial fracture with an intact mandible. By placing the patient in MMF, any movement of the mandible tends to dislodge the midfacial bones. Direct wiring techniques (i.e., wire osteosynthesis) or bone plates (i.e., rigid fixation) attempt to fixate the individual fractures directly.

Suspension wiring is sometimes used in addition to direct wiring or bone plating. The purpose of suspension wiring is to provide stabilization of fractured bones by suspending them to a more stable bone superiorly.[14] Suspension wiring techniques include those with wires attached to the piriform rim area, infraorbital rims, zygomatic arch, or frontal bone (Fig. 25.30). The suspension wires can be connected directly to the maxillary arch wire, or they can be connected with an intermediate wire to an interocclusal splint or to the mandible. These suspension wires prevent movement of the maxilla caused by the inferior pull of the mandible during attempted opening. The use of direct and suspension wire fixation does have significant limitations in many cases. The limited rigidity of wires may make it difficult to reconstruct and maintain the appropriate anatomic contours, particularly in concave and convex areas such as orbital rims and the prominence of the zygoma. Wires may not provide adequate resistance to muscular forces during the entire healing period, eventually resulting in some fracture displacement. Rigid fixation using plating systems for the most part has eliminated the need for suspension wires.

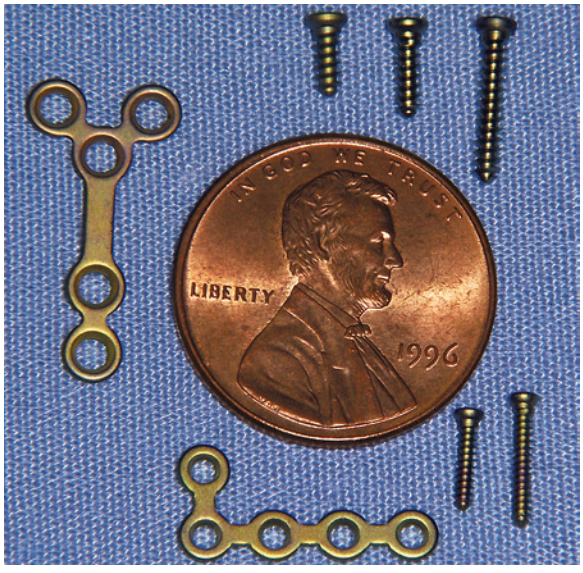
The development and improvement in miniature and micro–bone plate systems has greatly enhanced the treatment of midfacial fractures. These titanium alloy plates range in thickness from 0.6 to 1.5 mm and are secured by screws with 0.7 mm to 2.0 mm external thread diameters (Fig. 25.31). The advantages listed for rigid fixation of mandibular fractures also apply to midface fractures. In addition to these advantages, small bone plates have greatly improved the ability to obtain proper bony contours at the time of surgery. When limited to the use of direct-wiring or suspension-wiring techniques, reestablishing the curve configurations of bony anatomy is nearly impossible, particularly in the areas of severely comminuted small bone fragments. Severely comminuted unstable midface fractures can now routinely be treated by wide exposure of all fractured segments combined with the use of bone plates to reestablish the facial pillars, develop adequate contours, and stabilize as many facial bone fragments as possible (Fig. 25.32). These titanium bone plates and screws are biocompatible and do not require removal at a second surgery unless they become palpable, infected, or interfere with secondary reconstructive surgery (e.g., bone grafting or implants).

Various polymers of polyglycolic acid and polylactic acid have been developed for resorbable plate and screw systems (Fig. 25.33).[15,16] Resorbable plating systems may be particularly desirable in pediatric and skull trauma in which growth and CT reimaging are considerations. However, because of the current designs, mechanical limitations, need for tapping, and cost, these systems are not routinely used. The use of bone plates and screws has also facilitated the use of immediate bone grafting to replace comminuted or missing bone segments at the time of surgery and to improve stabilization of comminuted segments.

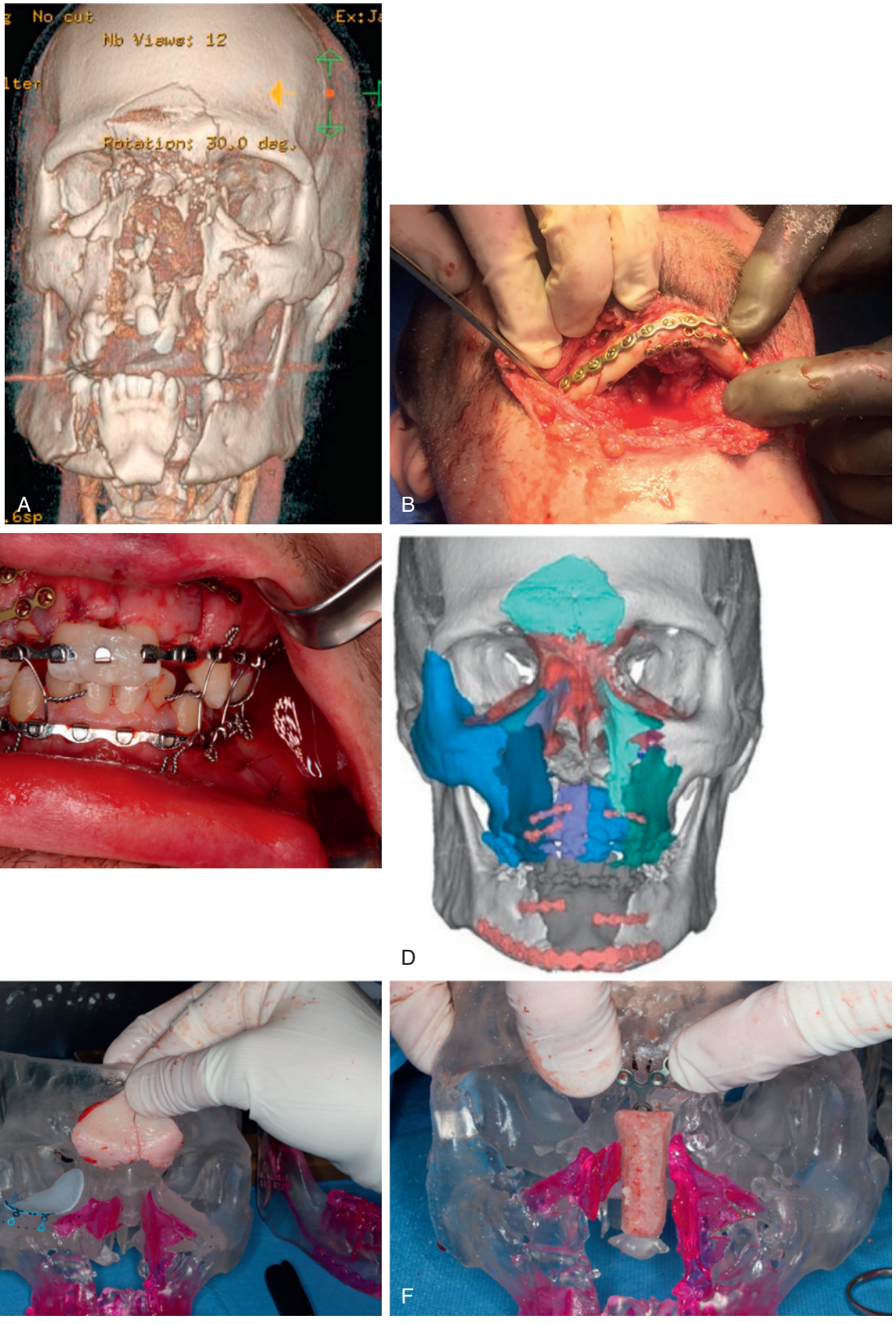
A recent development in the treatment of complex facial trauma involves the use of advanced technologies including virtual reconstruction, stereolithographic modeling, and intraoperative navigation to more accurately reposition and stabilize complex fractures.[17,18] One method for the treatment of complex fractures utilizes CT data to create a stereolithographic model exactly duplicating the fractures. Stereolithographic models can be generated from virtually manipulated fractured segments into a "perfected" model to assist with fixation, prebending plates and selecting orbital implant sizes. In unilateral orbital or zygomatic trauma, the contralateral side is used as a guide to develop surgical guides to reconstruct the damaged area using bone grafts, alloplastic implants, and anatomic titanium-reinforced implants. CT data can also be used to create a virtual, rather than an actual, stereolithographic reconstruction by "mirroring" the unaffected side to create a reverse or mirror image for correction of the fractured side. Intraoperatively, a navigation system is used to reproduce the desired position of the fractured side. By using technology similar to a global positioning system device, a localizer, a probe, and facial registration, points on the facial skeleton can be located, repositioned, stabilized, and verified by using the



• **Fig. 25.30** Suspension wiring techniques. *1*, Frontal bone suspension. *2*, Piriform rim wiring. *3*, Circumzygomatic suspension. *4*, Circumzygomatic suspension.



• **Fig. 25.31** Microplates and microscrews adjacent to penny for size comparison.



• **Fig. 25.32** (A) A patient who sustained severe panfacial trauma from a gunshot. (B) Anatomic reduction and fixation of the mandible. (C) Phase 1 postoperative clinical view of anatomic mandibular fixation, maxillomandibular fixation, and external fixation of the premaxilla. Due to severe palatal avulsion and compromised blood supply, these miniplates were utilized without stripping of the periosteum. (D) Virtual planning of surgical phase 2. Virtually repositioning of fractured segments. (E) Utilization of stereolithographic model for reduction of segments and sizing of anatomic orbital implant. (F) Utilization of stereolithographic model for prebending a plate to support a calvarial strut graft.

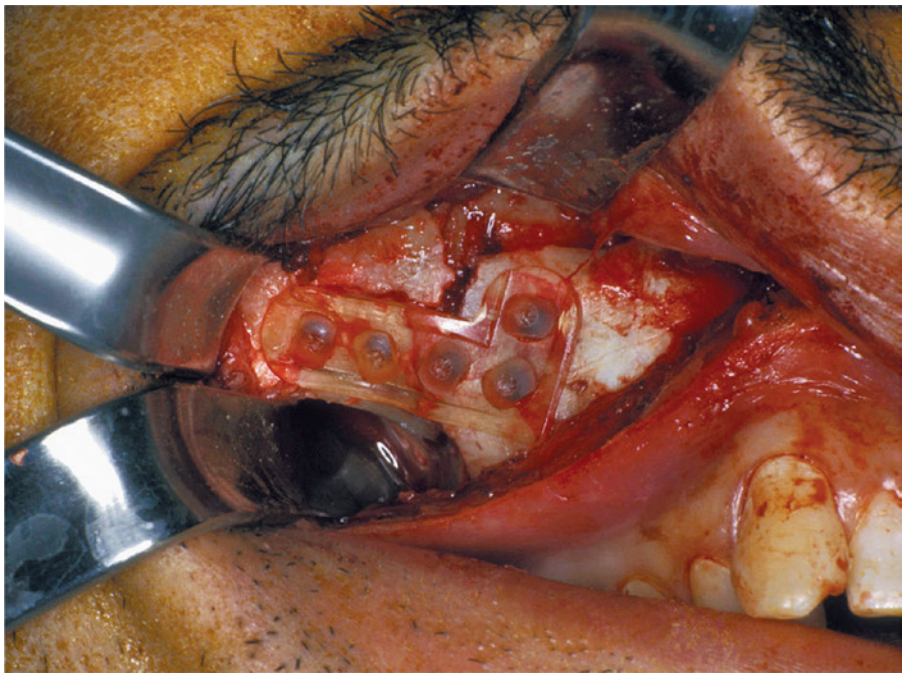
• **Fig. 25.32, cont'd** (G) Intraoperative navigation system in use. (H) Intraoperative navigation for verification of repositioned segments and orbital implants. (I) Overlay of virtual surgical plan and postoperative clinical appearance. (J) 3D rendering of postoperative computed tomography scan. (K) Preoperative and postoperative clinical appearance.

virtual model created with repositioned fractured segments (Fig. 25.34; see also Fig. 25.32).

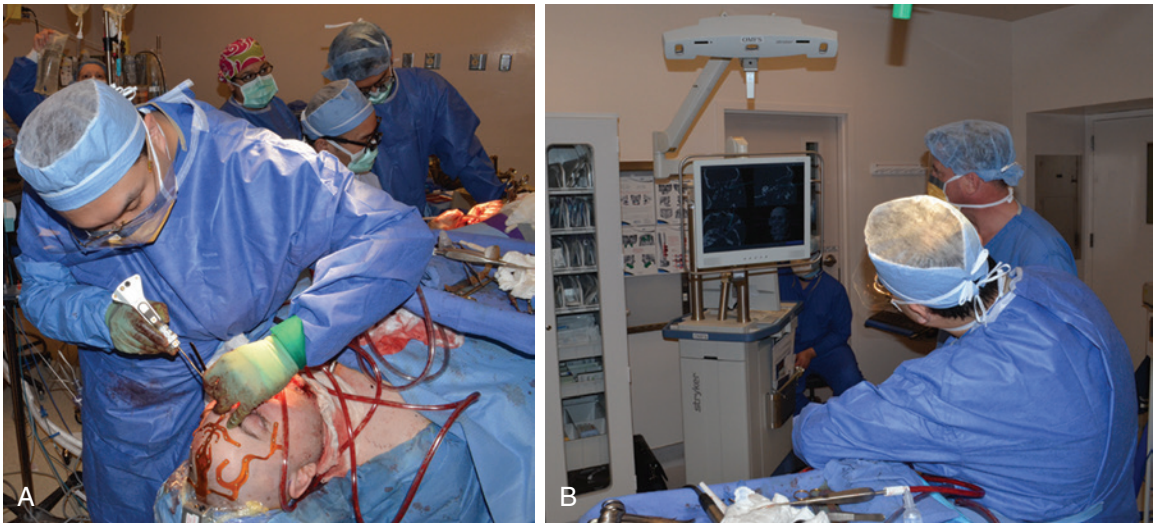
Lacerations

The general guidelines for management of facial lacerations are outlined in Chapter 24. Frequently, fractures of the facial bones are associated with severe facial lacerations. The principles of laceration repair remain the same regardless of how small or large the injury.

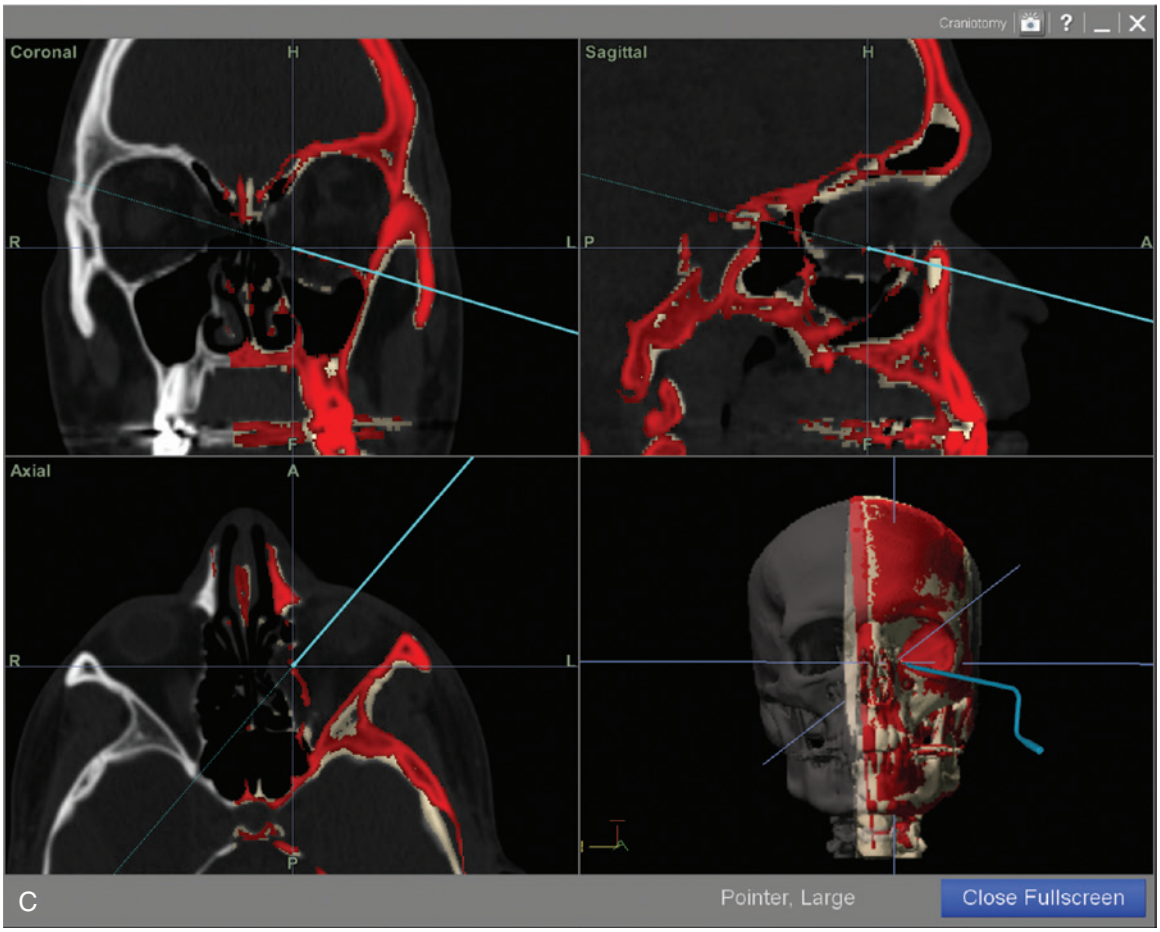
Cleansing of the laceration and examination of the area for disruption of any vital structures is important. Possible injuries include lacerations of the Stensen duct, the facial nerve, or major vessels. In these cases, attempts must be made to reanastomose the duct, identify and perform a primary repair of the severed nerve, or manage all associated bleeding (Fig. 25.35). Examination



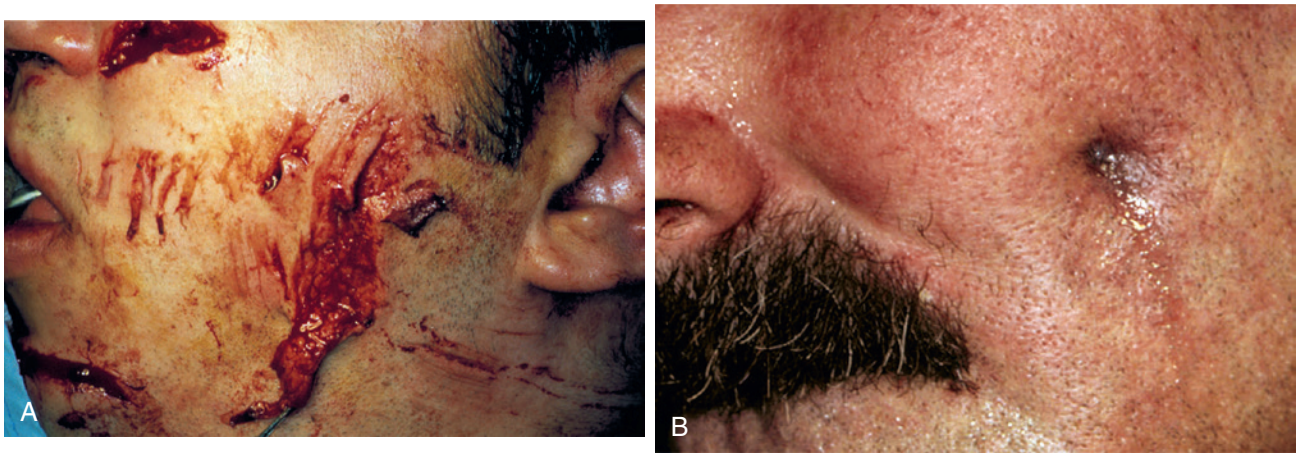
• **Fig. 25.33** **L**-shaped resorbable (nonmetallic and almost translucent) plates and screws securing a right zygomaticomaxillary fracture.



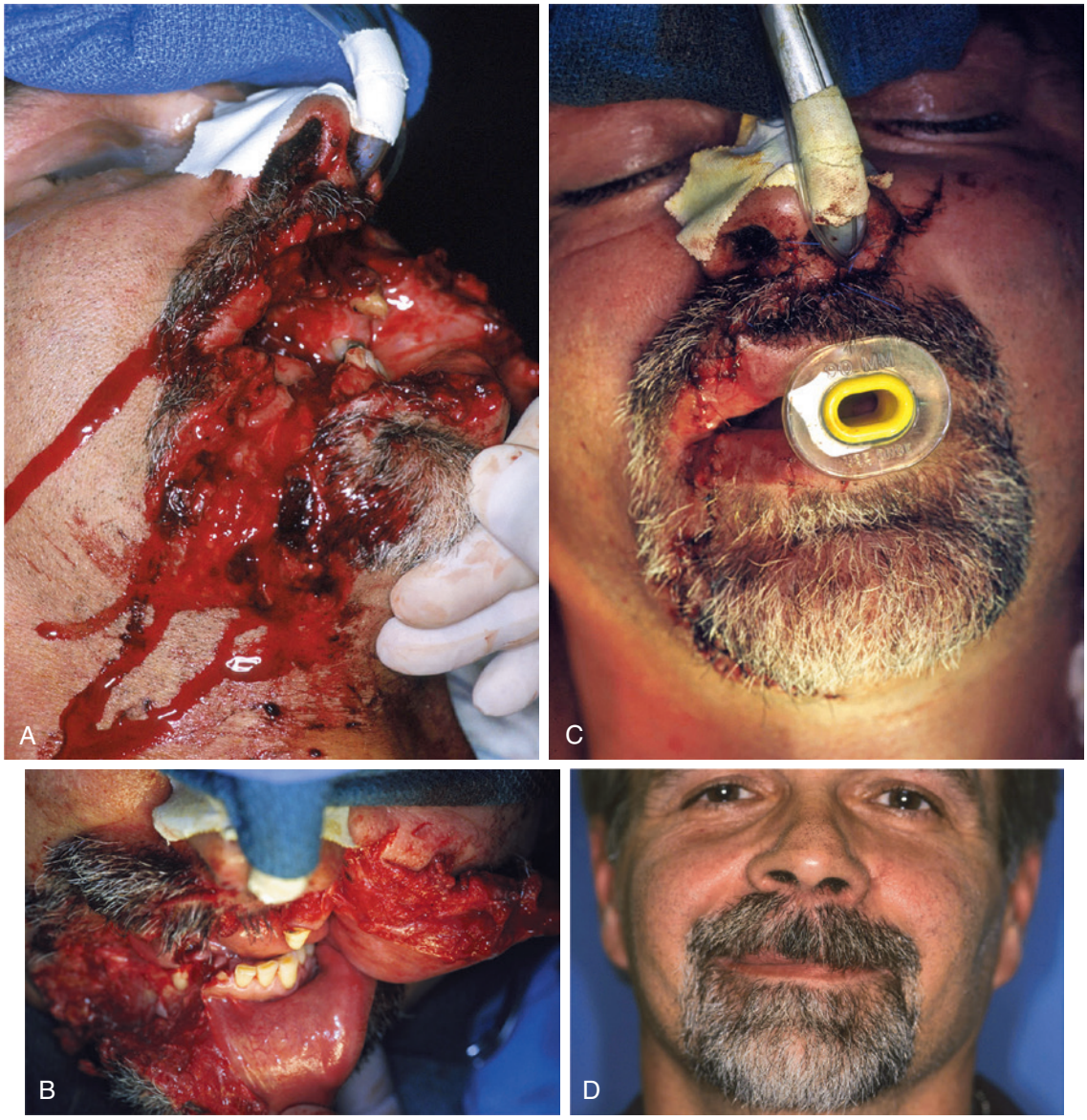
• **Fig. 25.34** Use of navigation in the treatment of facial fractures. The technology is similar to the global positioning system navigation in a car. (A) Adhesive mask or digital reference frame containing light-emitting diodes and surgical probe in place. (B) The localizer (analogous to a satellite) combined with a surgical probe and computed tomography scan data (the road map) are used to determine the appropriate corrected position of displaced bone and can be visualized on the screen as probe is moved.



• **Fig. 25.34, cont'd** (C) Navigated image with corrected position of bone *(red)* overlying optimal position of bone (*white*). (Courtesy Dr. R Bryan Bell).



• **Fig. 25.35** (A) A deep penetrating laceration over the area of the facial nerve and parotid duct. Exploration may be necessary to locate and repair these structures. (B) Postoperatively, the patient had breakdown of a wound margin with a persistent salivary fistula caused by an undetected injury to the parotid duct.



• **Fig. 25.36** (A) Chainsaw injury to the lips, jaws, and chin, resulting in loss of teeth and bone. (B) View from above after hemostasis has been achieved and the wound has been debrided and trimmed. Note the nearly avulsed upper lip pedicled on the left side. (C) View of repaired lacerations, with the patient nasally intubated and an oral airway in place. (D) Facial appearance 3 months after surgery.

for these injuries before injection of local anesthesia or induction of general anesthesia is important because structural integrity and function (i.e., facial motion and salivary flow) may not be assessable after anesthesia.

The lacerations should be closed from the inside out—that is, from the oral mucosa to the muscle to the subcutaneous tissue and skin. All closures should be completed in layers to orient tissues properly and to eliminate any dead space within the wound to prevent hematoma formation. Easily identifiable landmarks such as the vermilion border of the lip, the ala of the nose, or the areas of the laceration that can be easily identified and properly repositioned should be sutured first (Fig. 25.36), after which the surgeon should close areas where wound margins are not so clearly reapproximated. All wounds should be cleansed periodically with hydrogen peroxide. Some surgeons advocate including the use of antibiotic ointment in wound care. However, the use of dry occlusive dressings such as Steri-Strip coverings can be equally effective. Sutures from facial wounds are generally removed in 5 to 7 days, depending on the location of the wound and the amount of tension necessary to provide adequate wound closure.

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PART VII

Dentofacial Deformities

Patients with congenital or acquired abnormalities of facial bones and soft tissue generally require the assistance of many medical and dental specialists to achieve maximal rehabilitation. Patients with malocclusions and facial abnormalities resulting from an abnormal growth of facial bones usually require the services of general dentists, prosthodontists, periodontists, orthodontists, and oral-maxillofacial surgeons. Chapter 26 focuses on the evaluation of patients with dentofacial deformities and the application of various types of orthognathic surgery to create occlusal and facial harmony.

Surgical procedures designed to enhance facial and total body aesthetics are increasing in popularity. Patients of all ages are interested in procedures to improve abnormal or unaesthetic facial features such as poorly proportioned noses, weak chins, and protruding ears. Aging patients are interested in procedures that restore a more youthful appearance to the face. Oral-maxillofacial surgeons perform facial cosmetic procedures and help coordinate other aspects of cosmetic dental treatment to provide the best possible aesthetic improvement. Chapter 27 discusses these topics.

The care of patients with cleft lips and palates involves most of the dental specialists, as well as pediatricians, plastic surgeons, otolaryngologists, speech and hearing therapists, and psychologists. Chapter 28 outlines the treatments available for these patients, the sequence of treatment, and the need for participation of dental generalists and specialists.

Facial trauma and pathologic conditions such as head and neck cancer often result in the loss of large portions of the jaws and associated structures. Reconstruction of missing portions of the jaws and associated facial bones and soft tissues usually necessitates comprehensive and often multiple surgical treatments to rehabilitate the patient adequately. Chapter 29 discusses the principles of maxillofacial reconstruction, including the use of tissue grafts and flaps.

26

Correction of Dentofacial Deformities

MYRON R. TUCKER, BRIAN B. FARRELL, AND RICHARD E. BAUER

CHAPTER OUTLINE

Prevalence of Dentofacial Deformities

Epidemiologic surveys demonstrate that a large percentage of the U.S. population has a significant malocclusion.[1-3] Very little data describe the exact prevalence of significant skeletal facial deformity. This information can be extrapolated from studies that have evaluated the prevalence of severe malocclusion. The National Health and Nutrition Examination Survey III, conducted from 1989 to 1994, obtained a sample of 14,000 individuals ages 8 through 50 years, which roughly approximates the general U.S. population. In this study, information was collected describing overjet and reverse overjet, vertical overlap (deep bite and open bite), and posterior cross-bites.[1] It can be assumed that patients with extreme values in each of these categories have underlying facial deformities (Table 26.1). Because many patients have dental compensations for skeletal growth abnormalities (described later in this chapter), this study likely underestimates the severity of skeletal abnormalities. This type of data, combined with other criteria that clearly define the most severe characteristics of a malocclusion such as overjet versus crowding, can help estimate more accurately the prevalence of skeletal abnormality that may require surgical correction as part of the treatment for malocclusion.[2]

It appears that about 2% of the U.S. population has mandibular deficiency, vertical maxillary excess that is severe enough to be considered a handicap, or both.[3] Other abnormalities and their percentages of prevalence in the population include mandibular excess, maxillary deficiency, or both, 0.3%; open bite, 0.3%; and asymmetry, 0.1%. Therefore it appears that approximately 2.7% of the U.S. population may have a dentofacial deformity contributing to malocclusion that requires surgical treatment for correction.

Historically, treatment of malocclusions, even those associated with dentofacial deformities, has been aimed at correction of dental abnormalities, with little attention to the accompanying deformity of the facial skeleton. In the last 60 years, surgical techniques have been developed to allow positioning of the entire midface complex, the mandible, or dentoalveolar segments to any desired position. The combining of surgical and orthodontic procedures for dentofacial deformities has become an integral part of the correction of malocclusions and facial abnormalities.

Causes of Dentofacial Deformity

Malocclusion and associated abnormalities of the skeletal components of the face can occur as a result of a variety of factors, including inherited tendencies, prenatal problems, systemic conditions that occur during growth, trauma, and environmental influences. Although it is not within the scope of this book to present a detailed discussion of facial growth, an understanding of basic principles as they relate to the development of dentofacial deformities is essential. Enlow and Han's *Essentials of Facial Growth* should be reviewed for a more complete discussion of the principles of facial growth.[4]

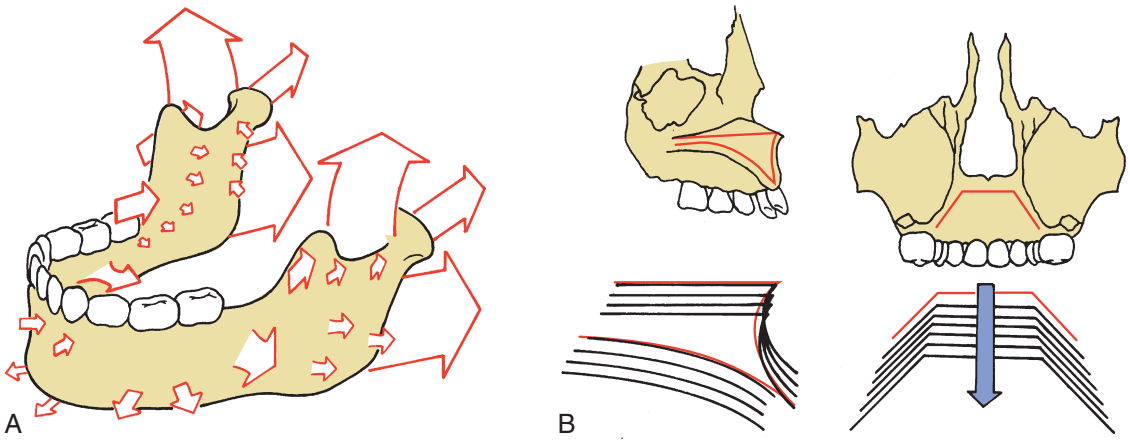
General Principles of Facial Growth

The development of proper craniofacial form and function is a complex process affected by many factors. In the area of the craniofacial complex, some parts appear to have their own intrinsic

TABLE 26.1 Percentage of the U.S. Population With Severe or Extreme Malocclusion

Type of Malocclusion	ALL AGES (AGE GROUPS COMBINED) 8–11	12–11	18–50	ALL RACIAL/ETHNIC GROUPS (RACIAL/ETHNIC GROUPS COMBINED) White	Black	Mexican-American
Class II: Overjet						
>10 mm (extreme)	0.2	0.2	0.4	0.3	0.4	0.4
7 to 10 mm (severe)	3.4	3.5	3.9	3.8	4.3	2.2
Class III: Reverse Overjet						
>–4 mm (extreme)	0.0	0.0	0.1	0.1	0.1	0.3
–3 to –4 mm (severe)	0.0	0.6	0.2	0.2	0.4	0.4
Open Bite						
>–4 mm (extreme)	0.3	0.2	0.1	0.1	0.7	0.0
–3 to –4 mm (severe)	0.6	0.5	0.5	0.4	1.3	0.0

Data from Proffit WR. Malocclusion and dentofacial deformity in contemporary society. In: Proffit WR, Fields HW Jr, Sarver DM, eds. *Contemporary Orthodontics*. 4th ed. St Louis: Mosby; 2007.



• **Fig. 26.1** (A) Mandibular growth resulting from apposition and resorption of bone. Primary areas of bony apposition include the superior surface of alveolar process and the posterior and superior surfaces of the mandibular ramus. (B) Forward and downward growth of the nasal complex and maxilla in "expanding V." Resorption of bone at the superior surface of the palate occurs simultaneously with apposition at the inferior surfaces of the palate and alveolar processes. In addition, growth in the posterior area of the maxilla results in the downward and forward expansion of the maxilla. (A, From Enlow OH, Harris DB. A study of the postnatal growth of the human mandible. *Am J Orthod.* 1964;50[1]:25-50. B, Modified from Enlow DH. *The Human Face*. New York: Harper & Row; 1968.)

growth potential, including the spheno-occipital and sphenoethmoidal synchondroses and the nasal septum. In addition, the majority of growth of the bones of the face occurs in response to adjacent soft tissue and the functional demands placed on underlying bone. These soft tissue influences include the nasal, oral, and hypopharyngeal airway; facial muscles; and muscles of mastication.[5]

The general direction of normal growth of the face is downward and forward with lateral expansion. The maxilla and the mandible appear to grow by remodeling or differential apposition and resorption of bone, producing changes in three dimensions. Enlow and Hans describe this phenomenon as *area relocation*, with the maxillary–mandibular complex enlarging in the downward and forward direction as an "expanding pyramid" (Fig. 26.1).[4] The direction and amount of growth characterize an individual's growth pattern.[6] Alterations in the pattern of growth or in the rate at which this growth occurs may result in abnormal skeletal morphology of the face and an accompanying malocclusion.

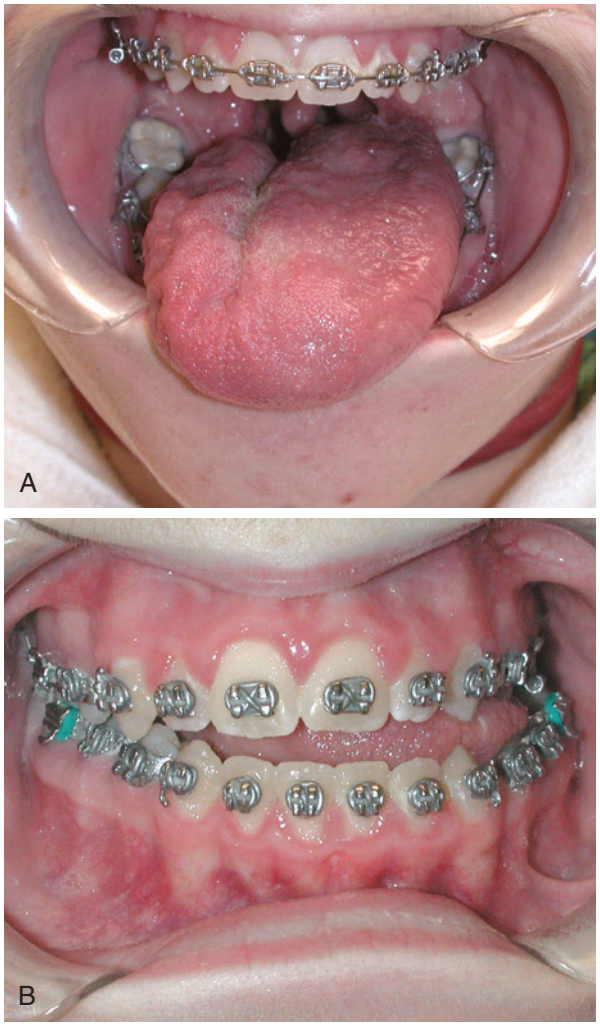
Genetic and Environmental Influences

Genetic influence certainly plays a role in dentofacial deformities. Patterns of inheritance such as a familial tendency toward a prognathic or deficient mandible are often seen in a patient with a dentofacial deformity. However, the multifactorial nature of facial development precludes the prediction of an inherited pattern of a particular facial abnormality.

Abnormal facial growth and associated malocclusions are sometimes associated with congenital abnormalities and syndromes. Some of these syndromes, such as hemifacial microsomia and mandibulofacial dysostosis (Treacher Collins syndrome), are related to embryonic abnormalities of neural crest cells. Other congenital

abnormalities affecting jaw growth include cleft lip and palate and craniosynostosis (premature fusions of craniofacial sutures). Facial growth abnormalities may be caused by conditions related to maternal systemic influences, for example, fetal alcohol syndrome, which may result in hypoplasia of midface structures.

Environmental influences also play a role in the development of dentofacial deformities. As early as the prenatal stage, intrauterine molding of the developing fetal head may result in a severe mandibular deficiency. Abnormal function after birth also may result in altered facial growth because soft tissue and muscular function often influence the position of teeth and growth of the jaws. Abnormal tongue position or size can affect the position and growth of the maxilla and the mandible (Fig. 26.2). Respiratory difficulty, mouth breathing, and abnormal tongue and lip postures can adversely influence facial growth.[7] Trauma to the bones of the face can result in severe abnormalities of the facial skeleton and the occlusion. In addition to the abnormality that occurs as an immediate result of trauma, further effects on the development of facial bones may occur. In the case of temporomandibular joint (TMJ) trauma in a growing child, significant restriction of jaw function may occur as a result of scarring or bony or fibrous ankylosis. Subsequent alteration of growth may result with deficient or asymmetric mandibular growth (Fig. 26.3).



• **Fig. 26.2** (A) Tongue asymmetry with unilateral hypertrophy. (B) Resulting unilateral open bite.

Evaluation of Patients With Dentofacial Deformity

In the past, patients with dentofacial deformities were often treated by individual practitioners. Some patients have been treated with orthodontics alone, with a resultant acceptable occlusion but a compromise in facial aesthetics. Other patients have had surgery without orthodontics in an attempt to correct a skeletal deformity, which resulted in improved facial aesthetics but a less than ideal occlusion. In addition to orthodontic and surgical needs, these patients often have many other problems requiring periodontic, endodontic, complex restorative, and prosthetic considerations.

Many areas of dental practice, in addition to orthodontics and surgery, must be integrated to address the complex problems of patients with dental deformities. This integrated approach, used throughout the evaluation, presurgical, and postsurgical phases of patient care, provides the best possible results for these patients.[8]

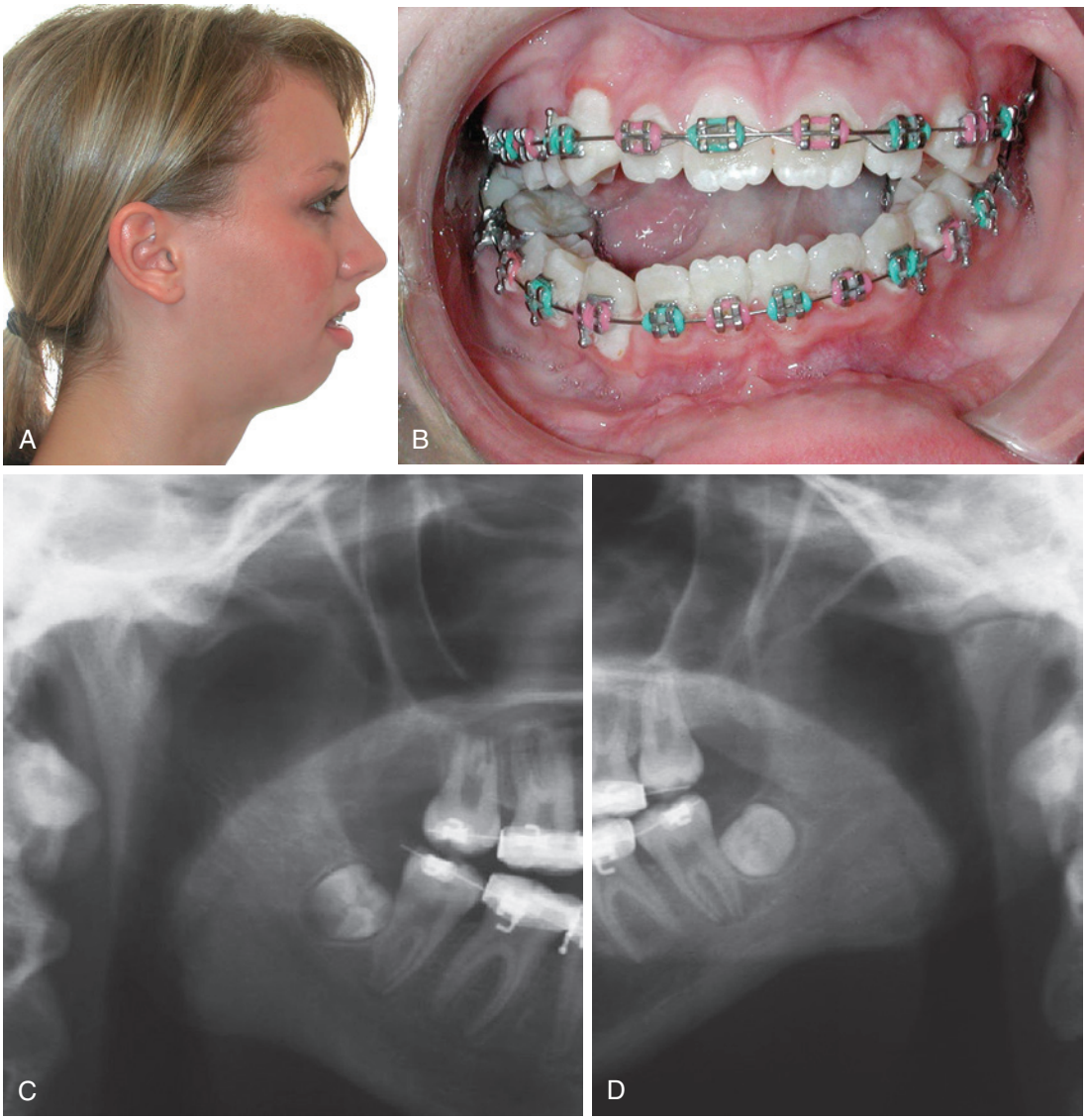
The most important phase in patient care centers on evaluation of the existing problems and definition of treatment goals. At the initial appointment, a thorough interview should be conducted with the patient to discuss the patient's perception of the problems and the goals of any possible treatment. The patient's current health status and any medical or psychological problems that may affect treatment are also discussed at this time.

The involved orthodontist and oral-maxillofacial surgeon should conduct a thorough examination of facial structure, with consideration of frontal and profile aesthetics.

Evaluation of facial aesthetics in the frontal view should assess the presence of asymmetries and evaluate overall facial balance. The evaluation should include assessment of the position of the forehead, eyes, infraorbital rims, and malar eminences; configuration of the nose, including the width of the alar base; paranasal areas; lip morphology; relationship of the lips to incisors; and overall proportional relationships of the face in the vertical and transverse dimensions. Fig. 26.4 demonstrates normal facial proportions. The profile evaluation allows an assessment of the anteroposterior and vertical relationships of all components of the face. The soft tissue configuration of the throat should also be evaluated. Photographic documentation of the pretreatment condition of the patient should be a standard part of the evaluation. Video and digital computerized images have been introduced over the past decade as an additional aid in evaluating facial morphology.

A complete dental examination should include assessment of dental arch form, symmetry, tooth alignment, and occlusal abnormalities in the transverse, anteroposterior, and vertical dimensions. The muscles of mastication and TMJ function should also be evaluated. A screening periodontal examination, including probing, should assess the patient's hygiene and current periodontal health status. Impressions and a bite registration for dental cast construction and evaluation should also be obtained at this time.

Lateral cephalometric and panoramic radiographs are routinely used in the patient evaluation and are an important part of the initial assessment. Initially these were created with conventional radiographic technology. Currently cone-beam computerized tomography (CBCT) has become state of the art for most radiographic examinations of facial bones for the purpose of planning orthognathic surgery. Cephalometric and panoramic views are then reconstructed from the CBCT. In addition to these views, other images, including posterior-anterior views, TMJ images, and detailed three-dimensional (3D) views of any or all of the boney structures of the facial skeleton, can be easily evaluated. The



• **Fig. 26.3** Condylar trauma at an early age resulting in restricted jaw function and subsequent deficient and asymmetric mandibular growth. (A) Profile view. (B) Occlusion with a right side anterior open bite caused by decreased growth in the left mandibular ramus area. (C) Radiograph of the right condyle and ramus (normal). (D) Left side with decreased growth.

cephalometric radiograph can be evaluated by several techniques to aid in the determination of the nature of the skeletal abnormality (Fig. 26.5; Table 26.2).[9,10] An important note, however, is that cephalometric radiographs are only a part of the evaluation process; they are used as adjunctive diagnostic tools in the clinical assessment of the patient's facial structure and occlusion. In difficult, complex cases, it may be helpful to view detailed 3D images of the facial skeleton (Fig. 26.6A). A stereolithic 3D model constructed from computed tomography (CT) data may also provide useful information for surgical planning (see Fig. 26.6B). Computerized digital technology helps integrate cephalometric data with digital images of the face to improve evaluation of the relationship of the underlying facial skeleton and overlying soft tissue. After careful clinical assessment and evaluation of the diagnostic records, a problem list and treatment plan should be developed, combining the opinions of all practitioners participating in the patient's care, including the orthodontist, oral-maxillofacial surgeon, periodontist, and restorative dentist.

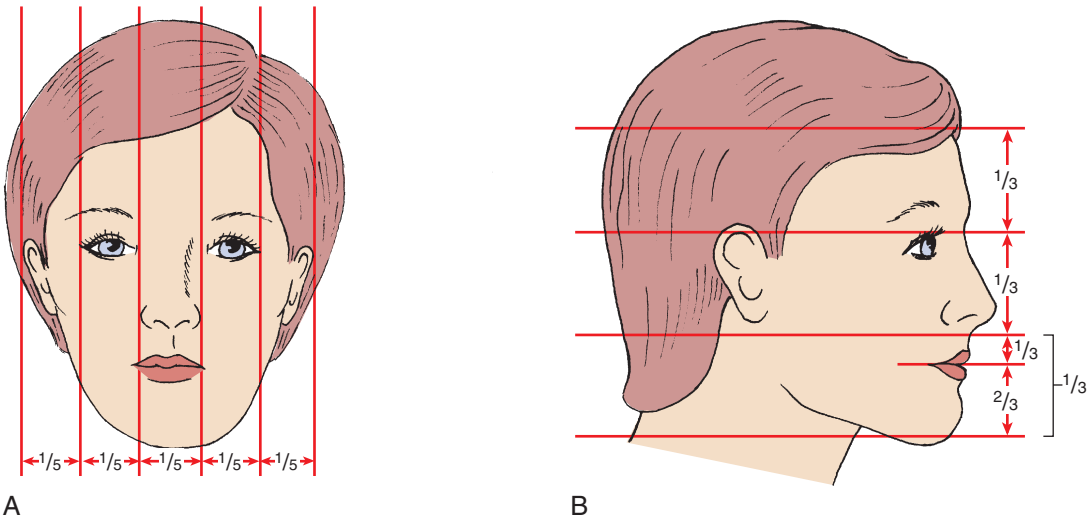
Presurgical Treatment Phase

Periodontal Considerations

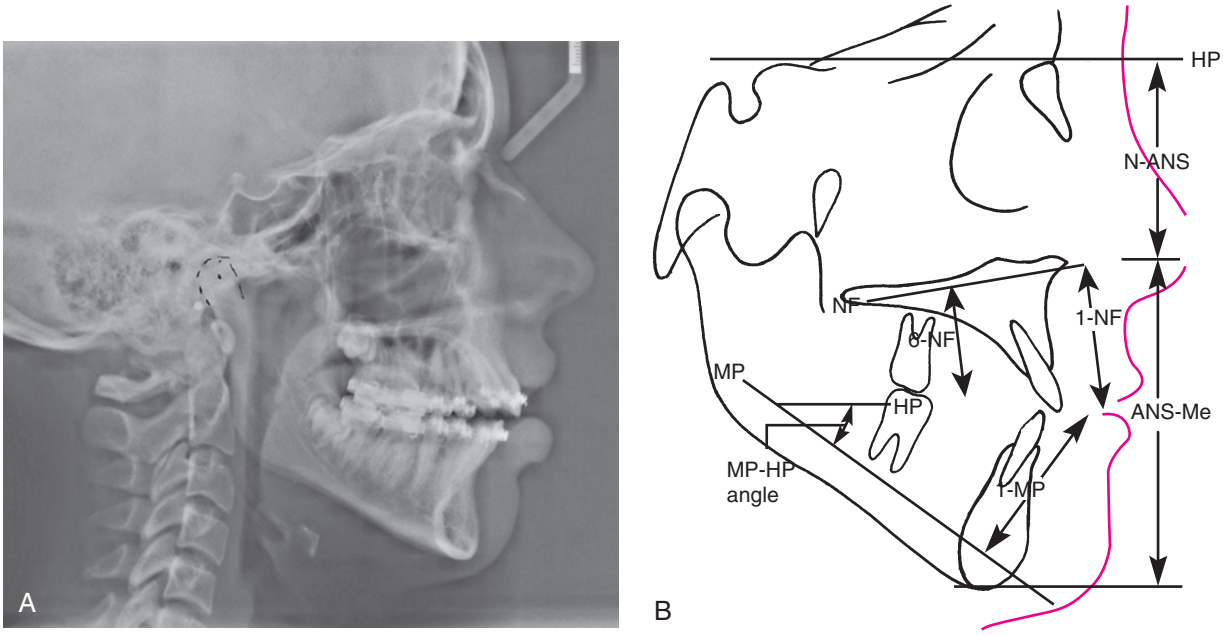
As the first step in treatment, gingival inflammation must be brought under control and the patient's cooperation ensured. In patients who are unwilling or unable to clean their teeth properly before the placement of orthodontic appliances, oral hygiene procedures will be even less effective when complicated by orthodontic band placement.

Periodontal therapy includes oral hygiene instruction, scaling, and root planing; in certain instances, flap surgery to gain access for root planing may be necessary to provide proper tissue health. Whenever possible, it is advisable to delay comprehensive treatment until adequate patient compliance and control of inflammation are achieved.

As a result of the periodontal examination findings and proposed orthodontic and surgical plan, mucogingival surgery is often



• **Fig. 26.4** Normal facial proportions. (A) Representation of proportional relationships of the full-face view. Relationships of medial intercanthal distance, alar base width, and lip proportions to remainder of facial structures are demonstrated. (B) Normal profile proportions demonstrate the relationships of the upper, middle, and lower thirds of the face and the proportional relationships of the lip and chin morphology within the lower third of the face.



• **Fig. 26.5** (A) Lateral cephalometric radiograph. (B) Tracing of the lateral cephalometric head film, with landmarks identified for evaluating facial, skeletal, and dental abnormalities by using a system of cephalometrics for orthognathic surgery (see Table 26.2). *1,* Upper incisor; *6,* upper first molar; *ANS,* anterior nasal spine; *HP,* horizontal plane; *Me,* menton; *MP,* mandibular plane; *N,* nasion; *NF,* nasal floor. (B, Modified from Burstone CJ, James RB, Legan H, et al. Cephalometrics for orthognathic surgery. *J Oral Surg.* 1978;36:269.)

accomplished during this initial phase of therapy to provide a zone of attached keratinized tissue that is more resistant to potential orthodontic and surgical trauma. Soft tissue grafting is indicated in areas that have no keratinized gingiva or where only a thin band of keratinized tissue with little or no attachment is found when an increase in tissue trauma is likely (Fig. 26.7). Such trauma to these areas includes labial orthodontic movement of teeth or a surgical procedure such as an inferior border osteotomy or segmental osteotomies in interdental areas.

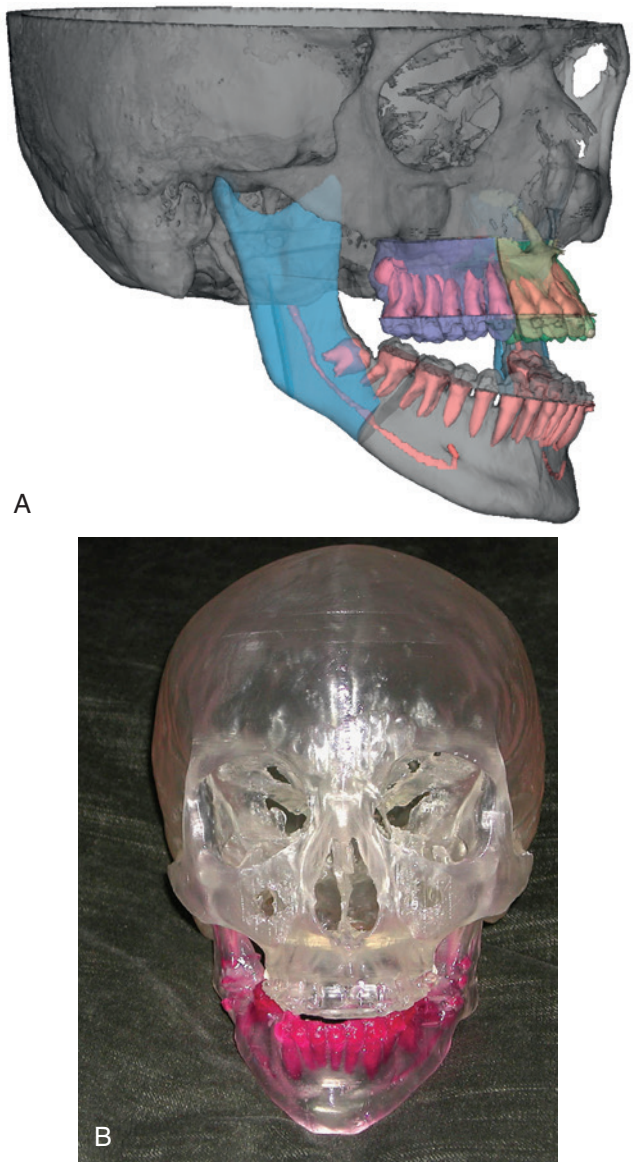
Restorative Considerations

During the presurgical restorative phase, the patient is evaluated for carious lesions and faulty restorations. Teeth should be evaluated endodontically and periodontally for restorability, and any nonrestorable teeth should be extracted before surgical intervention. All carious lesions must be restored early in the presurgical treatment phase. Existing restorations must function for 18 to 24 months during the orthodontic and surgical treatment phases, requiring

TABLE 26.2 Orthognathic Cephalometric Analysis

	Standard (Male)	Standard (Female)
Horizontal (Skeletal)		
N-A-Pg (angle)	3.9 degrees	2.6 degrees
N-A (II HP)	0.0 degrees	2.0 degrees
N-B (II HP)	–5.3 degrees	–6.9 degrees
N-Pg (II HP)	–4.3 degrees	–6.5 degrees
Vertical (Skeletal, Dental)		
N-ANS (HP)	54.7 mm	50.0 mm
ANS-Gn (HP)	68.6 mm	61.3 mm
PNS-N (HP)	53.9 mm	50.6 mm
MP-HP (angle)	23.0 degrees	24.2 degrees
1-NF (NF)	30.5 mm	27.5 mm
1-MP (MP)	45.0 mm	40.8 mm
6-NF (NF)	26.2 mm	23.0 mm
6-MP (MP)	35.8 mm	32.1 mm
Maxilla, Mandible		
PNS-ANS (II HP)	57.7 mm	52.6 mm
Ar-GO (linear)	52.0 mm	46.8 mm
GO-Pg (linear)	83.7 mm	74.3 mm
Ar-GO-Gn (angle)	119.1 degrees	122.0 degrees
Dental		
OP upper-HP (angle)	6.2 degrees	7.1 degrees
OP lower-HP (angle)	–	–
A-B (II OP)	–1.1 mm	–0.4 mm
1-NF (angle)	111.0 degrees	112.5 degrees
1-MP (angle)	95.9 degrees	95.9 degrees

A, A point-anterior maxilla; *ANS,* anterior nasal spine; *Ar,* articulare; *B,* B point-anterior mandible; *Gn,* gnathion; *GO,* gonion; *HP,* horizontal plane; *MP,* mandibular plane; *N,* nasion; *NF,* nasal floor; *OP,* occlusal plane; *Pg,* pogonion; *PNS,* posterionasal spine.
Modified from Burstone CJ, James RB, Legan H, Murphy GA, Norton LA. Cephalometrics for orthognathic surgery. *J Oral Surg.* 1978;36:269.



• **Fig. 26.6** (A) Cone-beam computed tomography scan clearly demonstrating bone deformity in three dimensions with detailed view of skeletal components, tooth root positioning, and location of the inferior alveolar nerve. (B) Stereolithographic model.

that more durable restorative materials (i.e., amalgam and composite resin) be used, even though they may be replaced during the definitive postsurgical treatment phase. It is wise to delay the final restorative treatment until the proper skeletal relationships are achieved and the finishing orthodontics are completed.

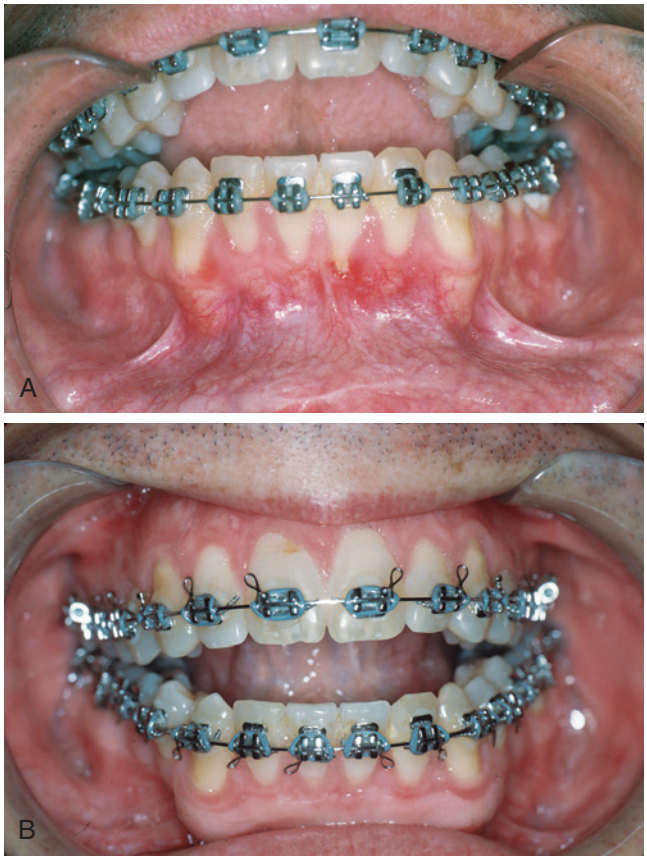
In the edentulous or partially edentulous patient, particular attention is paid to residual ridge shape and contour in denture-bearing areas. The distance between the maxillary tuberosity, posterior mandible, and ramus areas must be evaluated to ensure that adequate space is present for partial or complete dentures. Teeth that serve as removable partial denture abutments should be evaluated for potential retentive undercuts. If minor orthodontic movement can enhance undercuts, this information is conveyed to the orthodontist.

Presurgical Orthodontic Considerations

Obviously not all malocclusions require correction with surgery. When the skeletal discrepancy is minimal and orthodontic compensation does not adversely affect dental or facial aesthetics or posttreatment stability, orthodontic treatment alone may be the treatment of choice. However, in some cases, an adequate occlusal relationship cannot be achieved because of the skeletal discrepancy; some patients may be treated with orthodontic compensation for a skeletal abnormality, resulting in an adequate occlusion but poor facial or dental aesthetics or a poor long-term prognosis for posttreatment retention. These patients should be considered for surgery combined with orthodontic treatment.

Treatment Timing

Treatment of the stable adult deformity can be started without delay, but questions often arise about how best to manage the growing child who is identified as having a developing dentofacial deformity. If the facial pattern is favorable and significant growth potential remains, growth modification with techniques such as functional appliance therapy or headgear may be the preferred



• **Fig. 26.7** (A) Presurgical appearance of gingival tissue labial to lower anterior teeth. An adequate area of attachment and keratinization is visualized. (B) Significant improvement in attachment and keratinization of labial gingival tissue after gingival grafting.

approach. For patients with unfavorable growth patterns or severe skeletal abnormalities or who are unwilling to undergo attempts at growth modification, surgery is usually the preferred treatment. As a general guideline, orthognathic surgery should be delayed until growth is complete in patients who have problems of excess growth, although surgery can be considered earlier for patients with growth deficiencies.

Orthodontic Treatment Objectives

Undesirable angulation of the anterior teeth occurs as a compensatory response to a developing dentofacial deformity. For example, a patient with maxillary deficiency, mandibular excess, or both often has dental compensation for the skeletal abnormality with flared upper incisors and retracted or retroclined lower incisors (Fig. 26.8A–C). Dental compensations for the skeletal deformity are corrected before surgery by orthodontically repositioning teeth properly over the underlying skeletal component, without considerations for the bite relationship to the opposing arch. This presurgical orthodontic movement accentuates the patient's deformity but is necessary if normal occlusal relationships are to be achieved when the skeletal components are properly positioned at surgery (see Fig. 26.8D–F). The surgical treatment then results in an ideal position of the skeletal and dental components (see Fig. 26.8G–I). The opposite dental compensation may occur in maxillary protrusion or mandibular deficiency (Fig. 26.9). Again, the decompensation is aimed at improving angulation of teeth over underlying bone, after which skeletal problems are corrected.

The essential steps in orthodontic preparation are to align the arches individually, achieve compatibility of the arches or arch segments, and establish the proper anteroposterior and vertical position of the incisors. The amount of presurgical orthodontics can vary, ranging from appliance placement with minimal tooth movement in some patients to approximately 12 to 18 months of appliance therapy in those with severe crowding and incisor malposition.

As the patient is approaching the end of orthodontic preparation for surgery, it is helpful to take impressions and evaluate progress models for occlusal compatibility. Minor interferences that exist can be corrected easily with arch wire adjustment and significantly enhance the postsurgical occlusal result. After any final orthodontic adjustments have been made, large stabilizing arch wires are inserted into the brackets, which provide the strength necessary to withstand the forces resulting from intermaxillary fixation (IMF) and surgical manipulation.

Final Treatment Planning

After the completion of the presurgical periodontics, restorative dentistry, and orthodontics, the patient returns to the oral-maxillofacial surgeon for final presurgical planning. The evaluation completed at the initial patient examination is repeated. The patient's facial structure and the malocclusion are reexamined. Presurgical digital photographs and conventional radiographs or CT scans, and impressions or digital scans of the dentition are obtained in preparation for developing the final surgical plan.

Treatment Planning and Image Prediction

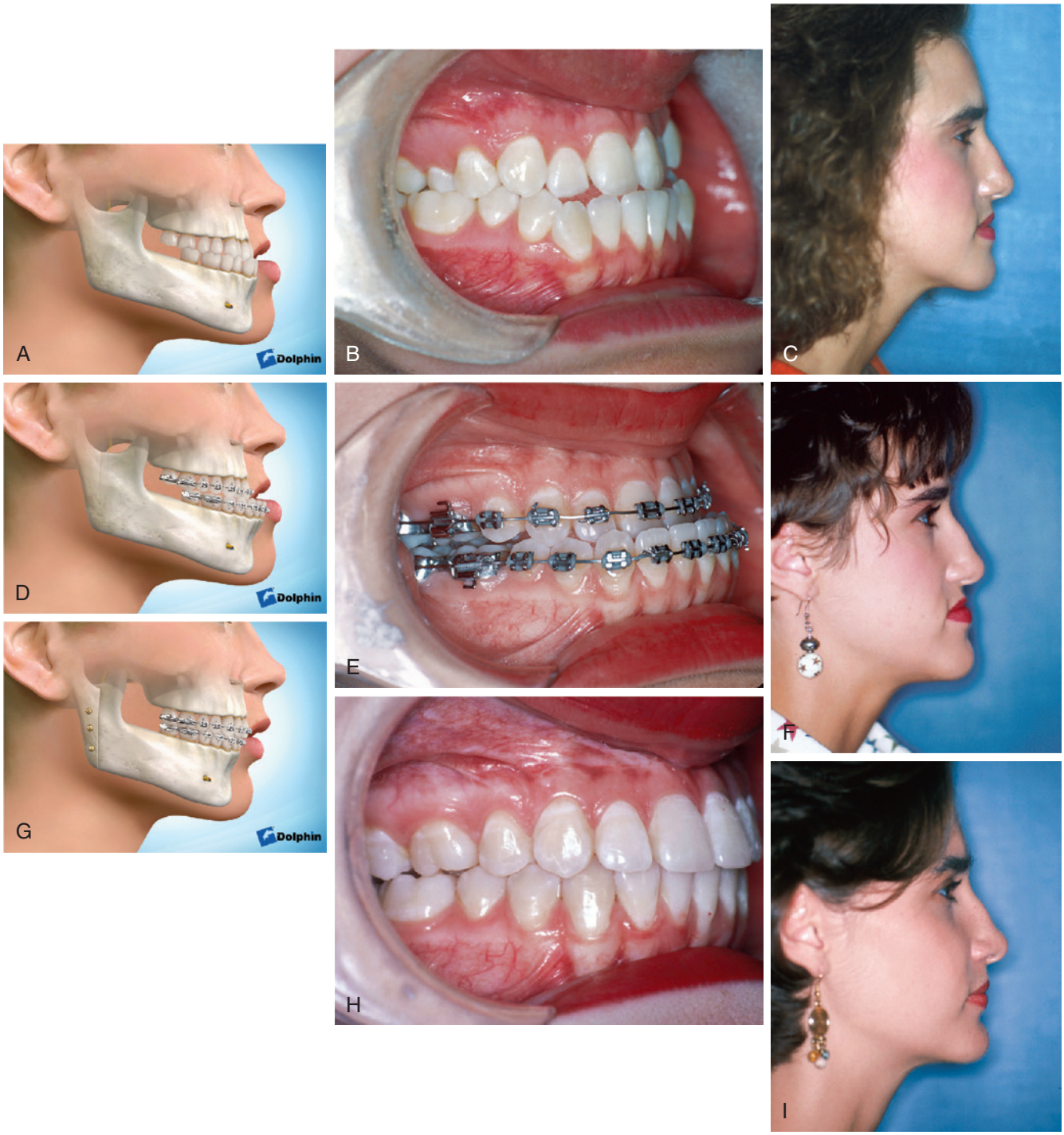
When using a traditional model surgery planning technique, presurgical models, a centric relation bite registration, and face-bow recording for model mounting are completed. Model surgery on a duplicated set of presurgical dental casts determines the exact surgical movements necessary to accomplish the desired postoperative occlusion (Fig. 26.10).

The change in facial appearance can be demonstrated with the use of computer technology by superimposing digital images of the patient's profile over bone landmarks obtained from the cephalometric radiograph. The bone structures are then manipulated to duplicate the bone movements desired at the time of surgery.

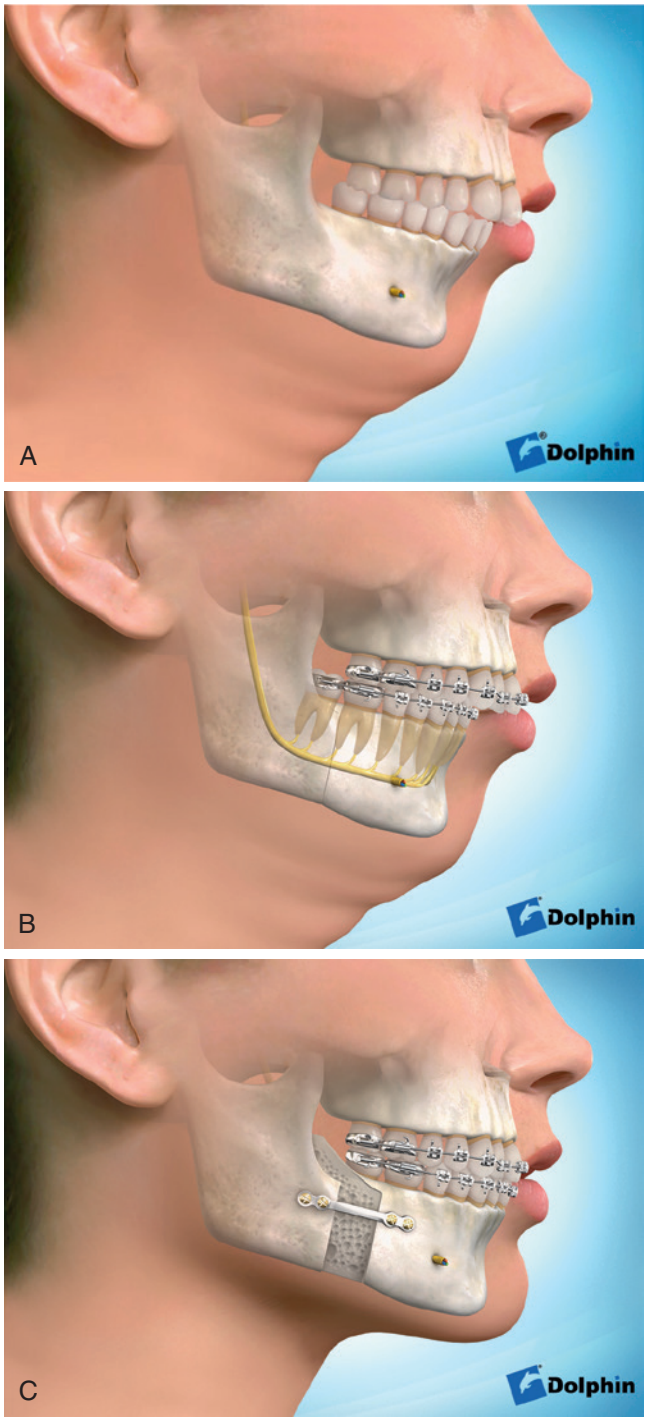
The computer can then produce a digital image that represents the facial aesthetic result produced by the associated facial skeletal change (Fig. 26.11). The advantage of using this type of technology is the ability to predict more accurately the facial changes that may result from a particular surgical correction. The facial images are also more easily evaluated by patients, allowing them to assess the predicted results and provide input into the surgical treatment plan. One disadvantage of this technology is that the predictions are limited to 2D predictions showing only the lateral profile. Another disadvantage of the technology is related to the inability of the computer to predict accurately every type of surgical change for every patient.[11] Different muscle tone and skin thicknesses and variable soft tissue responses to bone change, for example, make it impossible for the computer to predict each individual variation precisely.

Three-Dimensional Computerized Surgical Planning

Recent advances in imaging technology and 3D computer planning have improved the precision in surgical correction of complex



• **Fig. 26.8** (A) Class III skeletal malocclusion with maxillary deficiency and mandibular excess. (B) Dental compensation includes retroclined lower incisors and proclined upper incisors. (C) Facial profile. (D) After initial orthodontic treatment before surgery. (E) Dental compensations are removed with proclination of the lower incisors and retroclination of the upper incisors, which obviously increases the severity of malocclusion and facial discrepancy. (F) Facial profile at this stage. (G) Surgical correction with posterior positioning of mandible and advancement of maxilla. (H) Ideal occlusion. (I) Facial profile after treatment is complete.



• **Fig. 26.9** (A) Class II occlusion with compensation demonstrating proclination of lower incisors and upright upper incisors. (B) After orthodontic decompensation. (C) After surgical correction with mandibular advancement.

dentofacial deformities.[12,13] Conventional CT or CBCT data are combined with laser, optical, or CT scans of the dentition, to produce a computerized model of the skeletal and occlusal abnormalities. The planned osteotomies can then be designed and surgical movements created to reposition the skeletal and occlusal components into the corrected positions (Fig. 26.12). This type of surgical planning provides an improved understanding of the bone movements required at surgery. The potential difficulty with bone interference, the need for possible bone grafting and recontouring required to achieve symmetry can all be clearly visualized. The splint can also be designed using 3D computer technology with splint construction completed using computer aided design and computer aided manufacturing (CAD-CAM) rapid prototyping.

The ability to use 3D technology to predict facial aesthetic changes is also emerging. Digital photographs are superimposed on the 3D CT data and a virtual model of the face is constructed. Movement of the skeletal components produces soft tissue changes that can then be visualized in three dimensions. Although the precision of the predictions has not been studied extensively, this technology will continue to improve and provide useful information to doctors and patients.

After completion of the conventional or 3D virtual model surgery and facial imaging predictions, the orthodontist and the general dentist are often consulted to ensure that the predicted occlusal result is acceptable to all practitioners involved in the patient's treatment. Any orthodontic or restorative changes necessary to improve postsurgical position should be planned at this time.

Surgical Treatment Phase

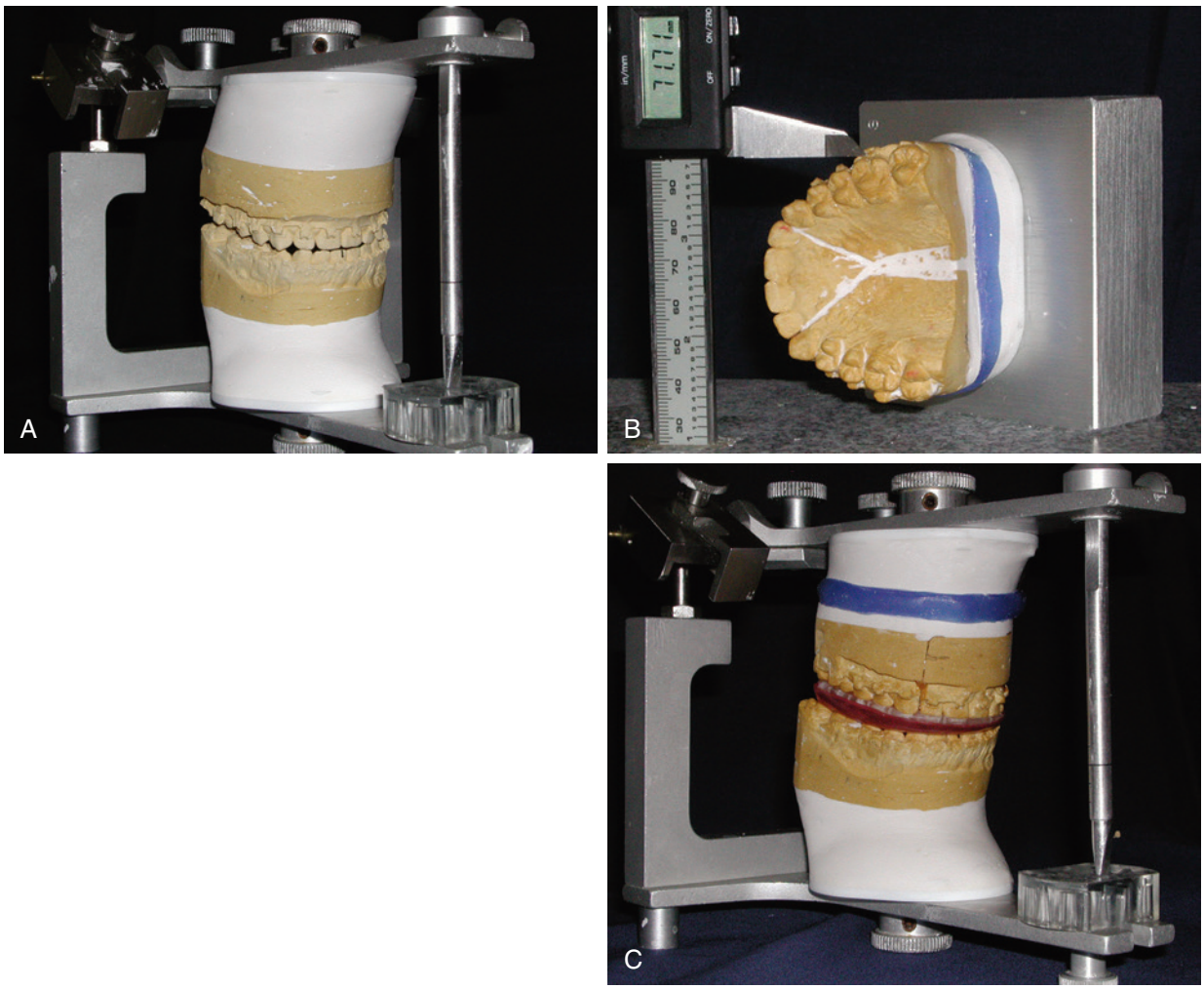
Dentofacial abnormalities frequently can be treated by isolated procedures in the mandible or the maxilla and the midface area. Because abnormalities can obviously occur in the maxilla and the mandible, surgical correction frequently requires a combination of surgical procedures. The following sections describe a variety of surgical procedures completed as isolated osteotomies or as combination procedures.

Mandibular Excess

Excess growth of the mandible frequently results in an abnormal occlusion with class III molar and cuspid relationships and a reverse overjet in the incisor area. An obvious facial deformity may also be evident. Facial features associated with mandibular excess include a prominence of the lower third of the face, particularly in the area of the lower lip and chin in the anteroposterior and vertical dimensions. In severe cases, the large reverse overjet may preclude the patient's ability to obtain adequate lip closure without abnormal strain of the orbicularis oris muscles.

Mandibular excess was one of the first dentofacial deformities recognized as being best treated by a combination of orthodontics and surgery. Although surgical techniques for correction of mandibular excess were reported as early as the late 1800s, widespread use of currently acceptable techniques only began in the middle of the 20th century. Early techniques for treatment of mandibular prognathism dealt with the deformity by removing sections of bone in the body of the mandible, which allowed the anterior segment to be moved posteriorly (Fig. 26.13). When the reverse overjet relationship is isolated to the anterior dentoalveolar area of the mandible, a subapical osteotomy technique can be used for correction of mandibular dental prognathism.[14] In this technique, bone is removed in the area of an extraction site of a premolar or molar tooth, and the anterior dentoalveolar segment of the mandible is moved to a more posterior position (Fig. 26.14). Although these procedures are rarely used, they are occasionally performed in cases with unusual arch forms in combination with edentulous spaces.

In the early 1950s, Caldwell and Letterman popularized an osteotomy performed in the ramus of the mandible for the correction of mandibular excess.[15] In this technique, the lateral aspect of the



• **Fig. 26.10** Model surgery used to determine direction and distance of surgical movement necessary to achieve desired postoperative occlusion and facial aesthetics. (A) Casts mounted on a semiadjustable articulator. (B) Repositioning of maxillary cast using a precision measuring instrument. Distances of model surgical movements are coordinated between desired facial aesthetics and movements necessary to create the ideal postoperative occlusion. (C) Maxillary cast remounted on a semiadjustable articulator after precision movements have been completed and verified. Intraocclusal wafers are constructed on this final occlusal setup for use at the time of surgery to align osteotomies and dental segments into the desired postsurgical position.

ramus is exposed through a submandibular incision, the ramus is sectioned in a vertical fashion, and the entire body and anterior ramus section of the mandible are moved posteriorly, which places the teeth in proper occlusion (Fig. 26.15).

The proximal segment of the ramus (i.e., the portion attached to the condyle) overlaps the anterior segment, and the jaw is stabilized during the healing phase with wiring of the bone segments combined with jaw immobilization using IMF. The extraoral approach is rarely used. A similar technique is performed with an intraoral incision and an angulated oscillating saw (Fig. 26.16).[16] The design of the osteotomy is identical to that performed through an extraoral incision. The bone segments can be stabilized using IMF, with or without direct wiring of the segments or using rigid fixation with bone plates or screws, eliminating the need for IMF. The advantages of the intraoral technique include elimination of the need for skin incision and decreased risk of damage to the mandibular branch of the facial nerve. Fig. 26.17 demonstrates the clinical results of a patient treated with an intraoral vertical ramus osteotomy to correct mandibular excess.

Another popular technique for correction of mandibular prognathism is the bilateral sagittal split osteotomy (BSSO) first described by Trauner and Obwegeser and later modified by Dalpont, Hunsick, and Epker.[17-20] The BSSO is accomplished through a transoral incision similar to that for the intraoral vertical ramus osteotomy. The osteotomy splits the ramus and posterior body of the mandible in a sagittal fashion, which allows setback or advancement of the mandible (Fig. 26.18). The telescoping effect in the area of the osteotomy produces large areas of bone overlap that have the flexibility necessary to move the mandible in several directions. The BSSO technique has become one of the most popular methods for treatment of mandibular deficiency and mandibular excess. Disadvantages include potential trauma of the inferior alveolar nerve, with subsequent decreased sensation, which

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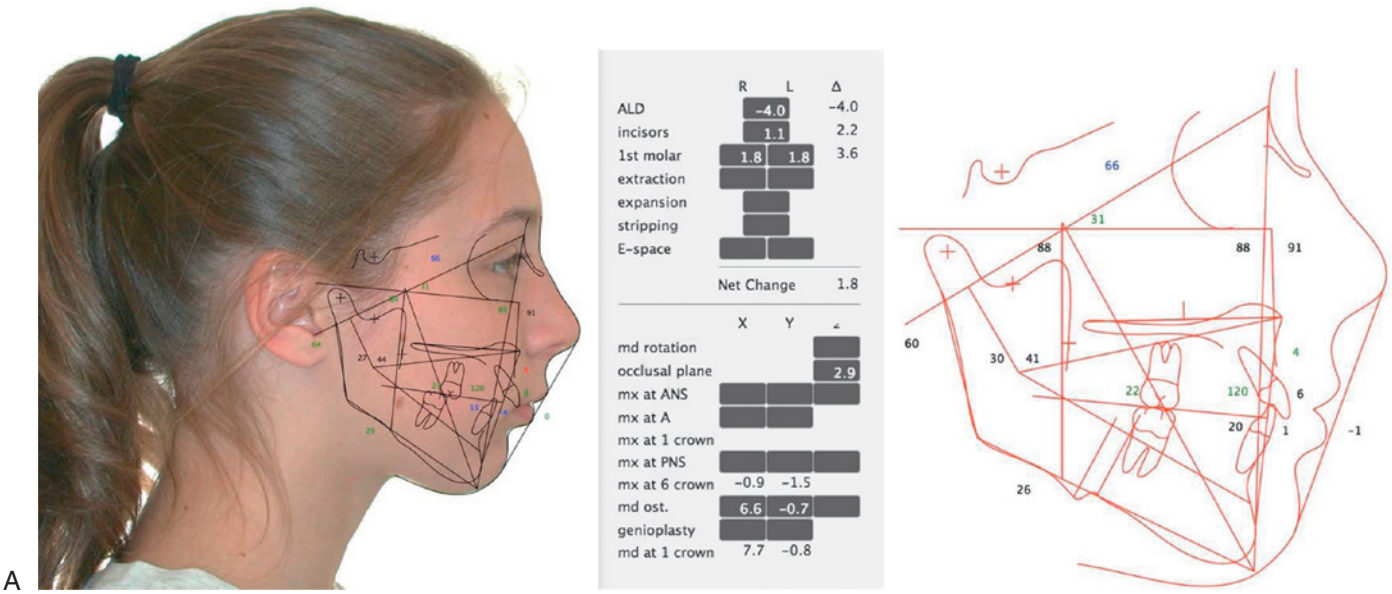
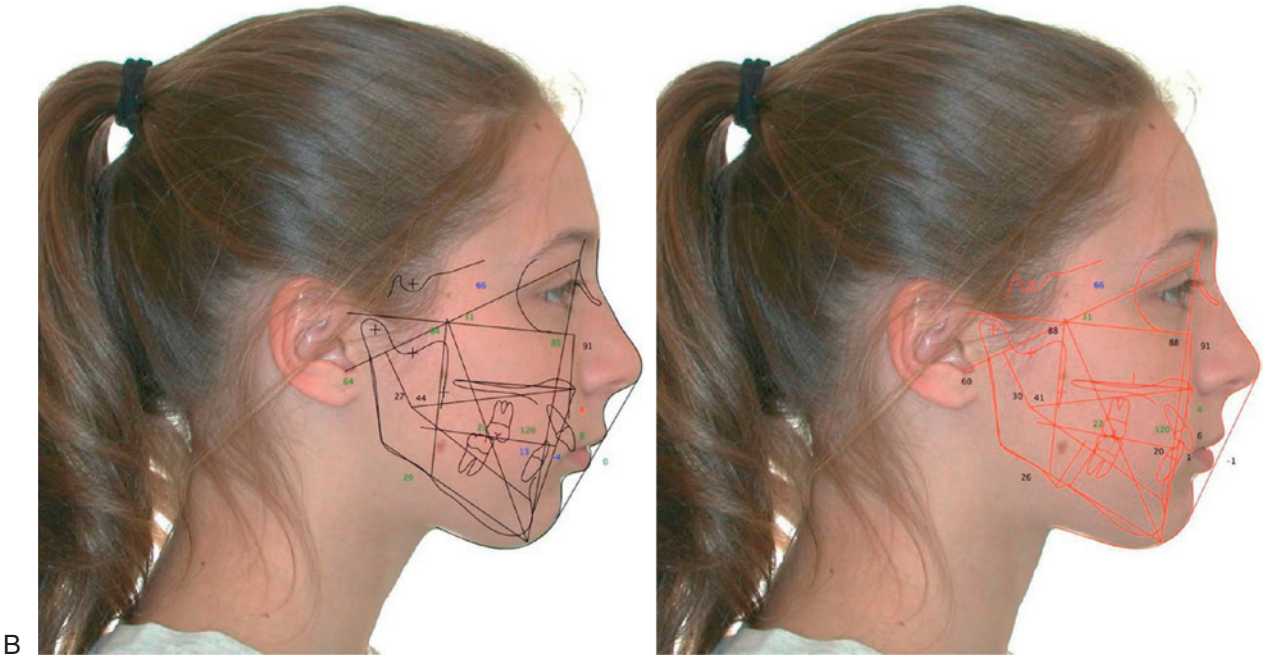
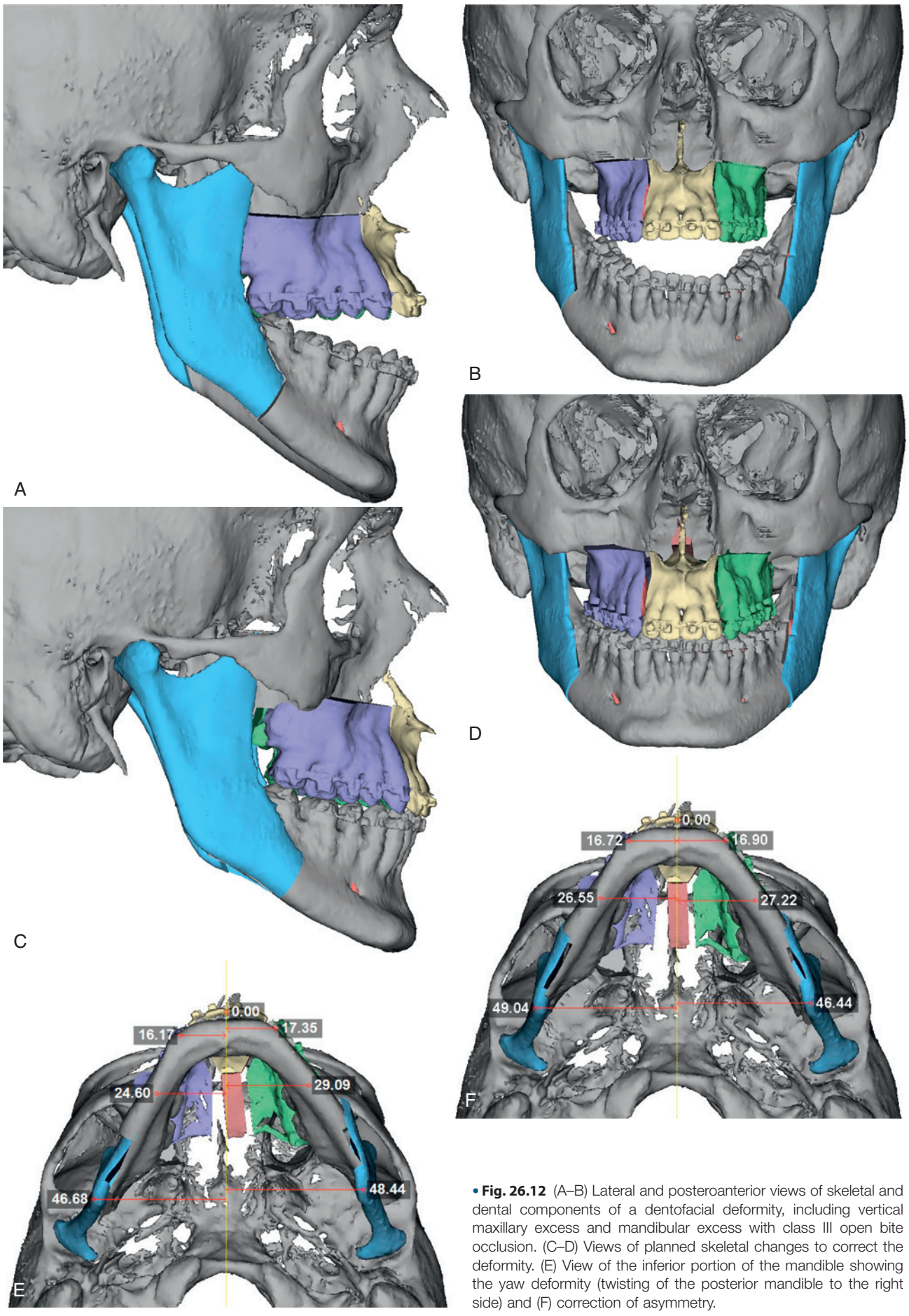
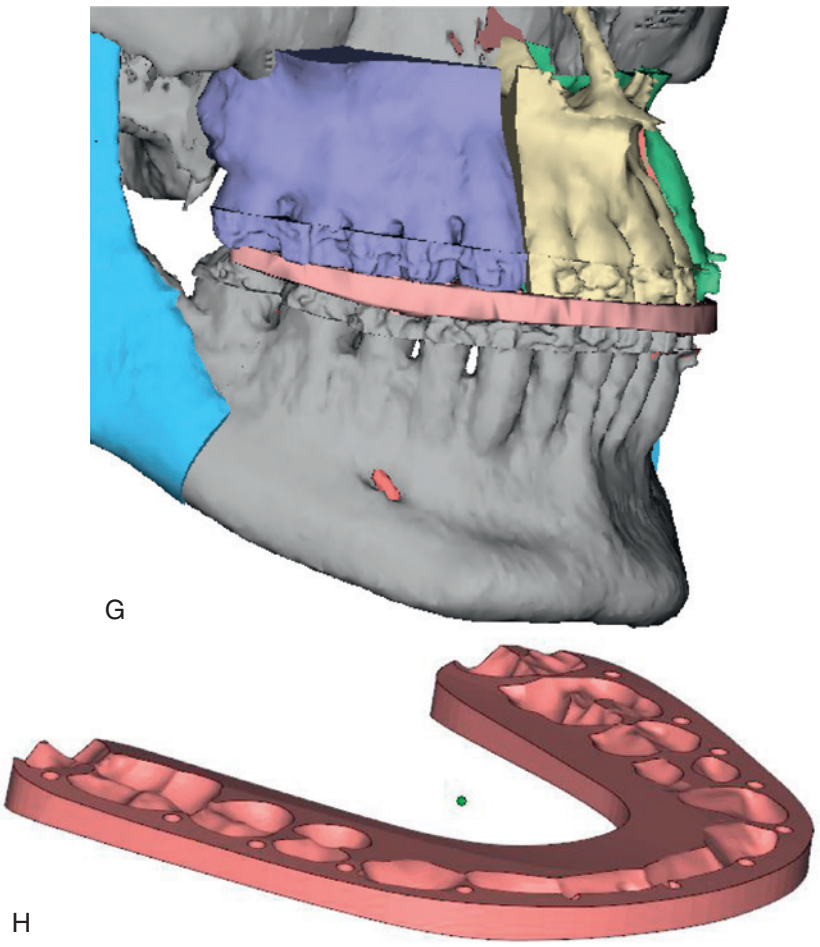




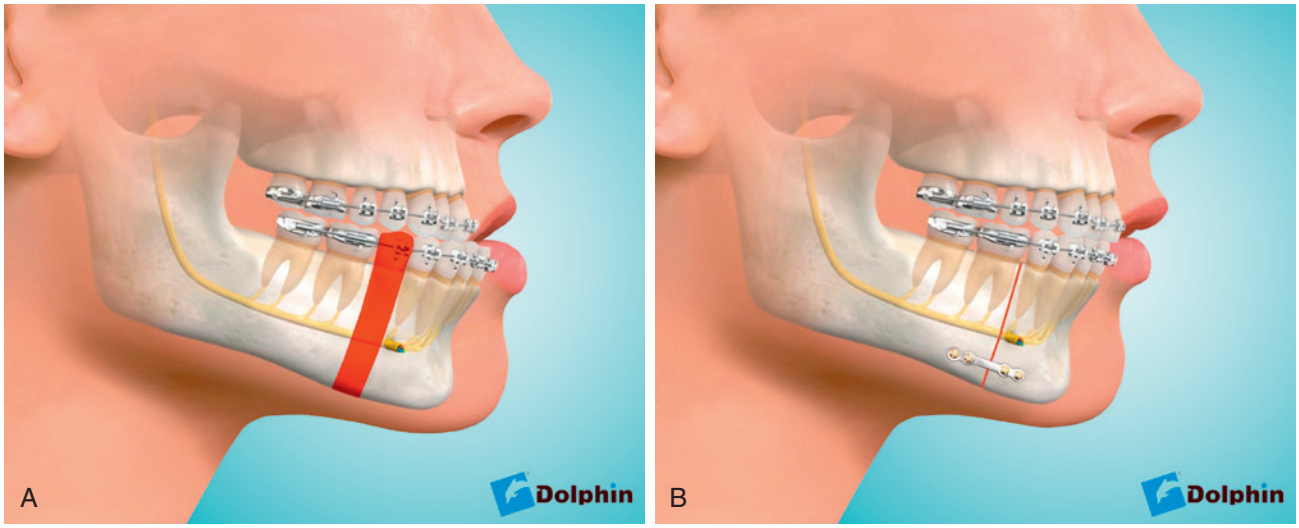
• **Fig. 26.11** Computerized imaging for dentofacial surgical treatment planning. A digital image is obtained and placed in the computer's memory. Landmarks from cephalometric tracing are superimposed over the digital image of the face. (A) Portions of cephalometric tracing can be moved to duplicate the anticipated surgical movements. The computer then manipulates the image to depict soft tissue changes. Digital images displayed on the computer monitor show predicted facial changes. (B) Presurgical and estimated final images that would result from anticipated surgical procedure (in this case, maxillary superior repositioning and chin advancement). (Courtesy Quick Ceph Systems, Inc., San Diego, CA.)



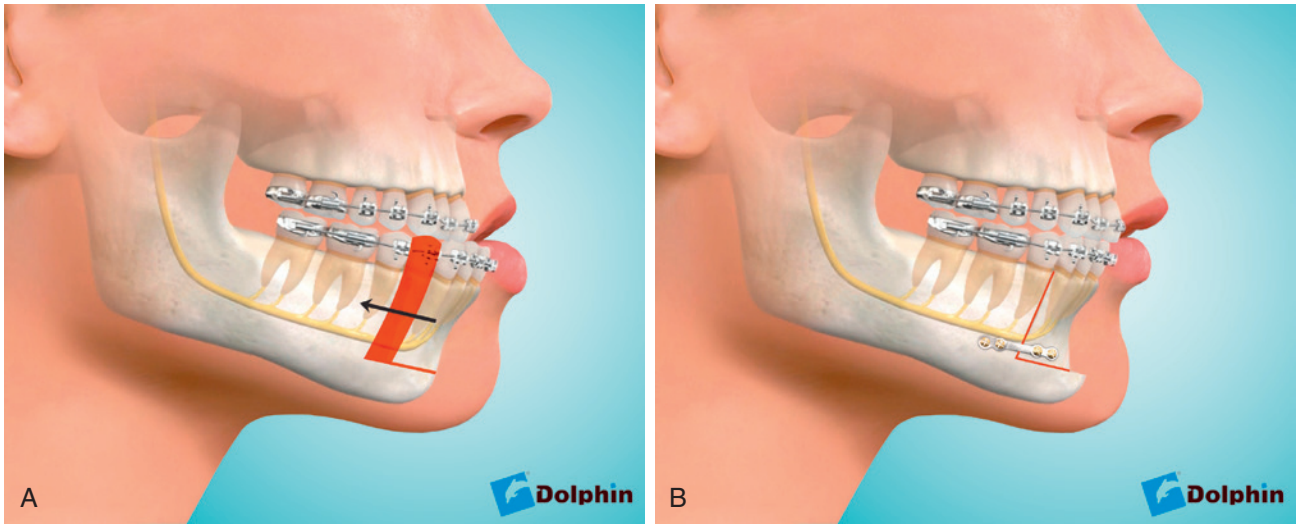
• **Fig. 26.12** (A–B) Lateral and posteroanterior views of skeletal and dental components of a dentofacial deformity, including vertical maxillary excess and mandibular excess with class III open bite occlusion. (C–D) Views of planned skeletal changes to correct the deformity. (E) View of the inferior portion of the mandible showing the yaw deformity (twisting of the posterior mandible to the right side) and (F) correction of asymmetry.



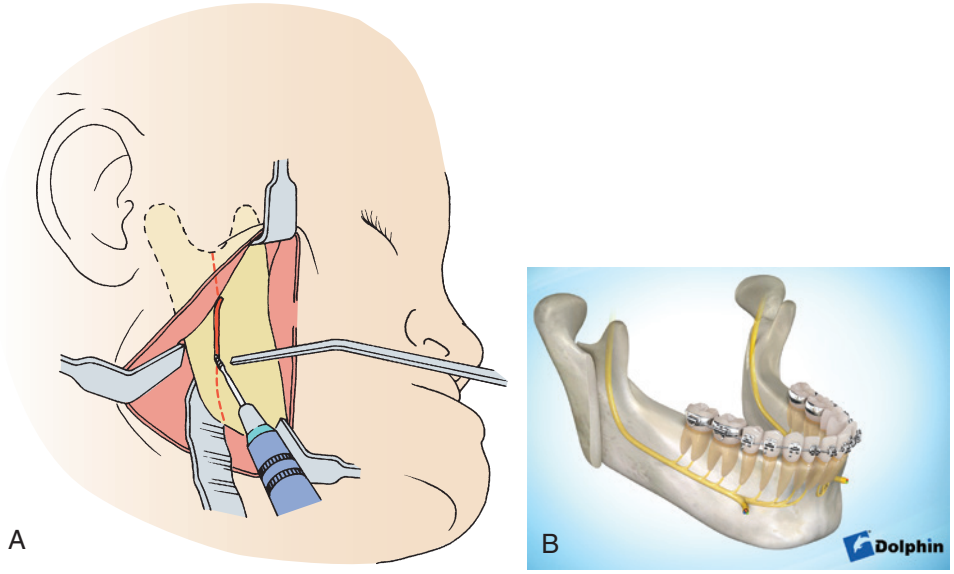
• **Fig. 16.12, cont'd** (G) Splint designed to guide positioning of the segments during surgery and numeric measurement of changes that will occur during surgery. (H) Computer image of splint.



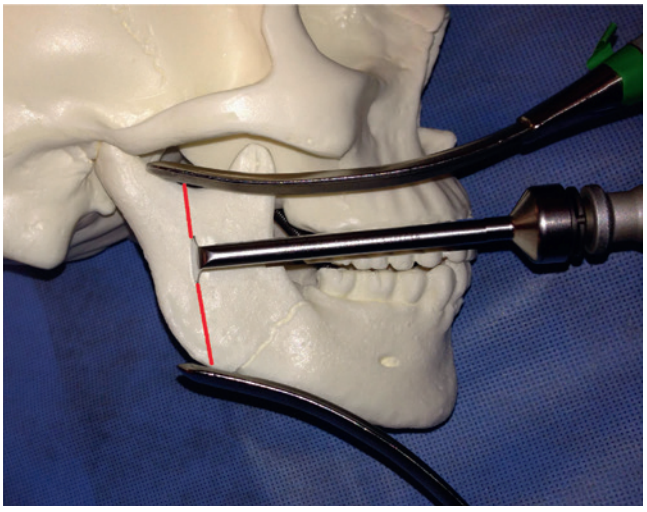
• **Fig. 26.13** Body ostectomy with resection of a portion of the body of the mandible followed by posterior repositioning of the anterior segment. (A) Preoperative view. (B) Postoperative view.



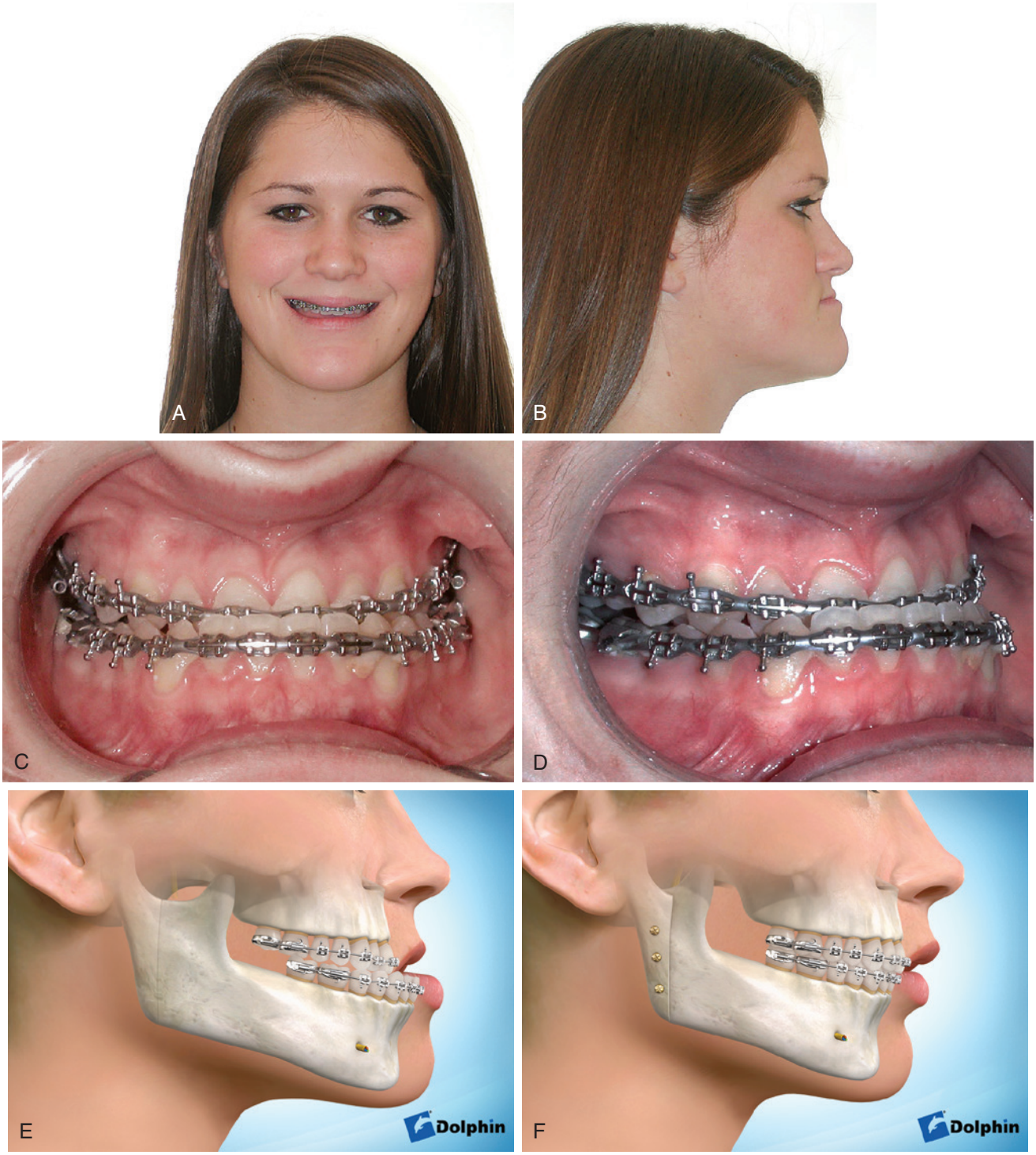
• **Fig. 26.14** Anterior mandibular subapical osteotomy. (A) Removal of premolar teeth and bone in the area of the extraction sites. (B) After separation, the anterior dentoalveolar segment is repositioned posteriorly, extraction sites are closed, and the anterior reverse overjet relationship is corrected.



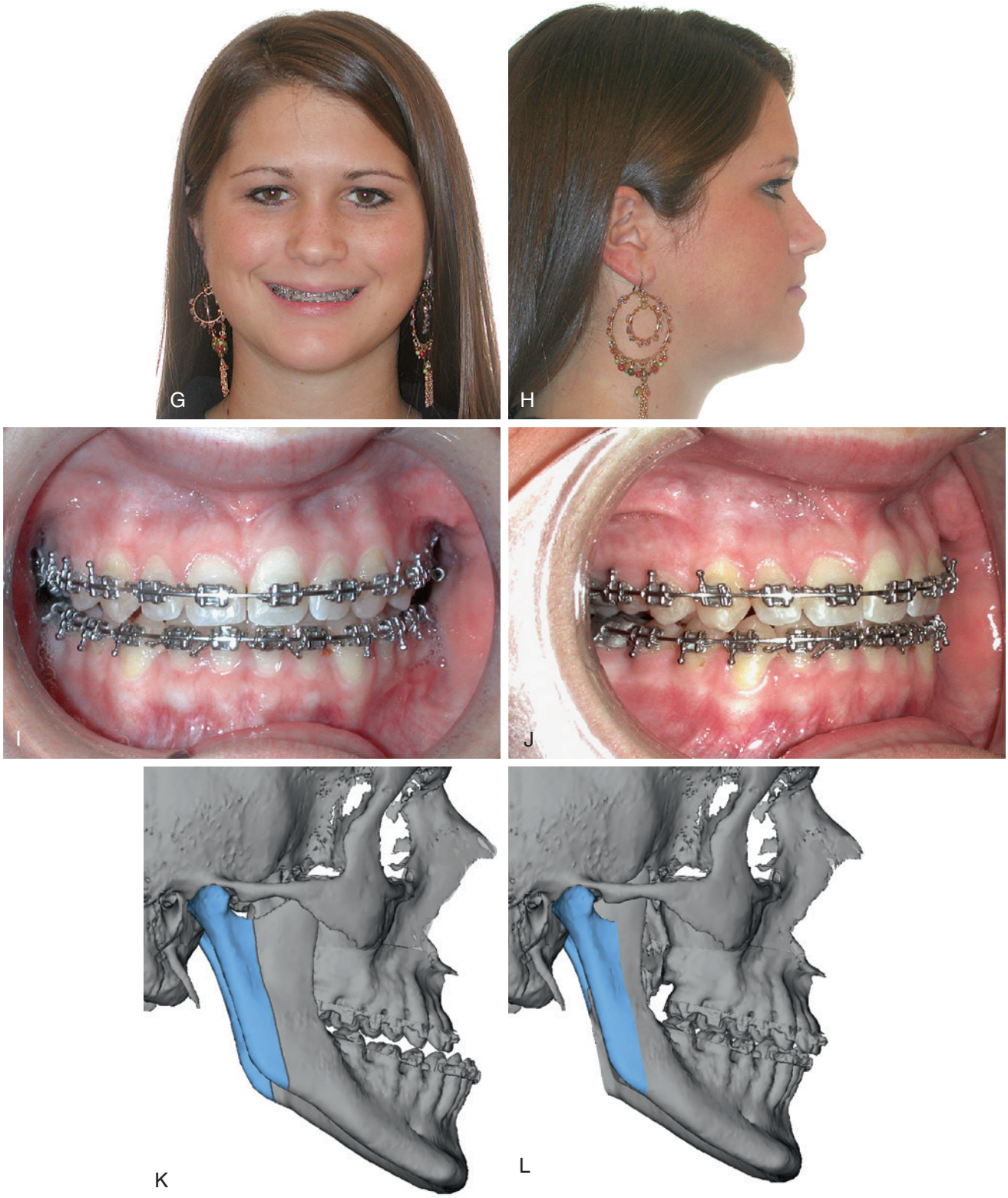
• **Fig. 26.15** Extraoral approach for vertical ramus osteotomy. (A) Submandibular approach to the lateral aspect of the ramus showing the vertical osteotomy from the sigmoid notch area to the angle of the mandible. (B) Overlapping of segments after posterior repositioning of the anterior portion of the mandible. The proximal segment containing the condyle is overlapped on the lateral aspect of the anterior portion of the ramus.



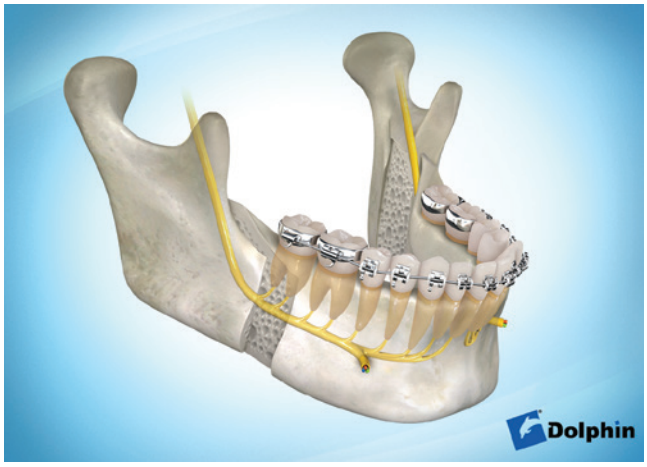
• **Fig. 26.16** Intraoral technique for vertical ramus osteotomy with an angulated oscillating saw.



• **Fig. 26.17** Mandibular excess. (A–B) Preoperative facial aesthetics demonstrate typical features of a class III malocclusion resulting from mandibular excess. (C–D) Presurgical occlusal images. (E–F) Diagram of the intraoral vertical ramus osteotomy with posterior positioning of the mandible and rigid fixation. Postoperative frontal and profile views of the patient seen in (A) and (B). *Continued*



•**Fig.26.17,cont'd** (G–H) Postoperative frontal and profile view of patient seen in (A) and (B). (I–J) Postoperative occlusion seen in (C) and (D). (K–L) Preoperative and postoperative radiographs.



• **Fig. 26.18** Sagittal split osteotomy. The ramus of the mandible is divided by creating a horizontal osteotomy on the medial aspect of the mandible and a vertical osteotomy on the lateral aspect of the mandible. These are connected by an anterior ramus osteotomy. The lateral cortex of the mandible is then separated from the medial aspect, and the mandible is advanced or set back for correction of mandibular deficiency or excess, respectively.

may be permanent, in the area of the lower lip and chin during the immediate postoperative period.

Mandibular Deficiency

The most obvious clinical feature of mandibular deficiency is the retruded position of the chin as viewed from the profile aspect. Other facial features often associated with mandibular deficiency may include an excess labiomental fold with a procumbent appearance of the lower lip, abnormal posture of the upper lip, and poor throat form. Intraorally, mandibular deficiency is associated with class II molar and canine relationships and an increased overjet in the incisor area.

Surgical correction of mandibular deficiency was described as early as 1909. However, early results with surgical advancement of the mandible before the 1950s were extremely disappointing. In 1957, Robinson described surgical correction of mandibular deficiency using an extraoral surgical approach, a vertical osteotomy, and iliac crest bone grafts in the area of the osteotomy defect.[21] Several modifications of this technique were described over subsequent years. This type of extraoral approach may be useful in rare circumstances, including severely abnormal bone anatomy or for revision surgery (see Fig. 26.30). However, the extraoral incisions have the disadvantages of facial scarring and potential injury to branches of the facial nerve.

Currently the BSSO, described previously in this chapter for mandibular setback, is the most popular technique for mandibular advancement (Fig. 26.19). This procedure is readily accomplished through an intraoral incision. The significant bone overlap produced with the BSSO allows for adequate bone healing and improved postoperative stability. The osteotomy is frequently stabilized with rigid fixation plates or screws, eliminating the need for IMF.

If the anteroposterior position of the chin is adequate but a class II malocclusion exists, a total subapical osteotomy may be the technique of choice for mandibular advancement (Fig. 26.20). By combining the osteotomy with interpositioned bone grafts, this technique can be used to increase lower facial height.

When a proper occlusal relationship exists or when anterior positioning of the mandible would not be sufficient to produce adequate projection of the chin, an inferior border osteotomy (i.e., genioplasty) with advancement may also be performed. This technique is usually performed through an intraoral incision. The inferior portion of mandible is osteotomized, moved forward, and stabilized (Fig. 26.21A, C–F). In addition to anterior or posterior repositioning of the chin, vertical reduction or augmentation and correction of asymmetries can also be accomplished with inferior border osteotomies. Alloplastic materials can occasionally be used to augment chin projection; the material is onlayed in areas of bone deficiencies (see Fig. 26.21B).

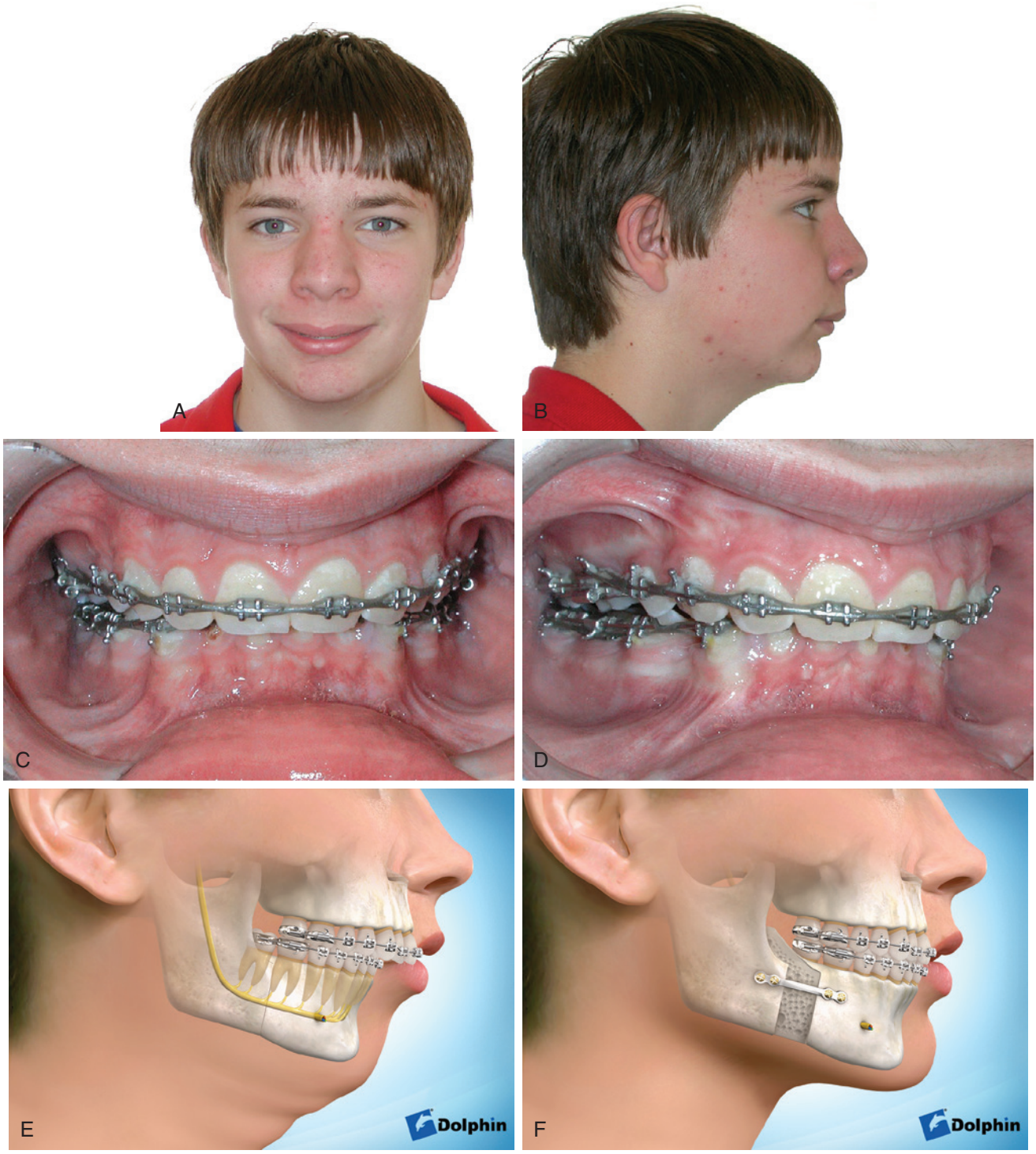
Maxillary Excess

Excessive growth of the maxilla may occur in the anteroposterior, vertical, or transverse dimensions. Surgical correction of dentofacial deformities with total maxillary surgery (i.e., Le Fort I) has only become popular since the early 1970s. Before that time, maxillary surgery was performed on a limited basis, and most techniques repositioned only portions of the maxilla with segmental surgery. During the early years of maxillary surgery, many techniques were performed in two stages: Facial or buccal cuts were performed during one operation, then sectioning of palatal bone was performed 3 to 4 weeks later. This staging was done under the assumption that this was necessary to maintain adequate vascular supply to the osteotomized segment. As experience and understanding of these techniques increased, several procedures for anterior and posterior segmental surgery evolved that used single-stage techniques.[22-24] In the early 1970s, research by Bell et al. demonstrated that total maxillary surgery could be performed without jeopardizing the vascular supply to the maxilla.[25] This work showed that the normal blood flow in the bone segments from larger feeding vessels could be reversed under certain surgical conditions. If a soft tissue pedicle is maintained in the palate and gingival area of the maxilla, the transosseous and soft tissue collateral circulation and anastomosing vascular plexuses of the gingiva, palate, and sinus can provide adequate vascular supply, which allows mobilization of the total maxilla. Total maxillary osteotomies are currently the most common procedures performed for correction of anteroposterior, transverse, and vertical abnormalities of the maxilla.[26]

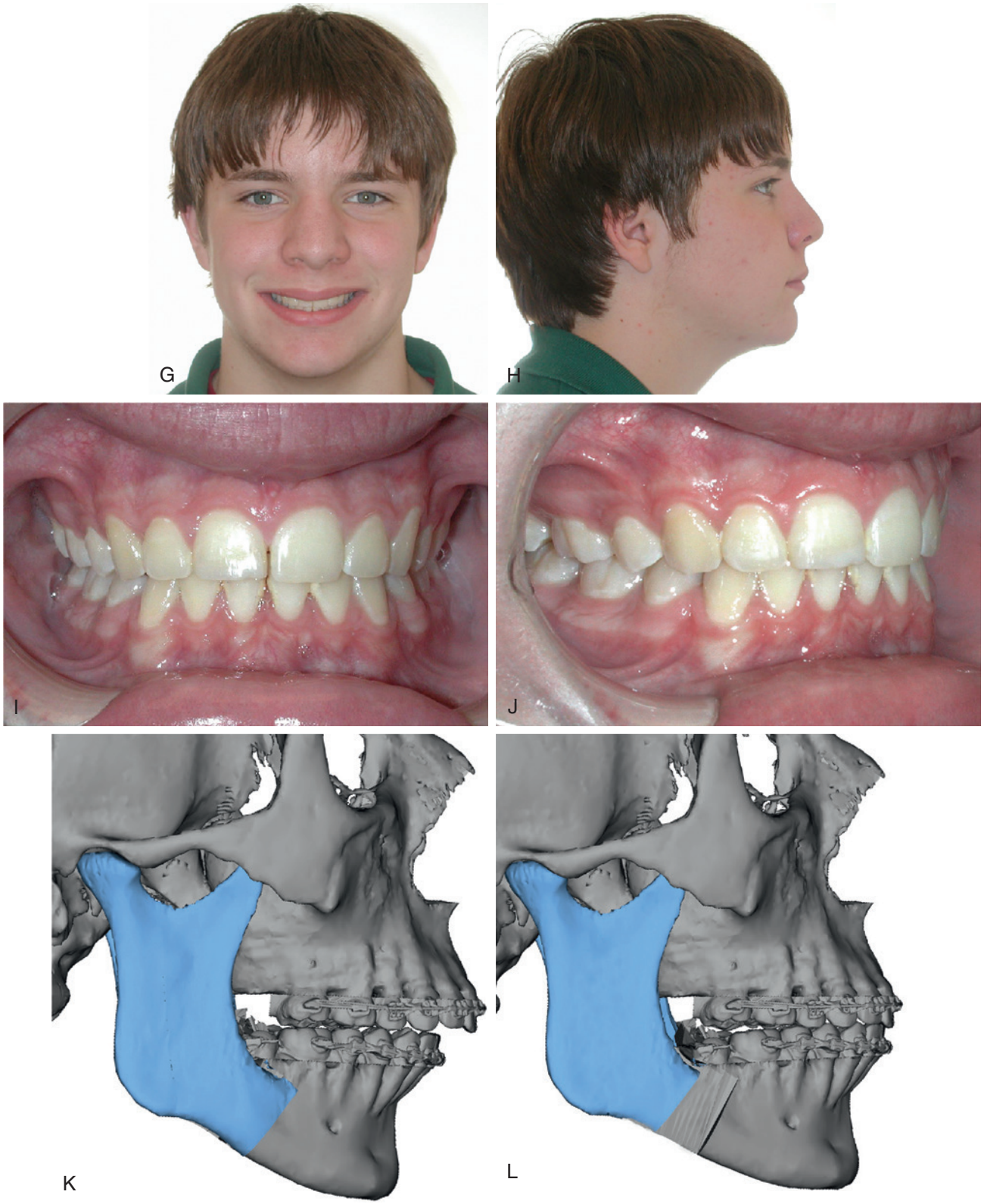
Vertical maxillary excess may result in associated facial characteristics, including elongation of the lower third of the face; a narrow nose, particularly in the area of the alar base; excessive incisive and gingival exposure; and lip incompetence (Fig. 26.22).

These patients may exhibit class I, class II, or class III dental malocclusions. A transverse maxillary deficiency with a posterior cross-bite relationship, constricted palate, and narrow arch form is often seen with this deformity.

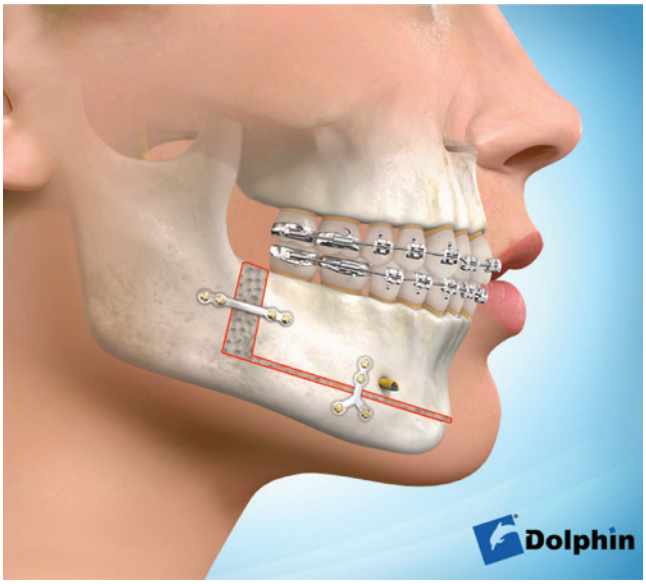
Vertical maxillary excess is frequently associated with an anterior open-bite relationship (i.e., apertognathia). This results from excessive downward growth of the maxilla, causing downward rotation of the mandible as a result of premature contact of posterior teeth. To correct this problem, the maxilla is repositioned superiorly (impacted), particularly in the posterior area. This allows the mandible to rotate upward and forward, establishing contact in all areas of the dentition. In some cases, the occlusal plane of the maxilla is level after orthodontic preparation, and the open-bite can be corrected by repositioning the maxilla in one piece (Fig. 26.23A–D). In other cases, a step in the occlusal plane must be



• **Fig. 26.19** Mandibular advancement. (A–B) Preoperative facial aesthetics demonstrating clinical features of mandibular deficiency. (C–D) Preoperative occlusion demonstrating a class II relationship and overjet. (E–F) Diagrammatic representation of bilateral sagittal split osteotomy with advancement of the mandible.



• **Fig. 26.19, cont'd** (G–H) Postoperative facial appearance. (I–J) Postoperative occlusion. (K–L) Preoperative and postoperative radiographs.



• **Fig. 26.20** Total subapical osteotomy. The dentoalveolar segment of the mandible is moved anteriorly, allowing correction of class II malocclusion without increasing chin prominence.

leveled to achieve the desired occlusion. This requires repositioning of the maxilla in segments (see Fig. 26.23E–H).

Anteroposterior maxillary excess results in a convex facial profile usually associated with incisor protrusion and a class II occlusal relationship. Total maxillary surgery can be completed to correct this problem.[27] In some cases, the entire maxilla can be moved in one piece in a posterior direction. In addition to procedures in which the maxilla is moved in one piece, bone can be sectioned into dentoalveolar segments to allow repositioning in the anteroposterior, superior, or inferior directions or to allow expanding in the transverse direction. Fig. 26.24 demonstrates a three-piece maxillary osteotomy performed to correct anteroposterior maxillary excess combined with vertical deficiency.

Maxillary and Midface Deficiency

Patients with maxillary deficiency commonly appear to have a retruded upper lip, deficiency of the paranasal and infraorbital rim areas, inadequate tooth exposure while smiling, and a prominent chin relative to the middle third of the face. Maxillary deficiency may occur in the anteroposterior, vertical, and transverse planes. The patient's clinical appearance depends on the location and severity of the deformity. In addition to the abnormal facial features, a class III malocclusion with reverse anterior overjet is frequently seen.

The primary technique for correction of maxillary deficiency is the Le Fort I osteotomy. This technique can be used for advancement of the maxilla to correct a class III malocclusion and associated facial abnormalities (Fig. 26.25). Depending on the magnitude of advancement, bone grafting may be required to improve bone healing and postoperative stability. In the case of vertical maxillary deficiency, elongation of the lower third of the face can be accomplished by bone grafting the maxilla in an inferior position with the Le Fort I osteotomy technique (Fig. 26.26). This technique improves overall facial proportion and normalizes exposure of the incisors while smiling. Also, in a large number of patients with class III occlusions the jaw blamed by the patients and sometimes by dental providers is the mandible, when the problem is actually maxillary deficiency. Surgery in the wrong jaw in these cases can create problems in facial aesthetics, especially in male patients.

In severe midface deformities with infraorbital rim and malar eminence deficiency, a Le Fort III or modified Le Fort III type of osteotomy is necessary. These procedures advance the maxilla and malar bones and, in some cases, the anterior portion of nasal bones. This type of treatment is commonly required in patients with craniofacial deformities such as Apert or Crouzon syndrome (Fig. 26.27).

Combination Deformities and Asymmetries

In many cases, facial deformity involves a combination of abnormalities in the maxilla and the mandible.[28] Here treatment may require a combination of maxillary and mandibular osteotomies to achieve the best possible occlusal, functional, and aesthetic results (Figs. 26.28 and 26.29). In some cases, surgical treatment may involve a combination of the standard surgical procedures described before in combination with more complicated osteotomies accomplished through extraoral approach using bone grafts harvested from the iliac crest (Fig. 26.30). Treatment of asymmetry in more than two planes of space frequently requires maxillary surgery, mandibular surgery, and inferior border osteotomies, as well as recontouring or augmentation of other areas of the maxilla and the mandible (Fig. 26.31).

Orthognathic Surgery for Obstructive Sleep Apnea

Obstructive sleep apnea is the occurrence of apneic events (breathing stops) during sleep such that a patient has cessation of airflow for more than 10 seconds. This can be a serious condition with manifestations ranging from sleep disruption or deprivation and daytime somnolence to severe hypoxia during sleep and the potential of associated respiratory and cardiac abnormalities, and even death.[29]

The primary problem is a collapse of the airway during sleep. This can be a result of decreased muscle tone in the palate, tongue, or pharyngeal musculature. This condition can be associated with mandibular deficiency, and the subsequent lack of forward suspension of the tongue and hypopharyngeal musculature (Fig. 26.32A). This is usually accentuated in the supine position. Other factors such as obesity and alcohol or sedative drug use prior to sleeping can aggravate the problem.

The complete workup for the patient with obstructive sleep apnea is beyond the scope of this chapter but usually includes a comprehensive physical evaluation, nasopharyngoscopy, a dentofacial evaluation, and polysomnography sleep study. Treatment may include nonsurgical measures such as weight loss, positional changes during sleep, jaw positioning devices, or continuous positive airway pressure using a facial or nasal mask during sleep.[30,31]

Surgical correction may include a limited uvulopalatoplasty or uvulopharyngopalatoplasty, in which varying portions of the soft palate, uvula, tonsils, and pharyngeal walls are resected to open the airway. Maxillary and mandibular advancement with orthognathic surgery has also been shown to be effective in improving the airway in many patients.[32] This improvement is a result of expanding the airway at the level of the soft palate, base of the tongue, and hypopharyngeal airway. This can be seen by comparing preoperative and postoperative radiographs (see Fig. 26.32). The airway expansion resulting from surgery actually includes all dimensions, even lateral expansion.[33]

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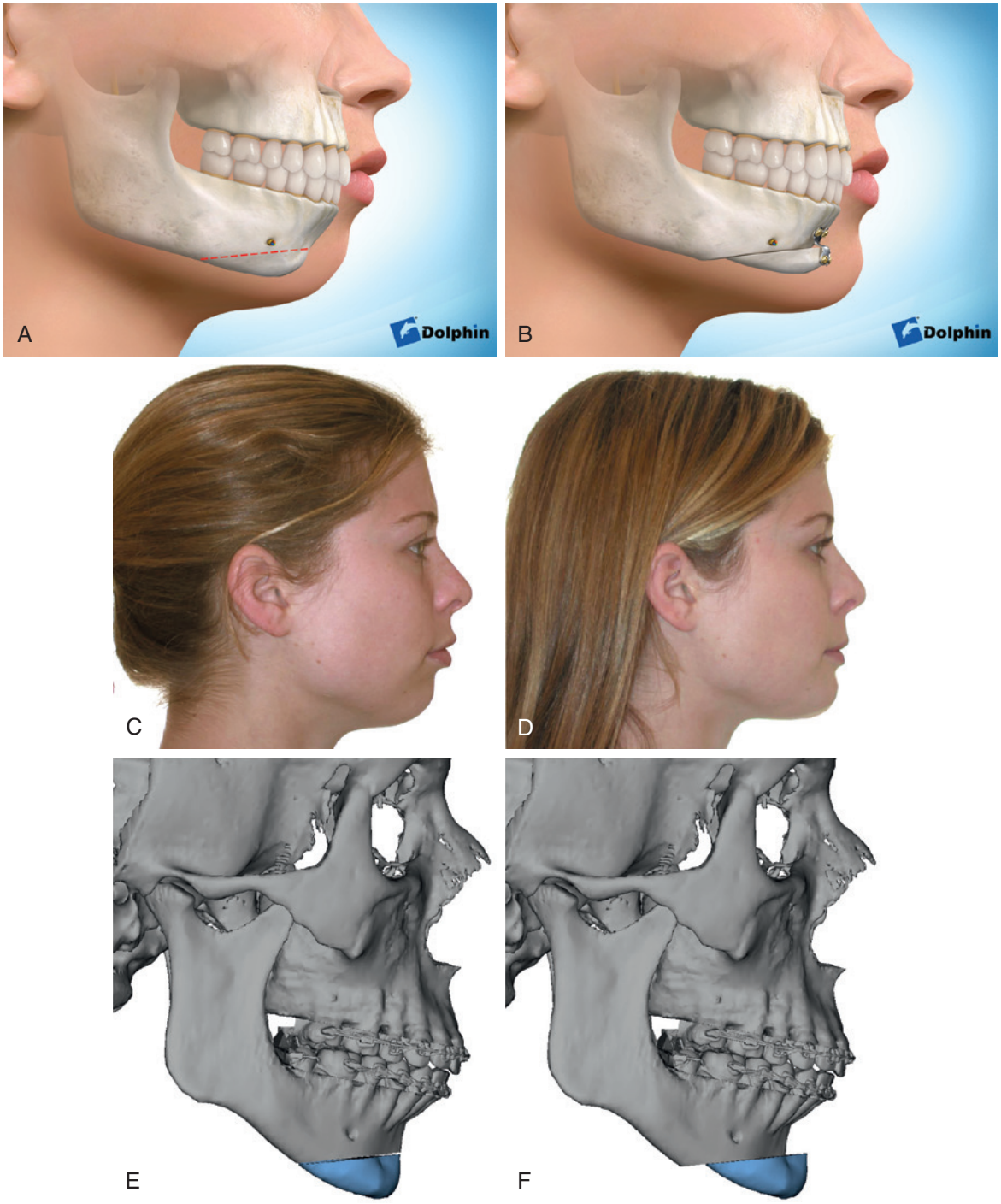
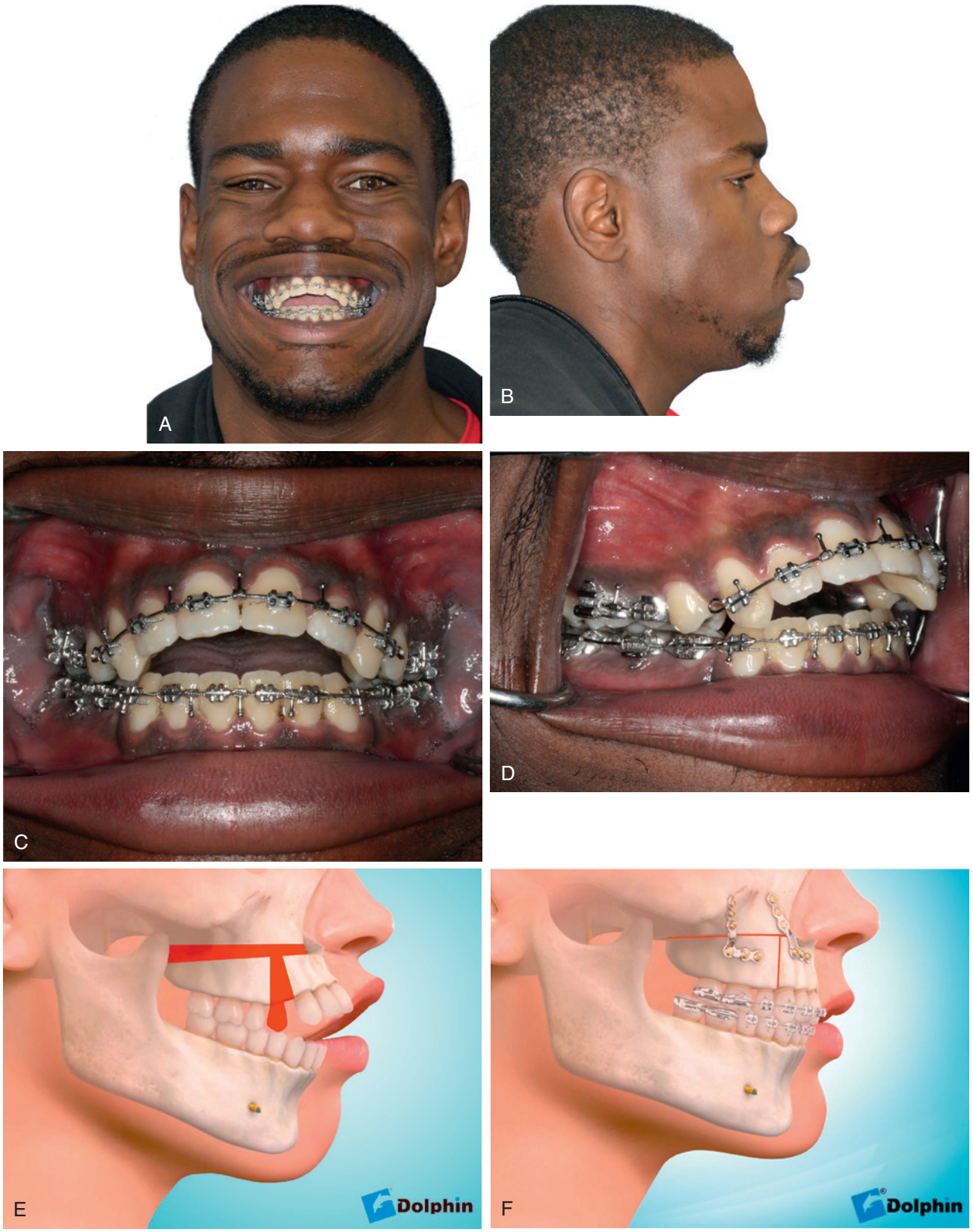


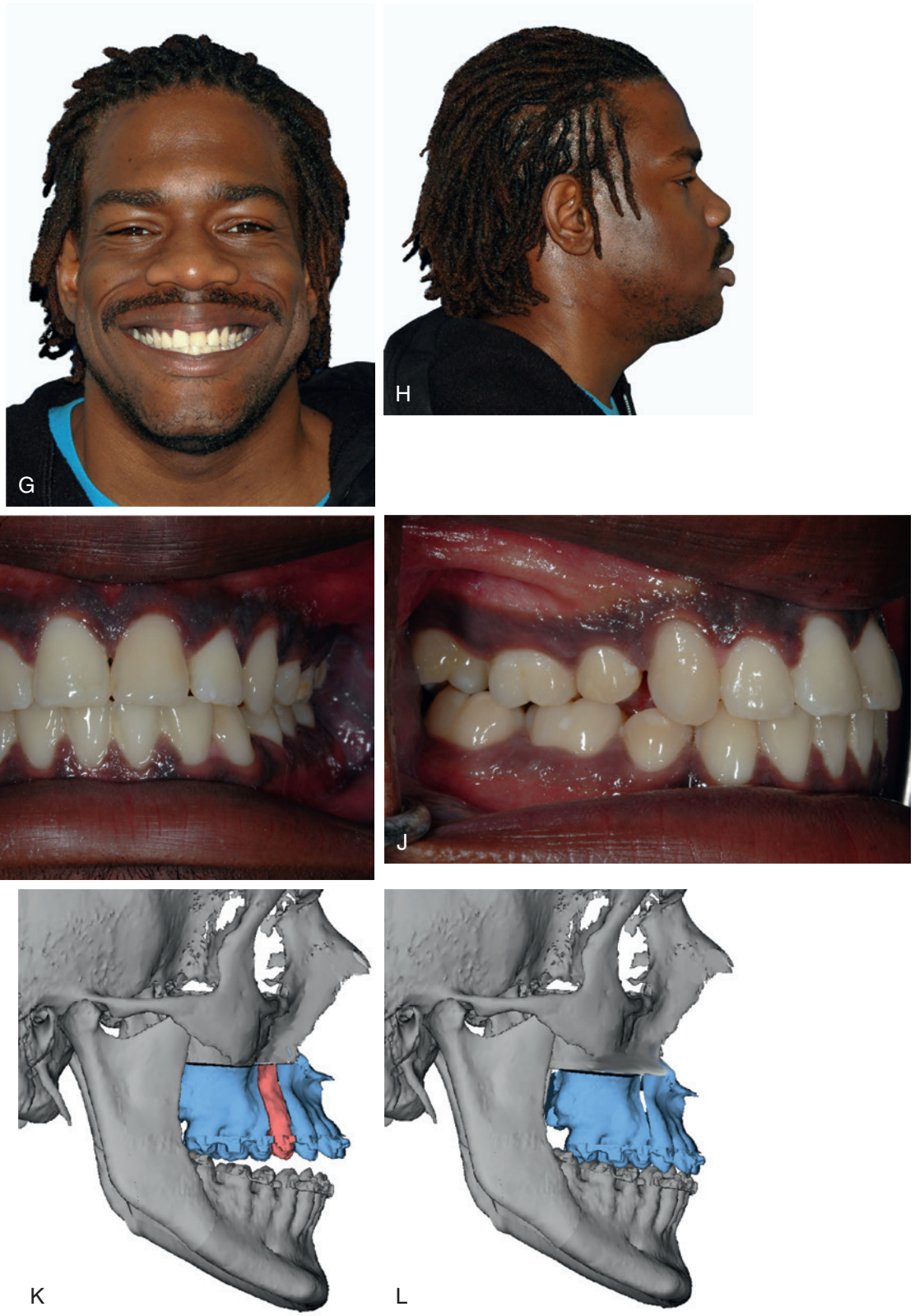
• **Fig. 26.21** Inferior border modification (i.e., genioplasty) techniques. (A) Advancement of the inferior border of the mandible to increase chin projection. (B) Implant used to augment the anterior portion of the chin, eliminating the need for osteotomy in this area. (C) Clinical image demonstrating chin deficiency. (D) Postoperative image after advancement of the inferior portion of the anterior mandible. (E) Preoperative radiograph. (F) Postoperative radiograph.

• **Fig. 26.22** Typical clinical features of vertical maxillary excess. (A–B) Full-face and profile views demonstrating elongation of lower third of face, lip incompetence, and excessive gingival exposure. (C–D) Total maxillary osteotomy with superior repositioning combined with advancement genioplasty. (E–F) Postoperative full-face and profile views after total maxillary osteotomy with superior repositioning and chin advancement.

• **Fig. 26.23** (A) Anterior open bite as a result of vertical maxillary excess with the entire maxillary occlusal plane on one level. (B) Presurgical occlusion. (C) Surgical correction with superior repositioning of the maxilla in one piece. (D) Postoperative occlusion. (E) Open bite with maxillary occlusal plane on two levels. (F) Presurgical occlusion. (G) Segmental maxillary repositioning to close the open bite and place segments on the same plane of occlusion. (H) Postoperative occlusion.

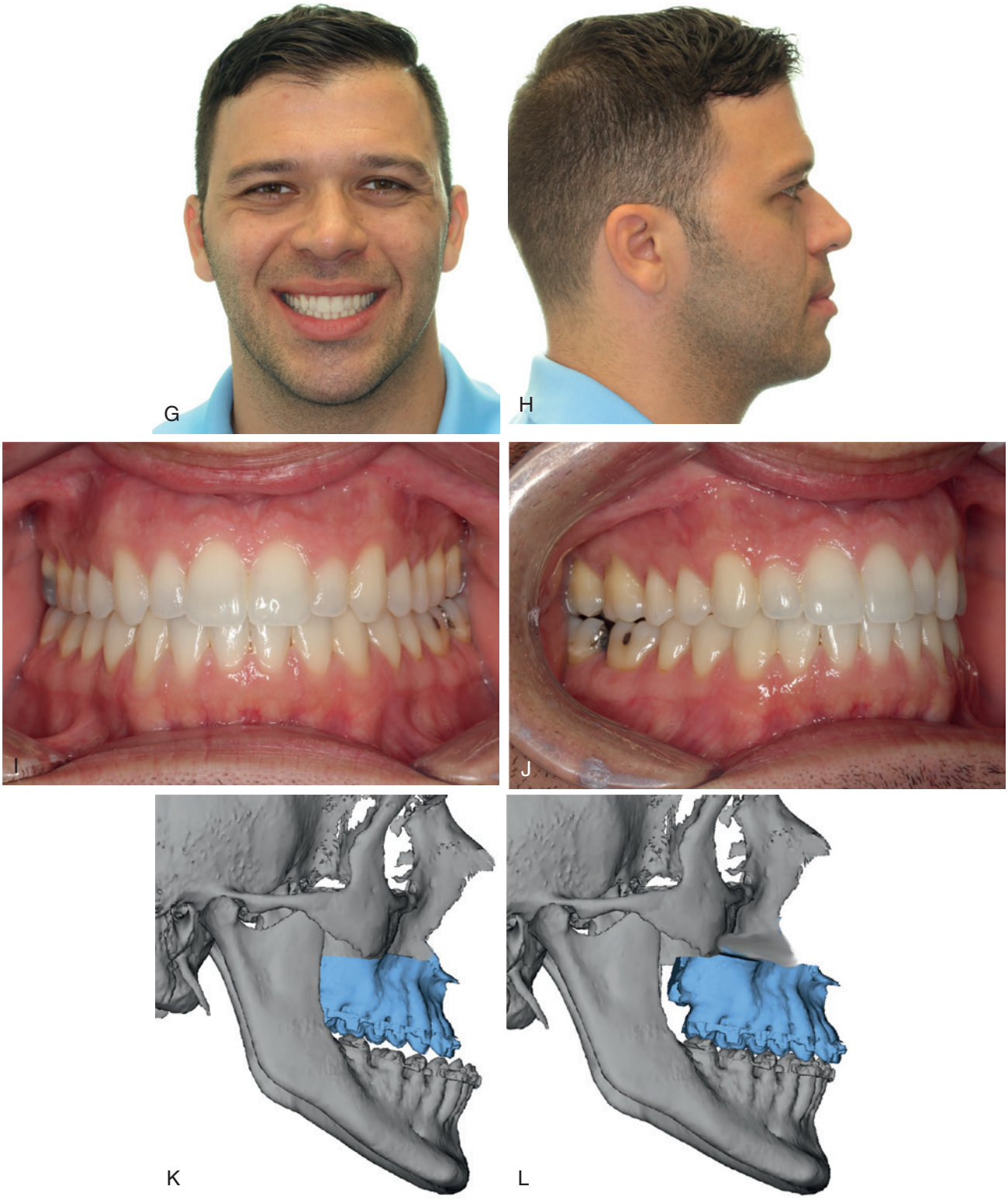


• **Fig. 26.24** Segmental maxillary osteotomy. (A–B) Preoperative facial appearance demonstrates extreme protrusion of the anterior maxillary segment and the upper lip, decreased nasolabial angle, and decreased lower face height as a result of maxillary vertical deficiency. (C–D) Preoperative occlusion demonstrates protrusive maxillary incisors and extraction space remaining after removal of maxillary premolar teeth bilaterally. (E–F) Segmental maxillary osteotomy with closure of premolar extraction space, retraction of anterior segment of maxilla, and placement of bone graft in posterior maxillary area.

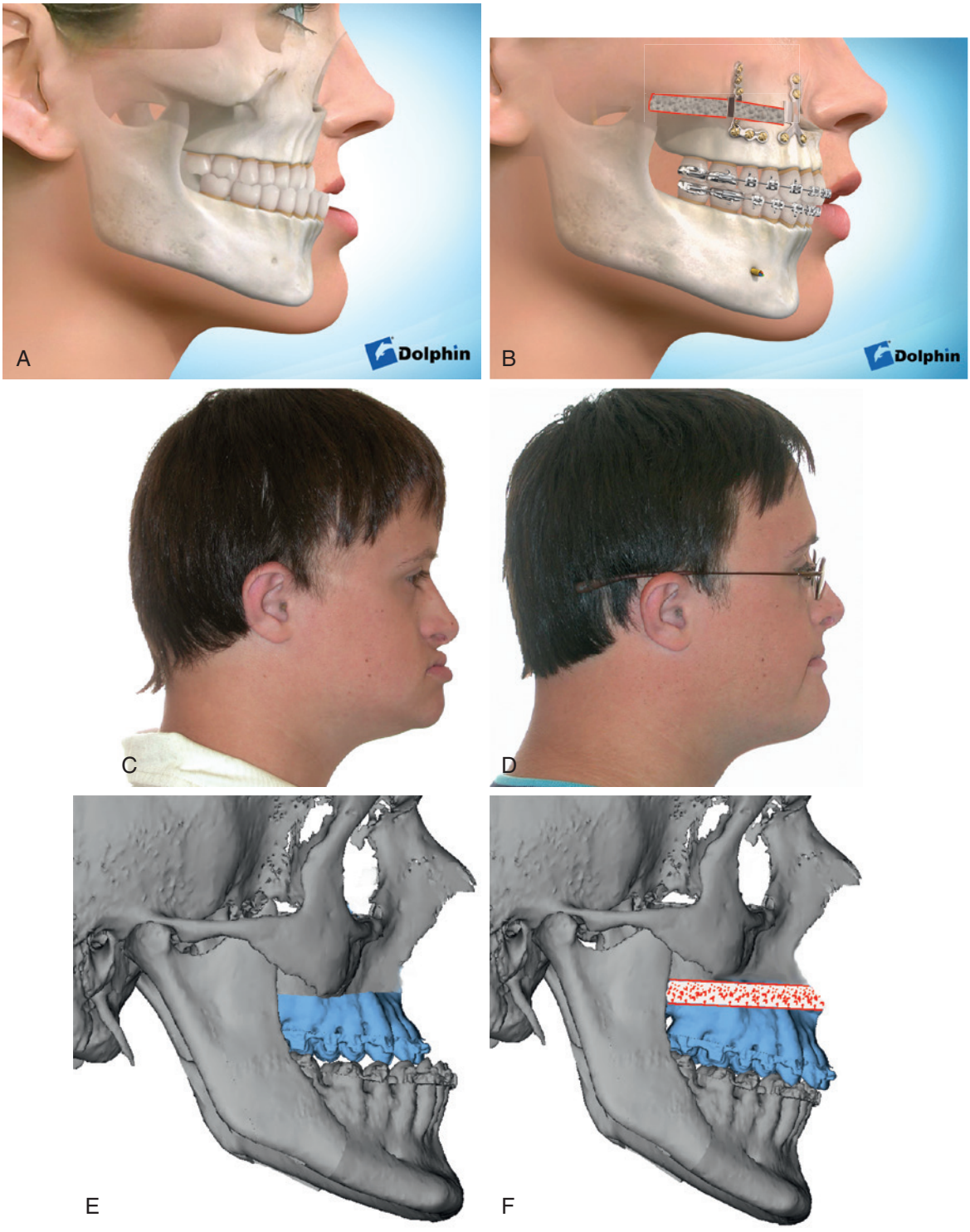


•**Fig. 26.24, cont'd** (G–H) Postoperative facial appearance. (I–J) Postoperative occlusion. (K–L) Preoperative and postoperative radiographs. (Courtesy Dr. Mark Ochs.)

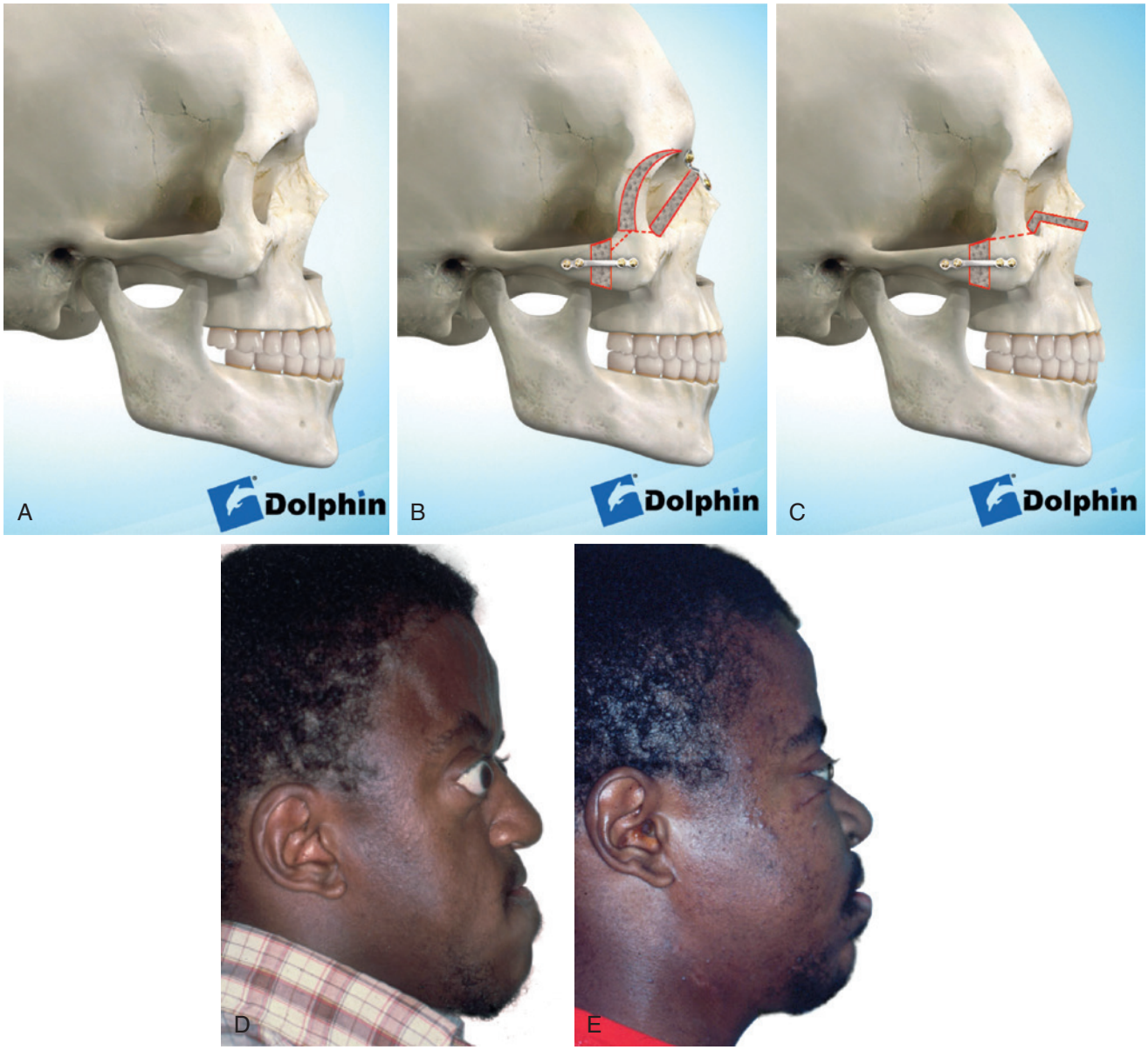
• **Fig. 26.25** Le Fort I advancement. (A–B) Preoperative facial aesthetics demonstrating maxillary deficiency evident by facial concavity and paranasal deficiency. (C–D) Preoperative occlusion demonstrating class III relationship. (E–F) Le Fort I osteotomy for maxillary advancement.



•**Fig. 26.25, cont'd** (G–H) Postoperative facial appearance. (This patient also underwent a simultaneous rhinoplasty procedure.) (I–J) Postoperative occlusion. (K–L) Preoperative and postoperative radiographs.

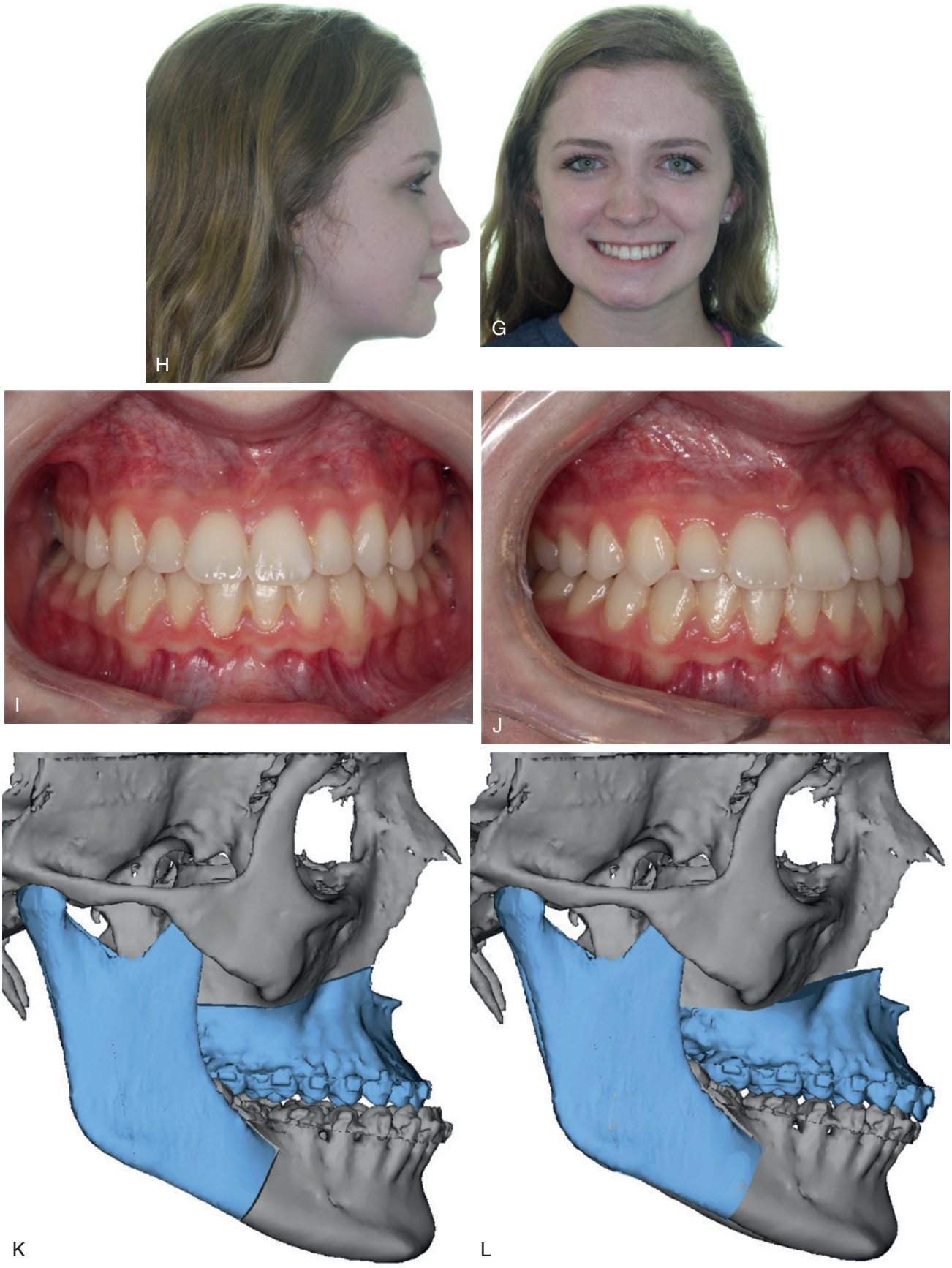


• **Fig. 26.26** (A–B) Inferior repositioning of the maxilla and interpositional bone grafting. (C) Preoperative profile view demonstrating vertical deficiency of the lower third of the face and resulting appearance of relative mandibular excess. (D) Postoperative view after inferior repositioning of the maxilla. Note the normal facial vertical and anteroposterior relationships. (E) Preoperative radiograph. (F) Postoperative radiograph. Bone plates and auxiliary vertical struts are seen in this view.

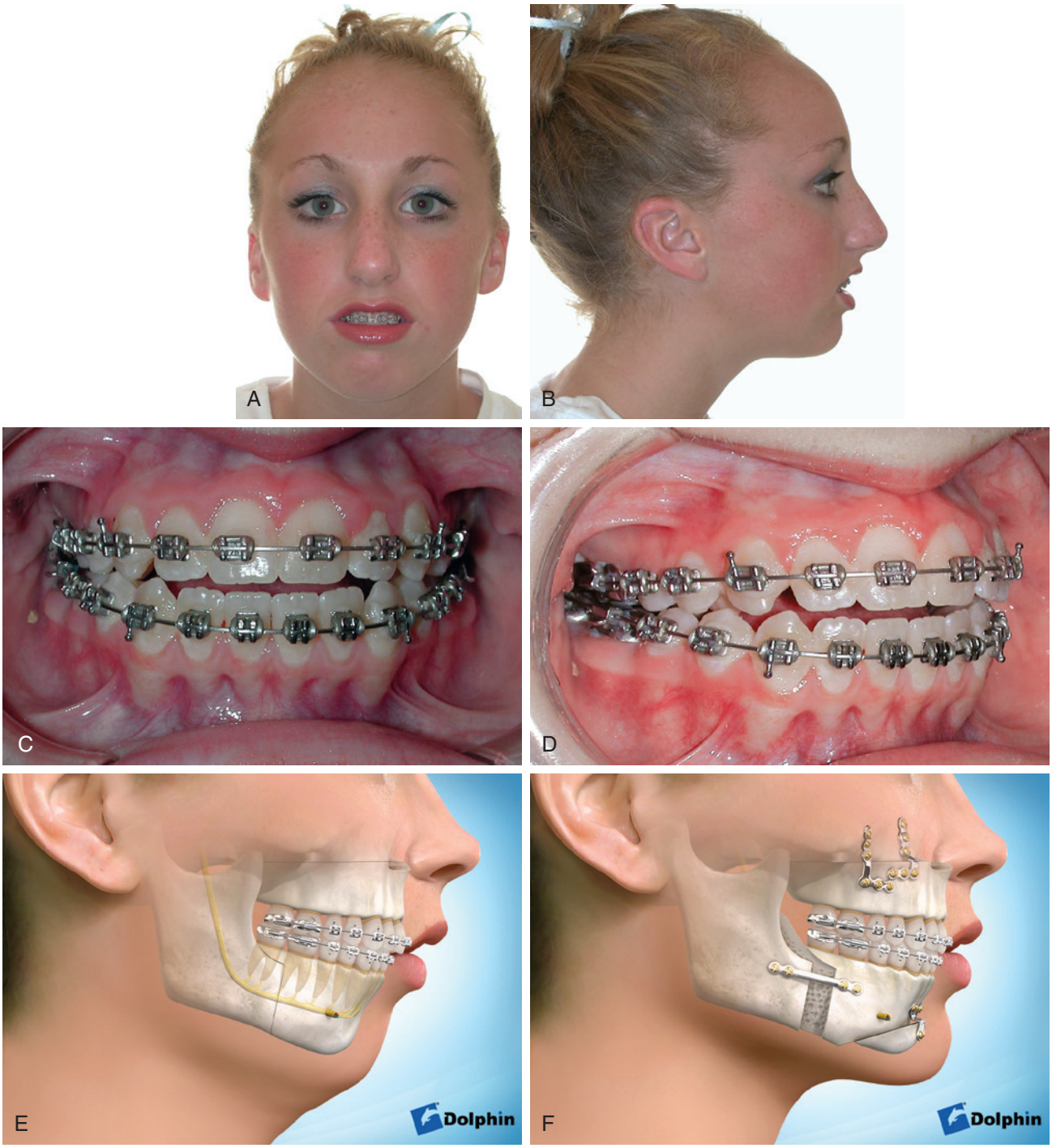


• **Fig. 26.27** (A) Severe midface deficiency. (B) Le Fort III advancement. (C) Modified Le Fort III advancement. (D) Preoperative profile view of a patient with Apert syndrome. (E) Postoperative profile view.

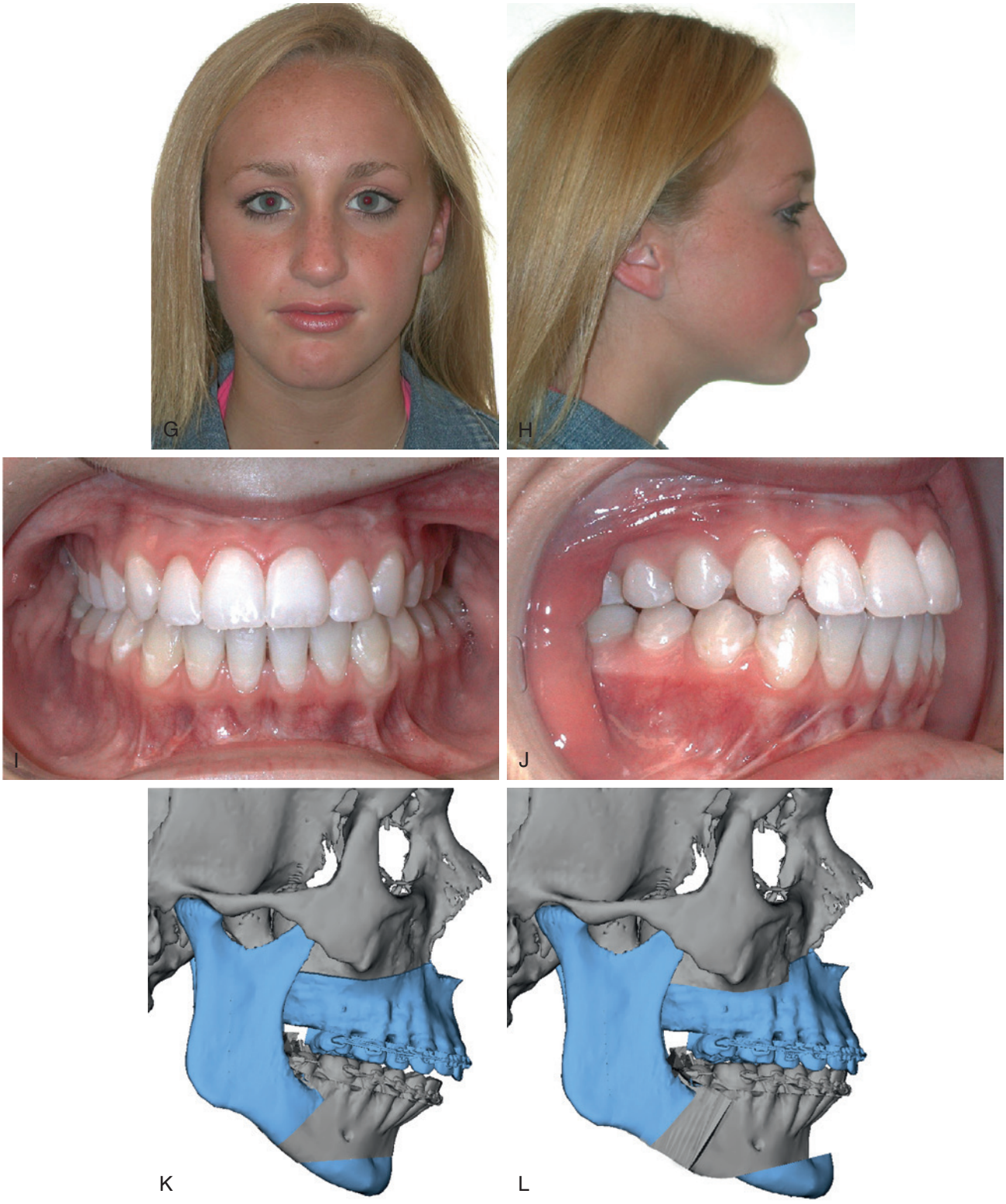
• **Fig. 26.28** Case report of maxillary advancement and mandibular setback. (A–B) Preoperative facial aesthetics demonstrating severe maxillary deficiency combined with mandibular excess. (C–D) Preoperative occlusion demonstrating a class III relationship. (E–F) Le Fort I osteotomy for maxillary advancement and bilateral sagittal osteotomies for setback of the mandible.



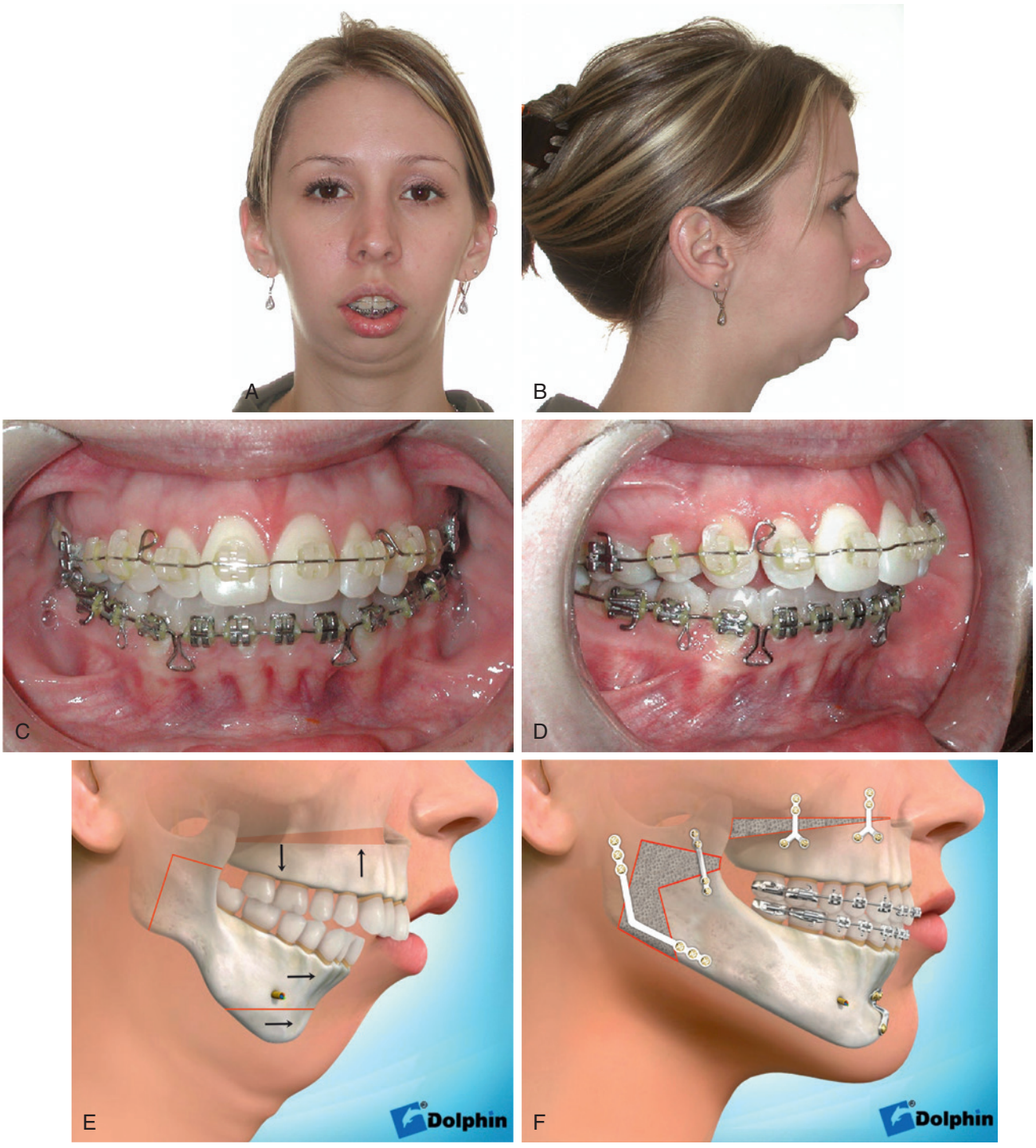
•**Fig.26.28,cont'd** (G–H) Postoperative facial appearance. (I–J) Postoperative occlusion. (K–L) Preoperative and postoperative radiographs.



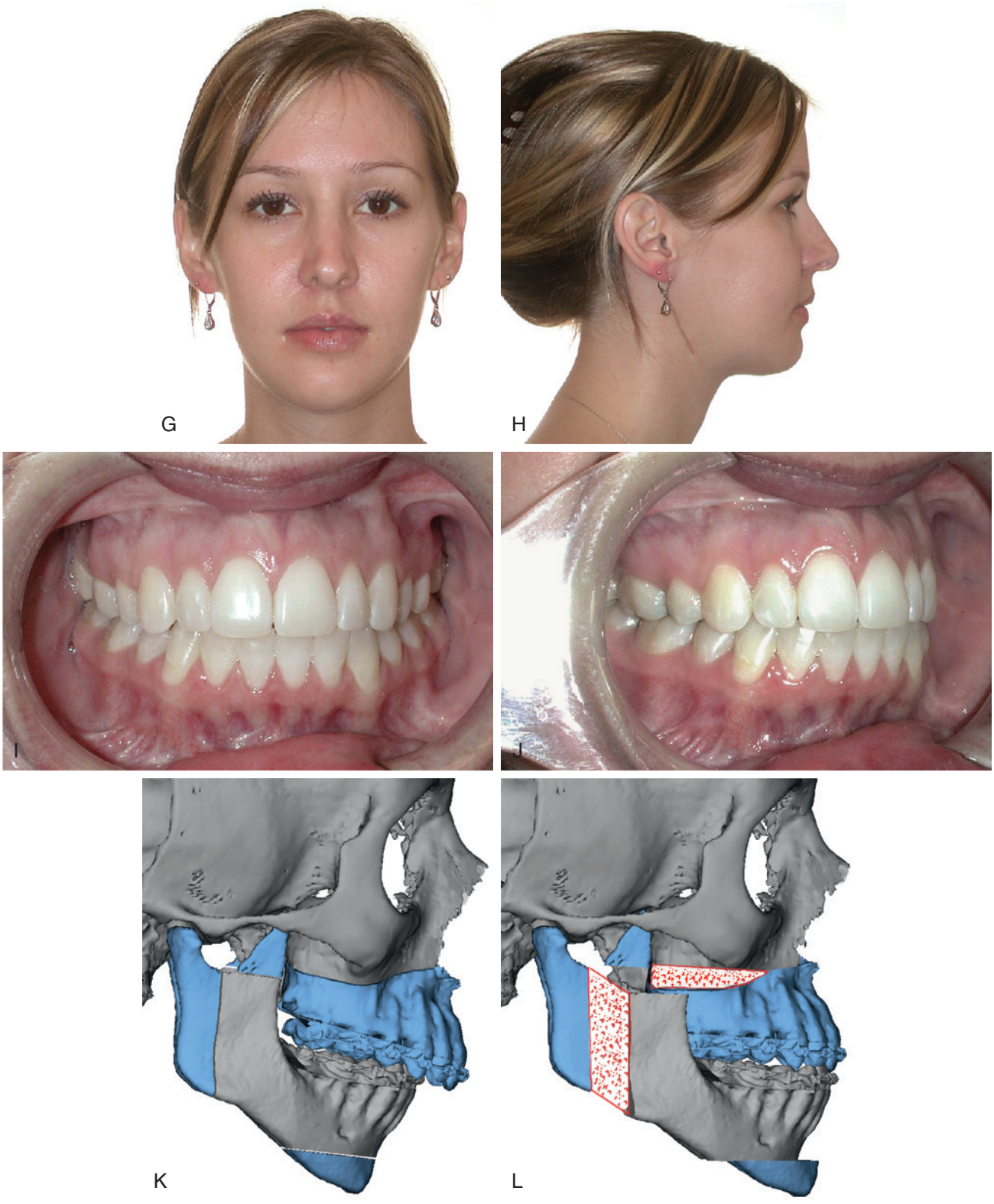
• **Fig. 26.29** Superior maxillary repositioning and advancement, mandibular advancement, and genioplasty. (A–B) Preoperative facial aesthetics demonstrating typical appearance of vertical maxillary excess and mandibular deficiency, including excess incisor exposure, lip incompetence, and lack of chin projection. (C–D) Preoperative occlusion demonstrating class II malocclusion. (E–F) Diagram of Le Fort I osteotomy with superior repositioning of the maxilla, sagittal osteotomies of the mandible for advancement, and advancement genioplasty.



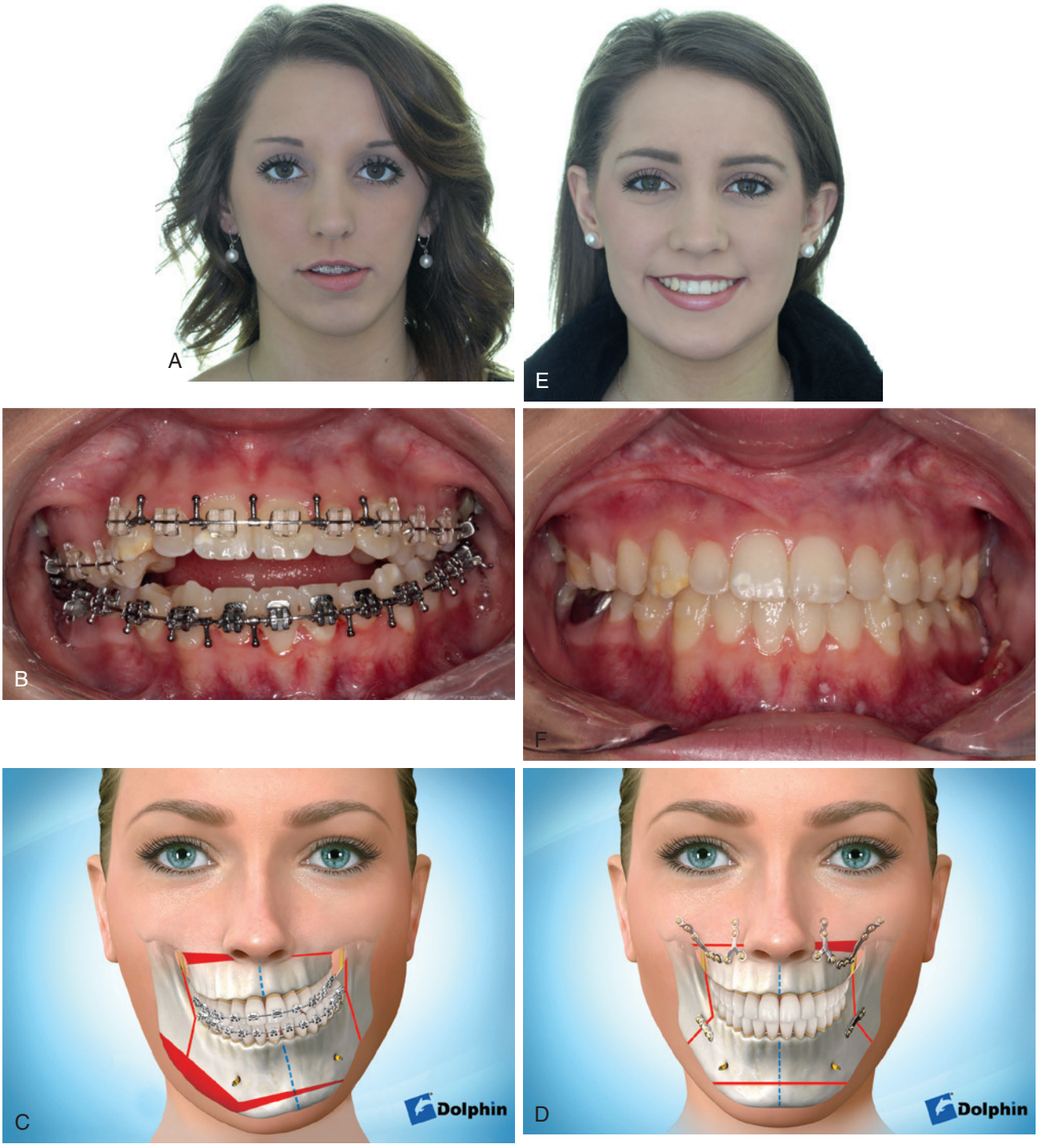
•**Fig. 26.29, cont'd** (G–H) Postoperative facial appearance. (I–J) Postoperative occlusion. (K–L) Preoperative and postoperative radiographs.



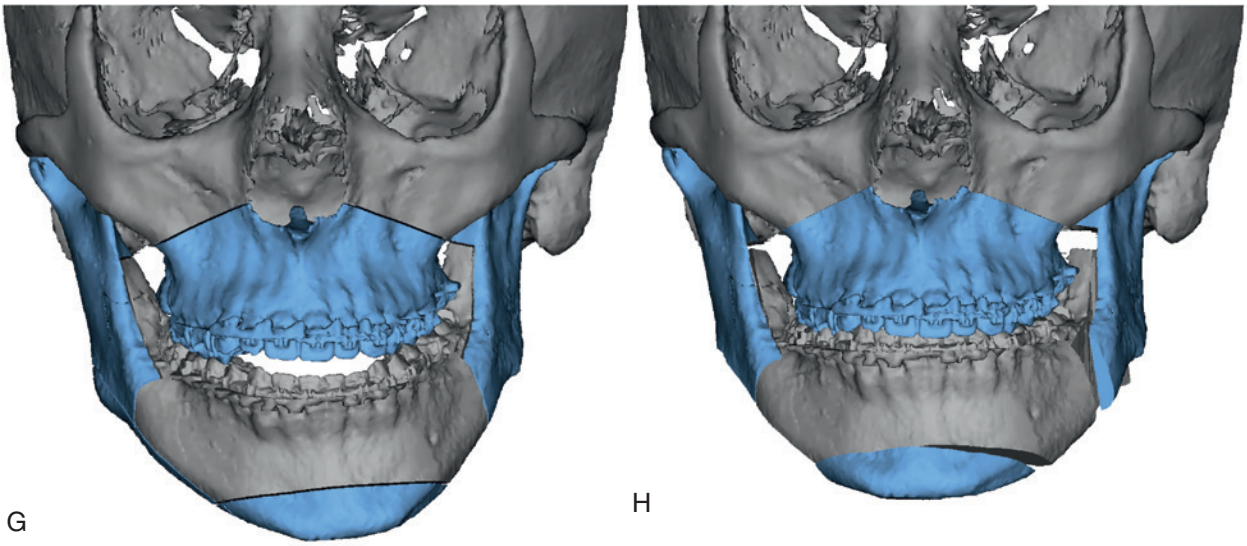
• **Fig. 26.30** Superior maxillary repositioning, extraoral approach for mandibular advancement, and genioplasty. (A–B) Preoperative facial aesthetics demonstrating typical appearance of vertical maxillary excess and mandibular deficiency, including excess incisor exposure, lip incompetence, and lack of chin projection. (C–D) Preoperative occlusion demonstrating class II malocclusion. (E–F) Diagram of Le Fort I osteotomy with superior repositioning of the maxilla, extraoral osteotomies of the mandible with bone grafts, and advancement genioplasty.



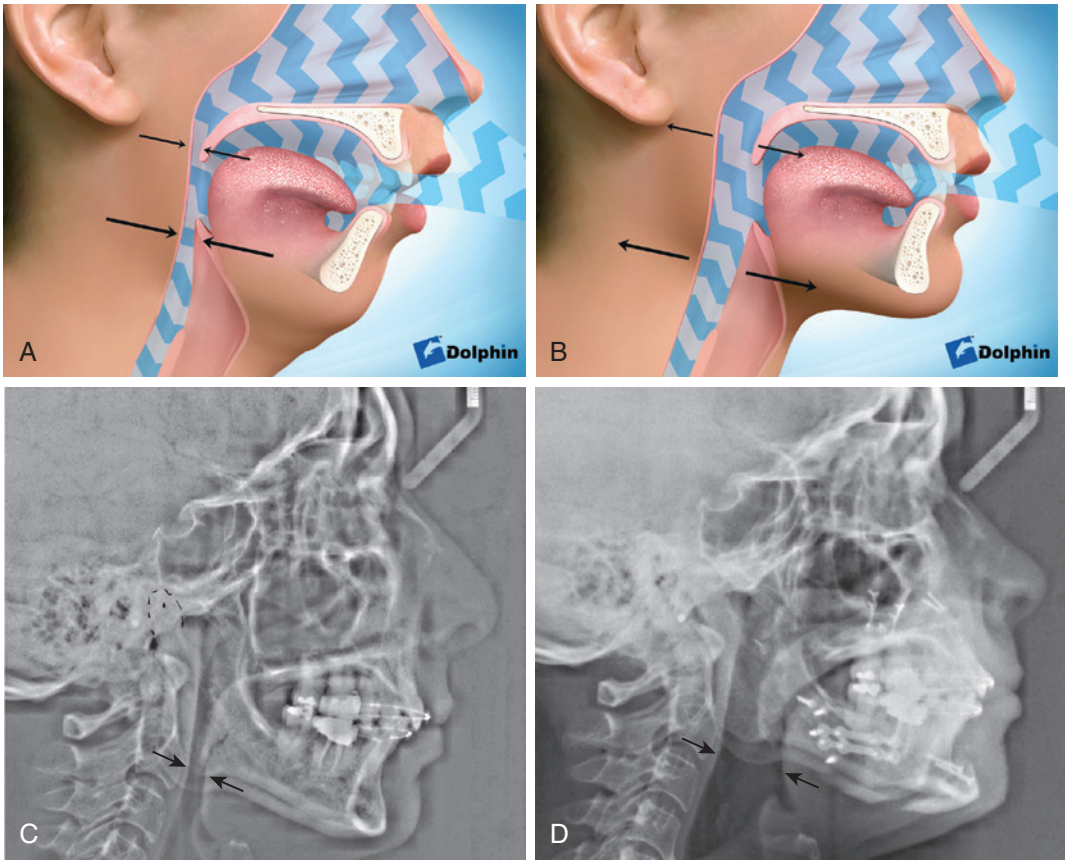
•**Fig. 26.30, cont'd** (G–H) Postoperative facial appearance. (I–J) Postoperative occlusion. (K–L) Preoperative and postoperative radiographs.



• **Fig. 26.31** Facial asymmetry requiring maxillary and mandibular osteotomies, genioplasty, and inferior border recontouring for correction. (A) Preoperative facial aesthetics. (B) Preoperative occlusion. (C–D) Diagrams of Le Fort I osteotomy with inferior repositioning on the left side and superior repositioning on the right, sagittal osteotomies of the mandible with advancement on the left side and superior repositioning on the right, asymmetric genioplasty, and right inferior border recontouring. (E) Postoperative facial appearance. (F) Postoperative occlusion.



•**Fig.26.31,cont'd** (G) Preoperative radiograph. (H) Postoperative radiograph.



• **Fig. 26.32** (A) Narrow or collapsed airway as a result of mandibular deficiency. (B) Simulation of an expanded airway as a result of maxillary and mandibular advancement. (C) Preoperative cephalometric radiograph showing narrow hypopharyngeal airway. (D) Postoperative cephalogram showing significant expansion of the airway.

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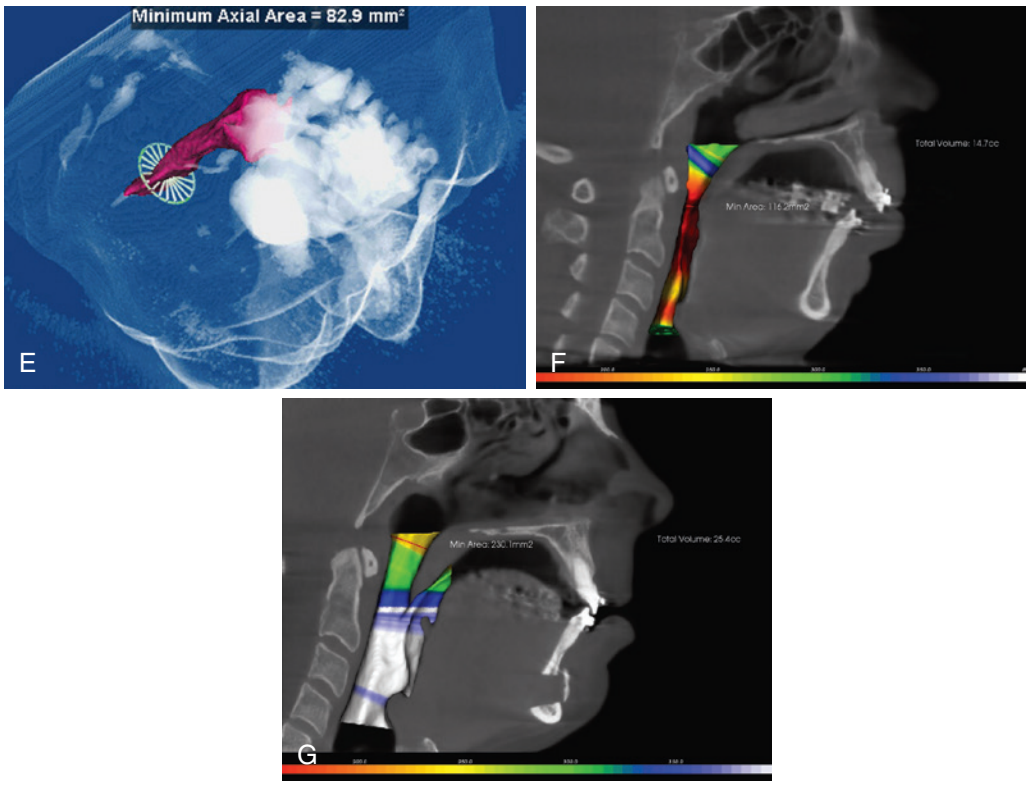


•**Fig. 26.32, cont'd** (E) Three-dimensional view of the airway can be obtained from computed tomography data. The skeletal components are subtracted and the airway enhanced (in red) using computer technology. (F) Enhanced view of the airway showing a small airway volume and area of maximum constriction. (G) Postoperative view showing an increase in the airway after maxillary and mandibular advancement.

Distraction Osteogenesis

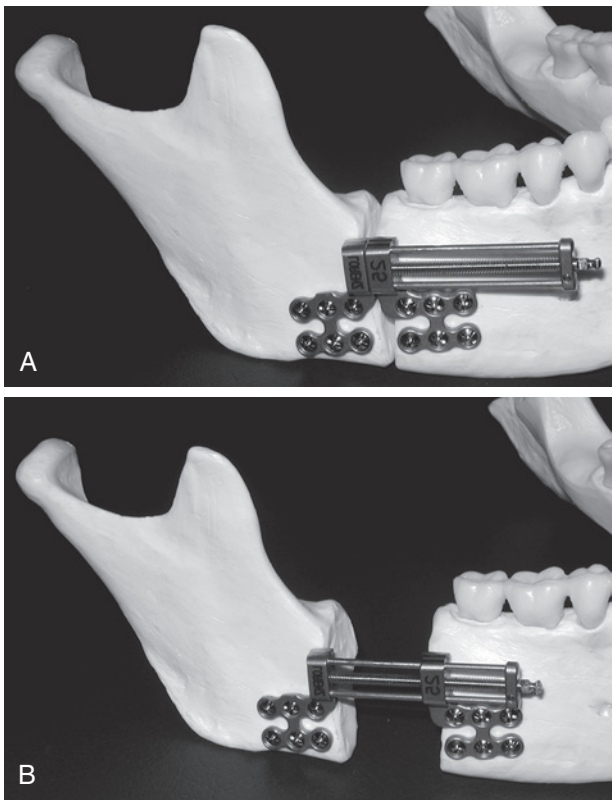
One new approach to correction of deficiencies in the mandible and the maxilla involves the use of distraction osteogenesis (DO). When correcting deformities associated with these deficiencies, the conventional osteotomy techniques have several potential limitations (described previously in this chapter). When large skeletal movements are required, the associated soft tissue often cannot adapt to the acute changes and stretching that result from the surgical repositioning of bone segments. This failure of tissue adaptation results in several problems, including surgical relapse, potential excessive loading of the TMJ structures, and increased severity of neurosensory loss as a result of stretching of nerves. In some cases, the amount of movement is so large that the gaps created require bone grafts harvested from secondary surgical sites such as the iliac crest.

DO involves cutting an osteotomy to separate segments of bone and the application of an appliance that will facilitate the gradual and incremental separation of bone segments (Fig. 26.33). The gradual tension placed on the distracting bone interface produces continuous bone formation. In addition, surrounding tissue appears to adapt to this gradual tension, producing adaptive changes in all surrounding tissues, including muscles and tendons, nerves, cartilage, blood vessels, and skin. Because the adaptation involves a variety of tissue types in addition to bone, this concept should also include the term *distraction histogenesis*.

The concept of distraction is not new. The use of traction techniques to help bones heal to a correct length can be traced back to the time of Hippocrates when an external device was used to apply traction to a fractured and shortened leg.[34] A Russian surgeon, Gavril Ilizarov, developed the current concept of correcting bone deficiencies in the 1950s. The result of his work was not widely disseminated to the rest of the world until the late 1970s and early 1980s.[35,36] Since that time, the application of these principles has extended to all forms of orthopedic correction, including craniofacial surgery.[37,38]

DO involves several phases, including the osteotomy or surgical phase, the latency period, the distraction phase, the consolidation phase, appliance removal, and remodeling. During the surgical phase, an osteotomy is completed, and the distraction appliance is secured. In the latency phase, very early stages of bone healing begin to take place at the osteotomy–bone interface. The latency phase lasts generally 7 days, during which time the appliance is not activated. After the latency period, the distraction phase begins at a rate of 1 mm/day. This distraction rate is usually applied by opening or activating the appliance 0.5 mm twice each day. The amount of activation per day is termed *rate of distraction*; the timing of appliance activation each day is termed *rhythm*. During the distraction phase, the new immature bone that forms is called *regenerate bone*. Once the appropriate amount of distraction has been achieved, the appliance remains in place during the consolidation phase, allowing for mineralization of the regenerate bone. The appliance is then removed, and the period from the application of normal functional loads to the complete maturation of the bone is termed the *remodeling period*.

Because the use of these techniques in orthognathic surgery is relatively new, few long-term studies are available that document all of the potential benefits of DO. Possible advantages include



• **Fig. 26.33** Distractor appliance used for mandibular advancement. (A) Osteotomy of the posterior mandibular body and ramus area with distractor in place. (B) View showing the distraction appliance fully expanded. Regenerate bone fills the intrabone gap during slow incremental activation of the distractor that slowly separates the segments.

the ability to produce larger skeletal movements, elimination of the need for bone grafts and the associated secondary surgical site, better long-term stability, less trauma to the TMJ, and decreased neurosensory loss. DO also has certain disadvantages: The placement and positioning of the appliance to produce the desired vector of bone movement is technique sensitive and sometimes results in less than ideal occlusal positioning, resulting in discrepancies such as small open bites or asymmetries. Other disadvantages include the need for two procedures: (1) placement and (2) removal of the distractors. It also involves increased cost and longer treatment time, with more frequent appointments with the surgeon and the orthodontist.

One of the earliest uses of the DO concept in orthognathic surgery involved widening of the maxilla with a technique termed *surgical-assisted rapid palatal expansion*.[39] An adult maxilla with significant transverse deficiency is nearly impossible to correct with conventional orthodontic treatment. Even correction with segmental maxillary surgery to produce expansion has often shown disappointing results.[40] The use of surgical-assisted palatal expansion, incorporating the concepts of DO, seems to produce better long-term results in these cases.[41] In these cases, the expansion device is secured in place by the orthodontist. A surgical procedure is then completed by performing the bone cuts as described for a Le Fort I osteotomy, with the exception that the most posterior attachment of the lateral nasal wall and perpendicular plate of the palatine bone are not divided. A midline cut is also completed to create separation between the central incisors extending along the midpalatal suture. After a latency period the expansion device is activated 1 mm/day until the desired expansion takes place (Fig. 26.34). During this time, a space develops between the central incisors, along the midpalatal suture, and at the area of the osteotomy, along the lateral maxillary wall.

The regenerate bone gradually fills and matures in these areas. The appliance is then removed, and active orthodontic treatment is begun to close the spaces between teeth, properly align the arch, and maintain the expansion.

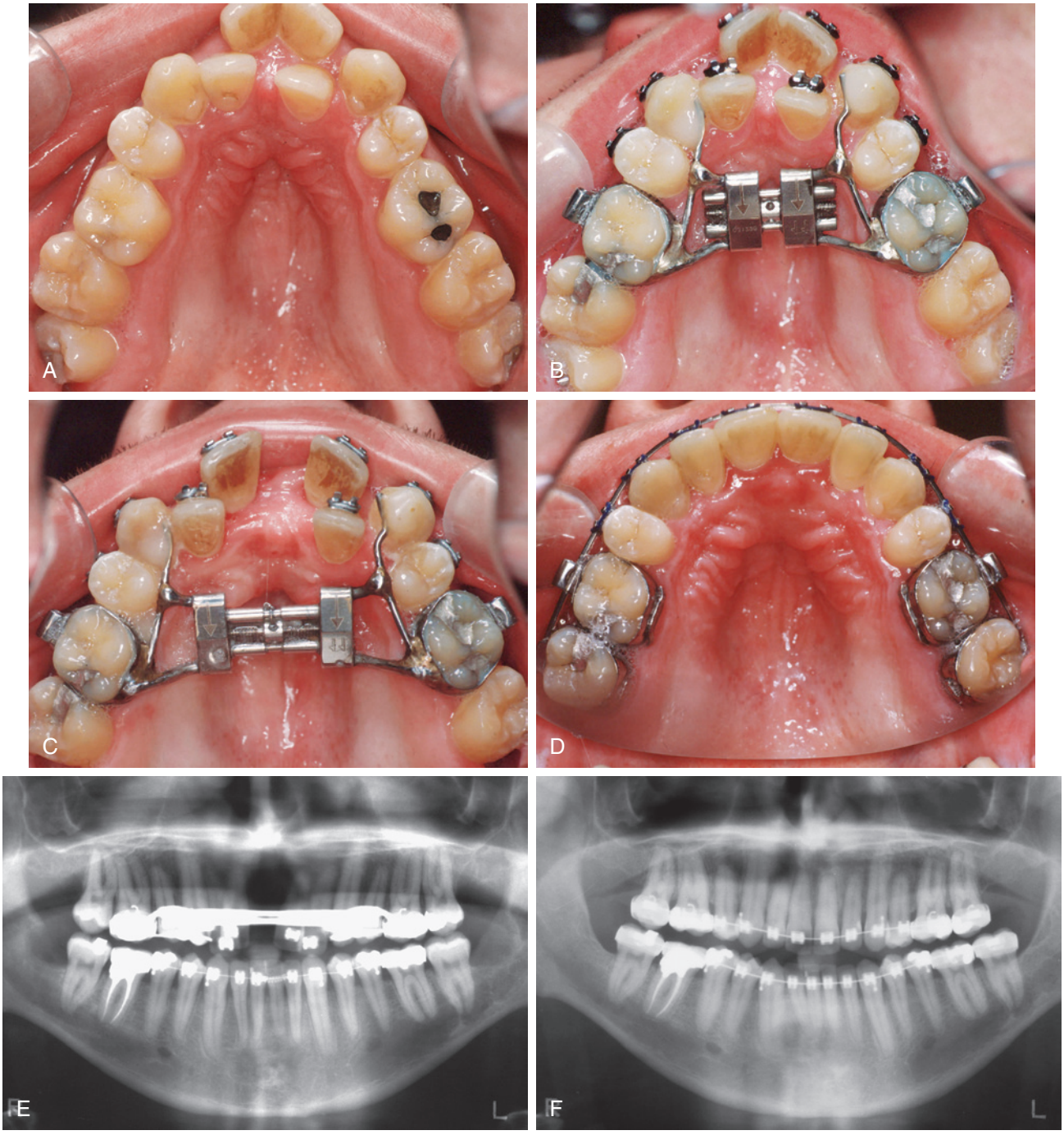
In the case of mandibular deficiency, the initial surgical procedure involves performing an osteotomy and placement of the distraction appliance. After a latency period of 7 days, the distraction occurs with a rate and rhythm of 1 mm/day (completed by activating the appliance 0.5 mm twice each day). Once this distraction is complete, the appliance is left in place for the consolidation phase, which is usually two or three times the amount of time required for the distraction phase. The appliance is then removed, and active orthodontic treatment continues. Fig. 26.35 demonstrates a case of DO of the mandible.

Distraction appliances are also available for maxillary and midface advancement. In some cases of traditional maxillary repositioning, autogenous bone may be required for grafting into the bone defect. The need for grafting obviously requires donor site surgery with the associated morbidities. DO eliminates the need for graft harvest in many of these patients. In patients with a cleft lip and palate, substantial scarring often occurs from multiple previous surgical procedures. This scarring combined with significant growth abnormalities creates soft tissue limitations that may prevent single-stage correction with conventional orthognathic surgical techniques. DO can be effective in treatment of these patients by gradually stretching the soft tissue envelope, generating new soft and hard tissue, eliminating the need for graft harvest, and providing satisfactory long-term stability.[42] Fig. 26.36 demonstrates the effective use of DO for maxillary advancement in such patients. Maxillary repositioning with DO may allow larger advancements with improved long-term stability.[43,44]

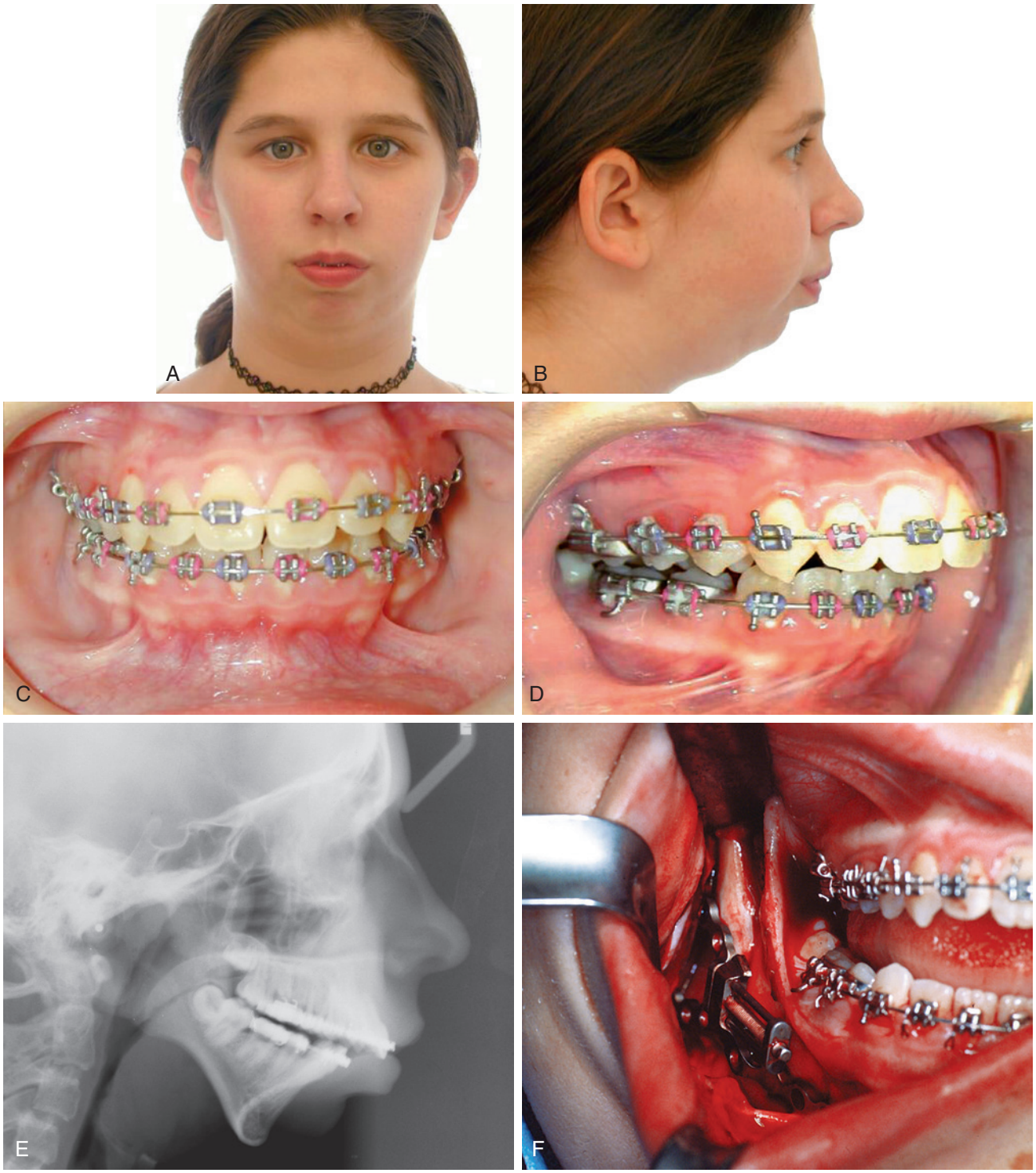
Perioperative Care of the Orthognathic Surgical Patient

Patients undergoing orthognathic surgery are usually admitted to the hospital on the day of surgery. Before surgery, medical history taking, complete physical examination, preoperative laboratory tests, radiographic examinations, and consultation with the anesthesiologist are completed. Orthognathic surgery is accomplished in the operating room, with the patient under general anesthesia. After surgery, the patient is taken to the postanesthesia care unit (i.e., recovery room) for an appropriate period, usually until alert, oriented, comfortable, and exhibiting stable vital signs; then the patient is returned to the hospital room. The nursing staff trained and experienced in the postoperative care of surgery patients continually monitor postoperative progress. The patient is discharged when he or she is feeling comfortable, urinating without assistance, taking food and fluid orally without difficulty, and ambulating well. The postsurgical hospital stay usually ranges from 1 to 4 days. Patients generally require only mild to moderate pain medication during this time and often require no analgesics after discharge. As soon as is feasible, postoperative radiographs are obtained to ensure that the predicted bone changes have taken place and that stabilization devices are in the proper position.

The importance of postoperative nutrition should be discussed with patients and their families before the hospital admission for



• **Fig. 26.34** Distraction osteogenesis with surgically assisted palatal expansion for correction of transverse maxillary deficiency. (A) Severe constriction of the maxilla with inadequate arch length. (Note that severe crowding exists even though premolars have been extracted.) (B) Expansion device in place. (C) Maxilla expanded (note space between central incisors). Osteogenesis with bone formation and histogenesis with formation of gingival tissue are occurring. (D) Space closed with anterior teeth orthodontically aligned using newly formed regenerate bone. (E) Radiograph showing expansion with immature regenerate bone in the anterior space. (F) Radiograph after orthodontic alignment.



• **Fig. 26.35** Distraction osteogenesis to correct severe mandibular deficiency. (A–B) Preoperative facial aesthetics demonstrating severe mandibular deficiency. (C–D) Preoperative occlusion demonstrating class II relationship. (E) Preoperative cephalometric radiograph. (F) Surgical procedure to create osteotomy and place the distraction appliance.

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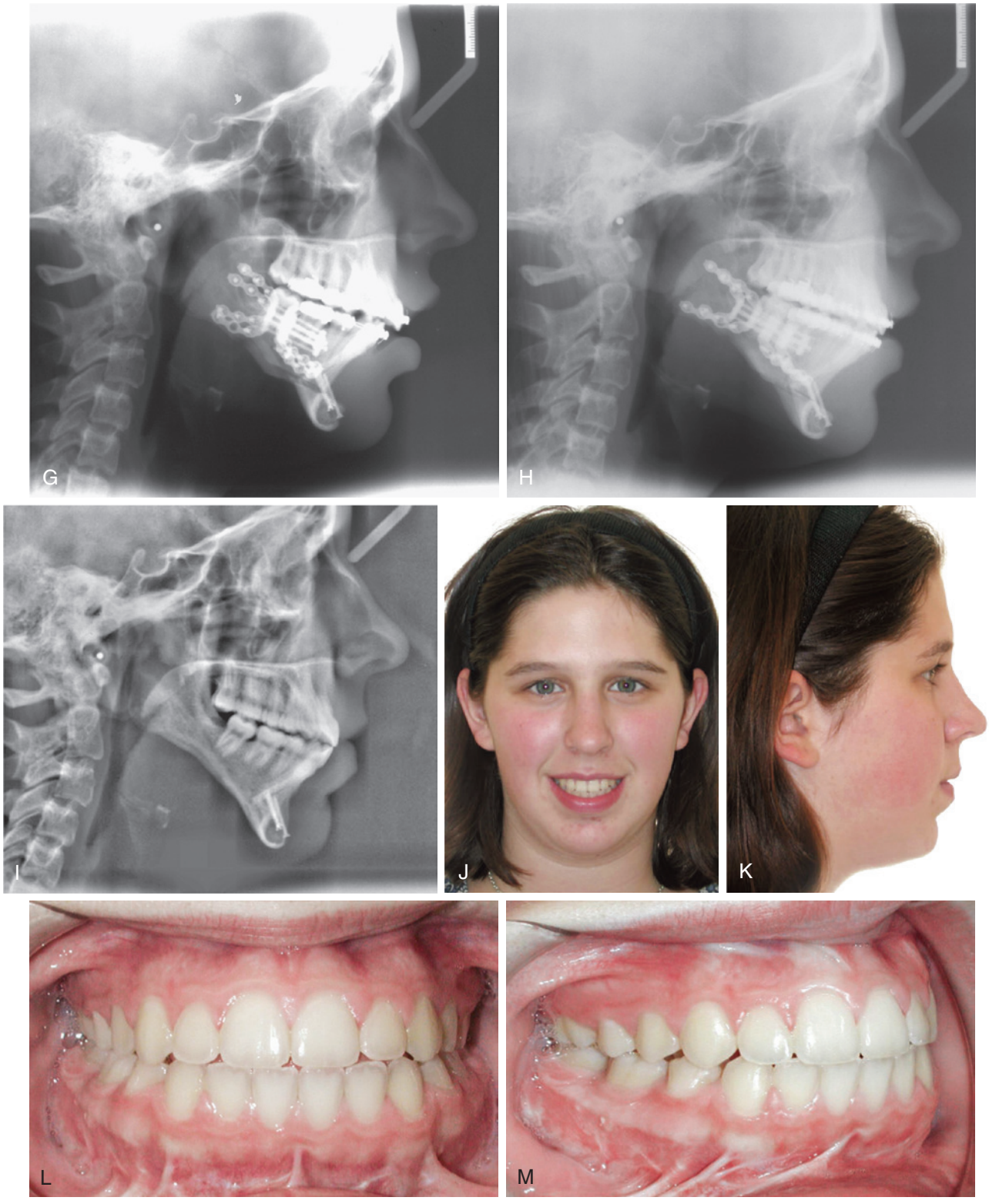
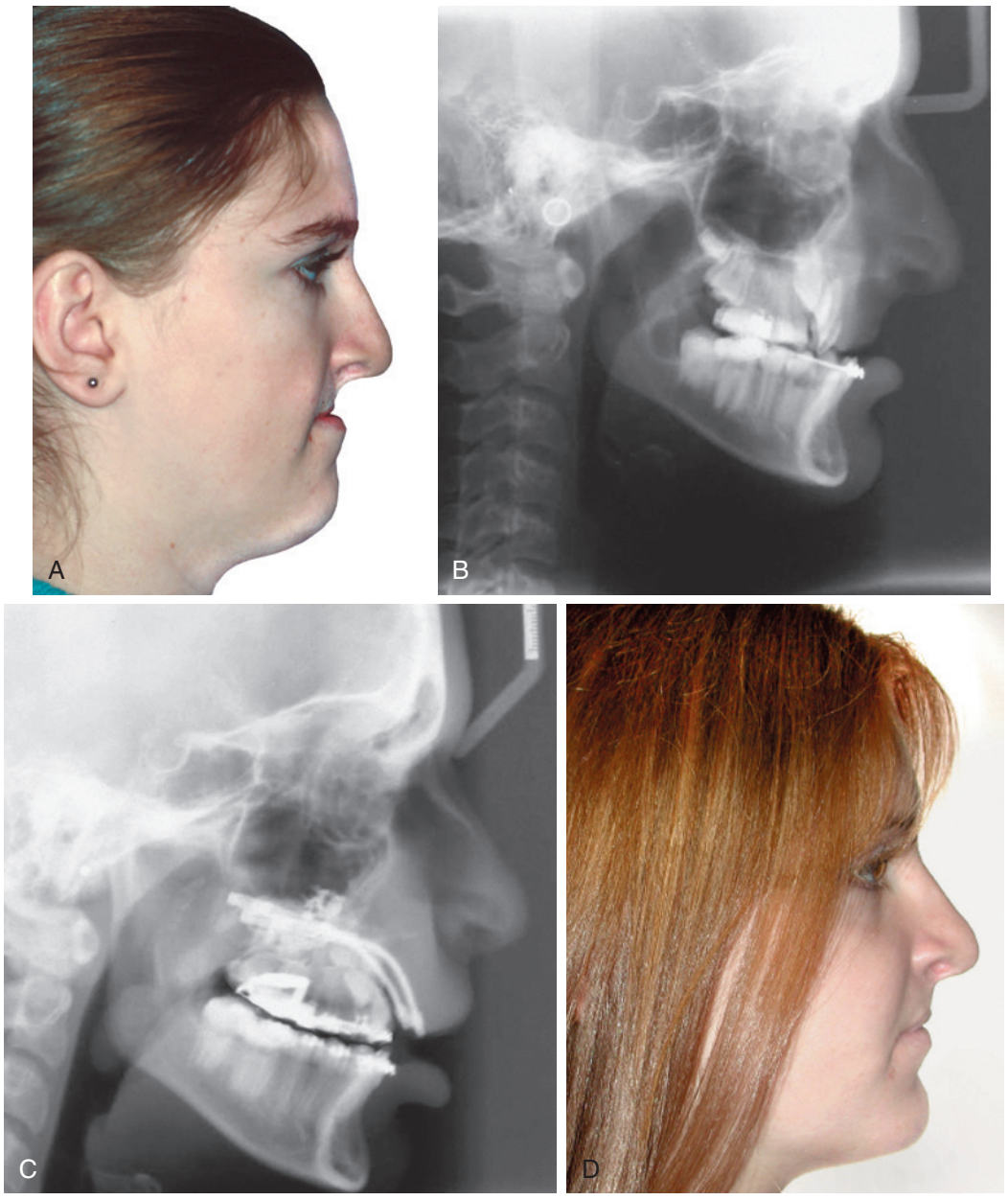


•**Fig. 26.35, cont'd** (G) Postoperative radiograph after latency phase is complete and distraction started (chin advancement was completed at the same time distractors were applied). (H) Radiograph after 16 days of distraction at 1 mm/day. (I) Radiograph after removal of distraction appliances, completion of orthodontic treatment, and debanding. (J–K) Postoperative facial appearance. (L–M) Postoperative occlusal views.



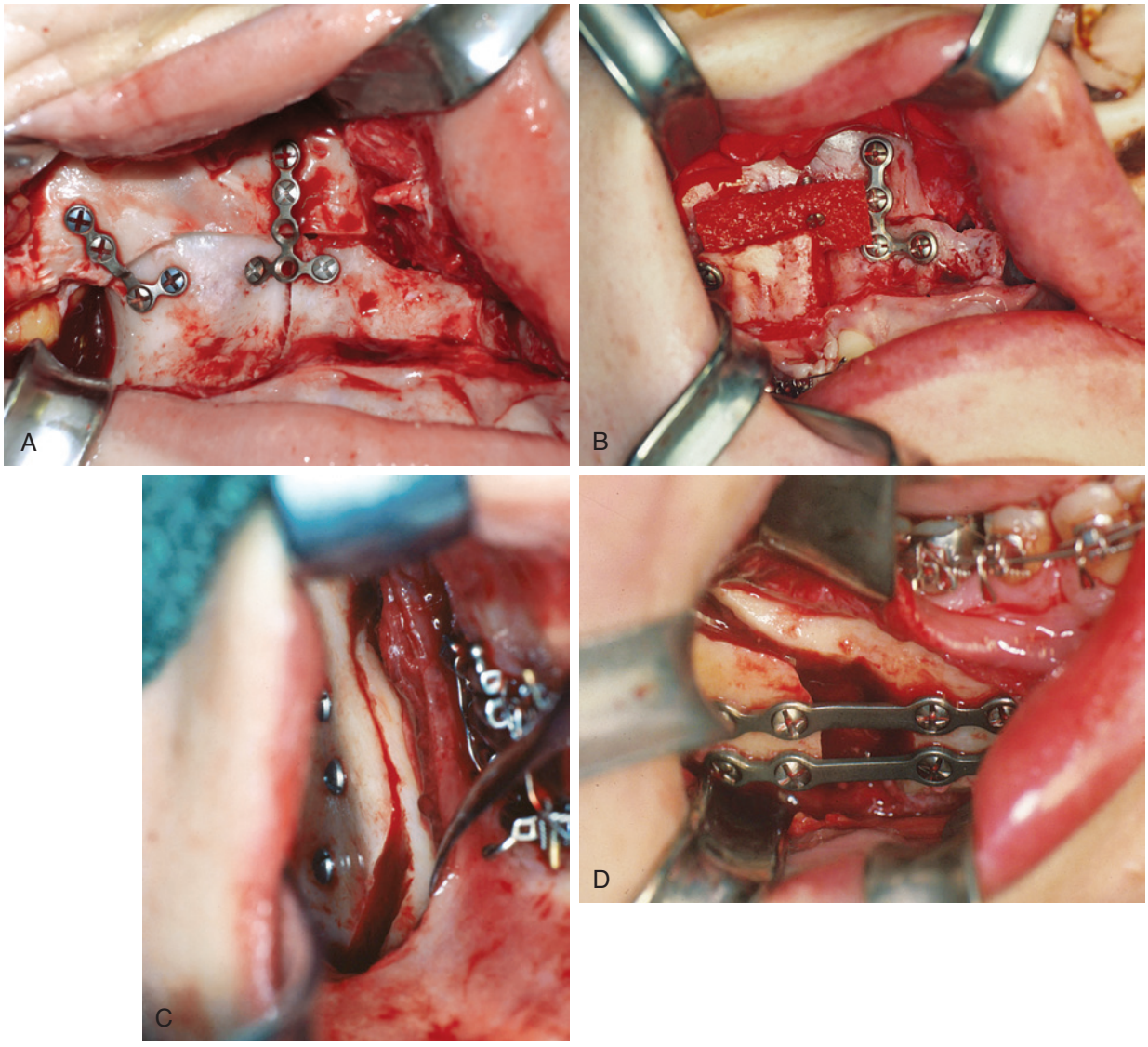
• **Fig. 26.36** Distraction osteogenesis for correction of maxillary deficiency. (A) Severe midface deficiency resulting from cleft lip and palate and multiple surgical interventions. (B) Radiograph demonstrating maxillary hypoplasia and class III malocclusion. (C) Radiograph showing advancement of the maxilla using distractors. (D) Final profile demonstrating improved facial balance and occlusion. (Courtesy Dr. Dan Spagnoli.)

surgery. During the postoperative hospital stay, a member of the dietary staff may instruct the patient in methods of obtaining adequate nutrition during the period of IMF or limited jaw function. Special cookbooks designed for patients undergoing jaw surgery contain instructions for the preparation of diets in a blender.

In the past, one of the major considerations in the immediate postoperative period was the difficulty resulting from IMF. When the jaws are wired together, the patient has initial difficulties in obtaining adequate nutrition, performing necessary oral hygiene, and communicating verbally. The average IMF period ranges from 6 to 8 weeks.

In the past few years, several systems using small bone screws and bone plates have been developed to provide direct bone stabilization in the area of the osteotomies (Fig. 26.37).[45-48] The most recent development in rigid internal fixation is the use of screws and plates made of resorbable material. The materials are capable of maintaining adequate strength to stabilize bone during the healing period and are then resorbed by hydrolyzation. The use of these rigid fixation systems allows for early release from or total elimination of IMF, which results in improved patient comfort, convenience of speech and oral hygiene, and improved postsurgical jaw stability and function.

At the time of surgery, a small acrylic occlusal wafer is usually used to help position and stabilize the occlusion. When the IMF is released (usually in the operating room), the splint, if left in place, is wired to the upper or lower jaw. Light elastics are then



• **Fig. 26.37** (A) Use of small bone plates for stabilization of a maxillary osteotomy. (B) Maxillary advancement and downgraft with iliac crest bone graft stabilized with bone plates. (C) Lag screws used to secure a mandibular sagittal split osteotomy. (D) Bone plates used to stabilize a sagittal split osteotomy.

placed on the surgical wires, and the combination of the splint and elastics serves to guide the jaw into the new postsurgical occlusion (Fig. 26.38). When an ideal occlusion can be achieved at the time of surgery, the use of a splint may be eliminated. After an adequate accommodation period, the occlusal splint is removed and the patient is returned to the orthodontist's care.

Postsurgical Treatment Phase

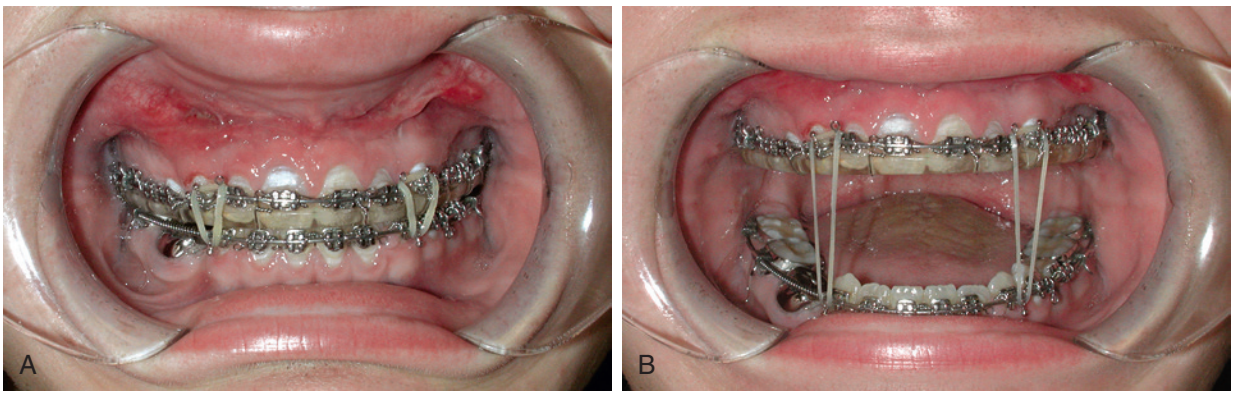
Completion of Orthodontics

When a satisfactory range of jaw motion and stability of the osteotomy sites are achieved, the orthodontic treatment can be ended. The heavy surgical arch wires are removed and replaced with light orthodontic wire. Final alignment and positioning of teeth is accomplished, as is closure of any residual extraction space. The light vertical elastics are left in place at this time to override proprioceptive impulses from teeth, which otherwise would cause the patient to seek a new position of maximal intercuspation. The settling process proceeds rapidly and rarely takes longer than 6 to 10 months.

Retention after surgical orthodontics is no different from that for other adult patients, and definitive periodontal and prosthetic treatment can be initiated immediately after the final occlusal relationships have been established.

Postsurgical Restorative and Prosthetic Considerations

When patients require complex final restorative treatment, it is important to establish stable, full-arch contact as soon after orthodontic debanding as possible. Posterior vertical contacts are important in patients who have only anterior components of occlusion remaining. Well-fitting, temporary, removable partial dentures may suffice, and these appliances should be relined with tissue-conditioning materials, as needed, to maintain the posterior



• **Fig. 26.38** (A) Interocclusal splint wired to the maxilla. Light elastics are used to help guide the patient into the new postoperative occlusion. (B) Patient 7 days after maxillary osteotomy.

support during healing. When postsurgical orthodontics is complete, the remainder of restorative treatment can be accomplished in the same manner as for any nonsurgical patient.

Postsurgical Dental and Periodontal Considerations

The patient should be seen for a maintenance dental and periodontal evaluation approximately 10 to 14 weeks postoperatively. The mucogingival status is reevaluated, the teeth deplaqued, and areas of inflammation or pocketing lightly scaled. Frequent recall maintenance should continue during the remainder of orthodontic care, when necessary. After the orthodontic appliances are removed, a thorough prophylaxis with a review of oral hygiene techniques is advisable. A thorough periodontal reevaluation 3 to 6 months after completion of the postsurgical orthodontics will determine future treatment needs. Periodontal surgery, including crown-lengthening or regenerative procedures, should be performed after the inflammation associated with orthodontic appliances has resolved. Areas of hyperplastic tissue should be observed for 3 to 6 months after orthodontic therapy, unless aesthetic or restorative considerations necessitate earlier tissue removal. After completion of periodontal treatment, recall intervals should be adjusted to accommodate the individual patient's needs.

Summary

The treatment of patients with dentofacial deformity involves the evaluation and treatment of many types of dental and skeletal problems. These problems require that all practitioners involved in patient care interact in a multidisciplinary team approach to treatment. This sequential, team approach yields the most satisfying results.

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27

Facial Cosmetic Surgery

TIRBOD FATTAHI AND SALAM SALMAN

CHAPTER OUTLINE

Introduction and Historical Perspective

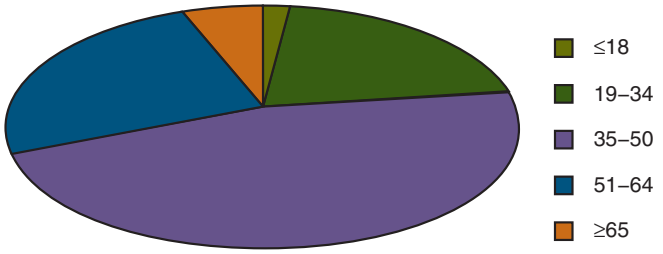
From a historical perspective, cosmetic surgery in the United States has been primarily performed by plastic surgeons, including both facial and body cosmetic surgery. As time went on, with the introduction of competing specialties, such as otolaryngology, a shift in this practice occurred. Otolaryngologists, with their expertise in nasal surgery, began to expand the field and slowly entered the arena of facial cosmetic surgery. Over the past 25 years, other specialties, such as dermatology, oral and maxillofacial surgery (OMS), ophthalmology, and others have begun to routinely perform cosmetic procedures. As the practice of cosmetic surgery has expanded, so have the number of specialists who are trained and qualified to perform such procedures. Today, all OMS residents in training are expected to be knowledgeable and able to perform, to various degrees, facial cosmetic procedures. Postresidency training fellowships in cosmetic surgery, both facial and body surgery, are now available to oral and maxillofacial surgeons with an interest in cosmetic surgery. In addition, there are now recognized governing bodies, such as the American Board of Cosmetic Surgery, that can bestow board certification to any individual, regardless of specialty background, who has satisfied the necessary requirements.

There is a tremendous amount of money spent on cosmetic surgery in the United States annually. According to the latest data, in 2016, $10.5 billion was spent on surgical and nonsurgical procedures in our country. Prior to the recession of 2008, this number was close to $14 billion and each year since then has shown a steady increase in the number of consumers (patients) and the number of procedures. Another major shift, compared with 25 years ago, is the age distribution of patients seeking cosmetic procedures. Traditionally, patients opted to wait until they were in the fifth decade of life or older before seeking these types of procedures; recent data clearly show how this trend has shifted (Fig. 27.1). Almost two-thirds of all patients seeking cosmetic surgery in the United States are between the ages of 19 and 50 years. Today, patients are more knowledgeable and motivated to pursue cosmetic procedures at an earlier age, almost in a preventative manner, to slow the effects of the aging process. This trend is also seen in other parts of the world.

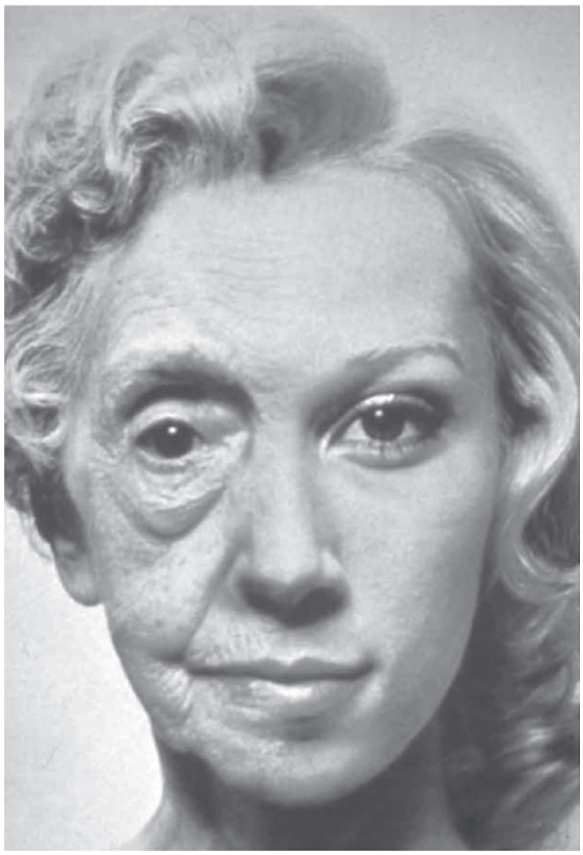
Physiology of Aging

Before embarking on any discussion regarding surgical and nonsurgical management of a given condition, it is imperative to have a clear understanding of the disease process. This is no different when discussing facial cosmetic surgery; clinicians must have a firm appreciation of the aging process, both at the surface and deep within the tissues. The aging process includes two different categories: extrinsic aging and intrinsic aging. Extrinsic aging, also known as photoaging, is the cumulative effects of environmental factors under the control of the patient. These include habits such as smoking, lifestyle (individuals who work outdoors all day vs. those who work indoors), geographic location (individuals who live close to a power plant or areas with high pollution), and long exposure to sunlight. Intrinsic aging is the cumulative effect of physiologic and chronologic aging; it is the genetic and biologic action of cellular senescence. Intrinsic aging includes loss of collagen and elastin fibers, production of cytokines at the cellular level such as collagenase and elastase, impairment of DNA signal transduction, loss of tissue hydration and volume, selective resorption of bone, and descent and laxity of muscles and surrounding fascia. This process, coupled with extrinsic aging, is responsible for the visual depiction that most individuals associate with an aged person (Fig. 27.2). Other pertinent considerations include ethnicity, hormonal differences between males and females, and anatomic variations (thickness of skin of the eyelids compared with the skin of the palms of the hands). Although intrinsic aging is difficult to manipulate, the focus of skin care and topical medications used in cosmetic surgery is extrinsic aging (photoaging).

In addition to understanding the aging process, each patient must also be evaluated in a systematic manner. Although there are

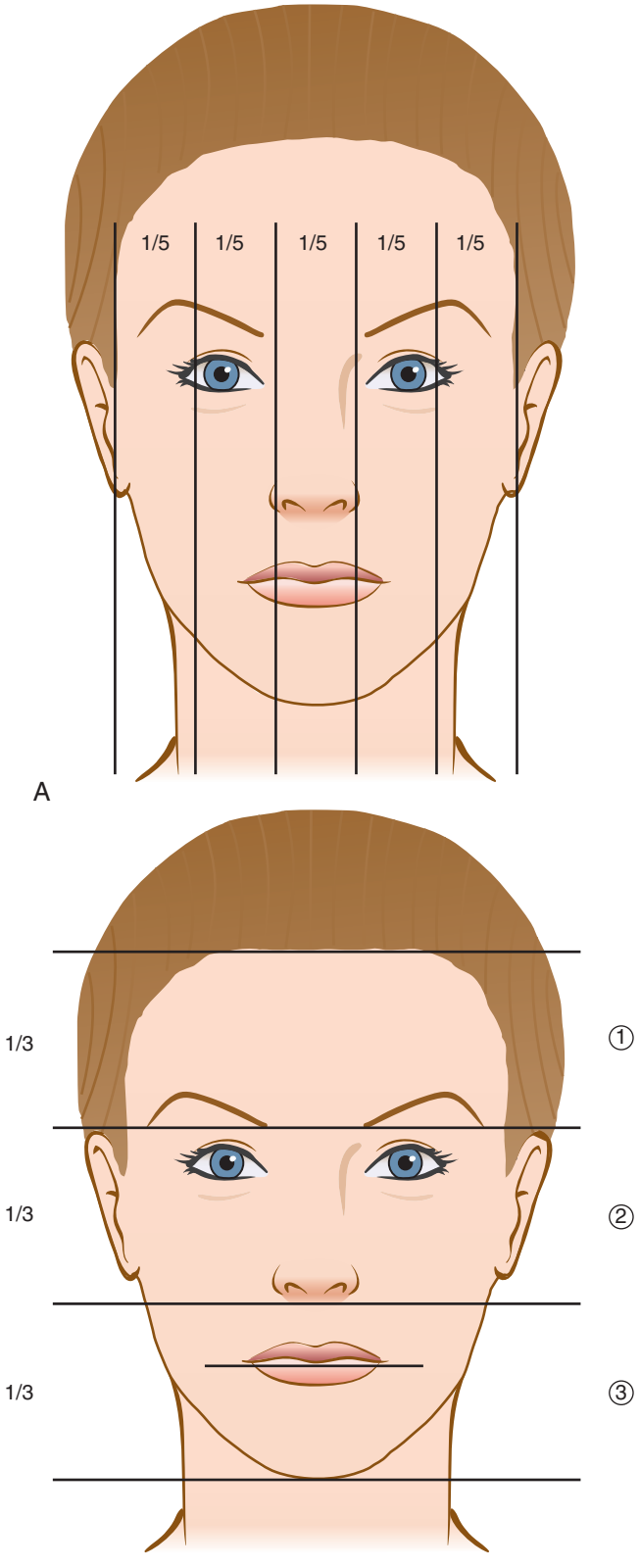


• **Fig. 27.1** Age distribution of patients seeking cosmetic surgery.



• **Fig. 27.2** Comparison of the facial aging process between the young and old.

individual, ethnic, and age-related differences between each patient, there are well-defined parameters in evaluating the face. This process attempts to answer the age-old question of what comprises "beauty." Clearly, cultural norms of beauty have changed from the 1930s. A quick web search for "symbols of beauty" from the early part of the 20th century reveals how vastly different the current definition of beauty is. What is fairly standard is that the more symmetric one's face is, the more attractive the person appears. There are components of the face that clearly augment or detract from an overall image of beauty such as the eyes, smile, jawline, skin tone, and texture. When these features appear youthful, combined with symmetry, we tend to recognize the individual as attractive. Other parameters of facial evaluation deal with zones and subunits of the face and attempt to correlate a degree of symmetry and/or parity between each area.[1] The face can be divided into equal horizontal thirds and equal vertical fifths (Fig. 27.3). The upper third of the face is between the ideal hairline and nasion; middle third between the nasion and stomion; and lower third between



• **Fig. 27.3** Ideal (A) horizontal and (B) vertical divisions of the face.

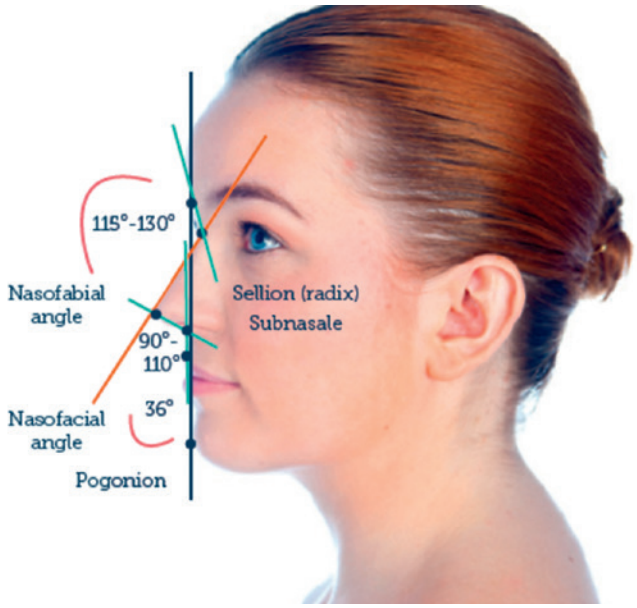
the stomion and soft tissue pogonion. Ideally, there is a balance among all three horizontal sections. The middle and lower thirds of the face are the main target of corrective jaw surgery (orthognathic surgery), which is discussed elsewhere in this textbook. The vertical fifths of the face begin with the outer aspects of normally positioned and oriented ears and divide the face into five equal parts. Again, major disparity between these vertical dimensions can detract from symmetry of the face. In addition to horizontal and vertical divisions, there are well-known and recognized facial angles and measurements that can aid in evaluation of the ideal face (Fig. 27.4). It is important to recognize that cultural and ethnic variations and norms play a major role in this arena.

Assessment of skin and the aging process can also be enhanced by using long-recognized classification systems such as the Glogau classification (aimed to determine the amount of photoaging and wrinkling), as well as the Fitzpatrick classification (aimed to determine how reactive one's skin is to sunlight) (Fig. 27.5 and Table 27.1).

All of the aforementioned assessment tools must be taken into consideration when evaluating a patient for any type of cosmetic procedure.

Surgical Versus Nonsurgical Options

Facial cosmetic procedures can generally fall into two major categories: surgical and nonsurgical. Some clinicians include the term "minimally invasive" into the category of nonsurgical, although this inclusion is not always accurate (i.e., a minimally invasive endoscopic forehead lift is a surgical procedure, albeit with smaller incisions). Surgical options include any procedure in which an actual incision is made on or around the facial region (including inside the oral cavity). Nonsurgical options include any procedure in which incisions are not made and, rather, other modalities such as an injection of a medication or a source of energy (lights, lasers, etc.) is used to modify the appearance of facial structures.



• **Fig. 27.4** Common angles and planes of the face.

Surgical Procedures

Lower Face and Neck

Surgical options in rejuvenation of the lower face include submental liposuction, neck lift (cervicoplasty), and chin augmentation.

Before determining the proper surgical option for a patient, a thorough evaluation of the facial region must be performed according to the previous section. Specific deformities such as loss of jaw definition, submental fullness, laxity of skin, lack of proper chin projection, evaluation of occlusion, and the status of the platysma muscle must be taken into consideration before finalizing the surgical options.

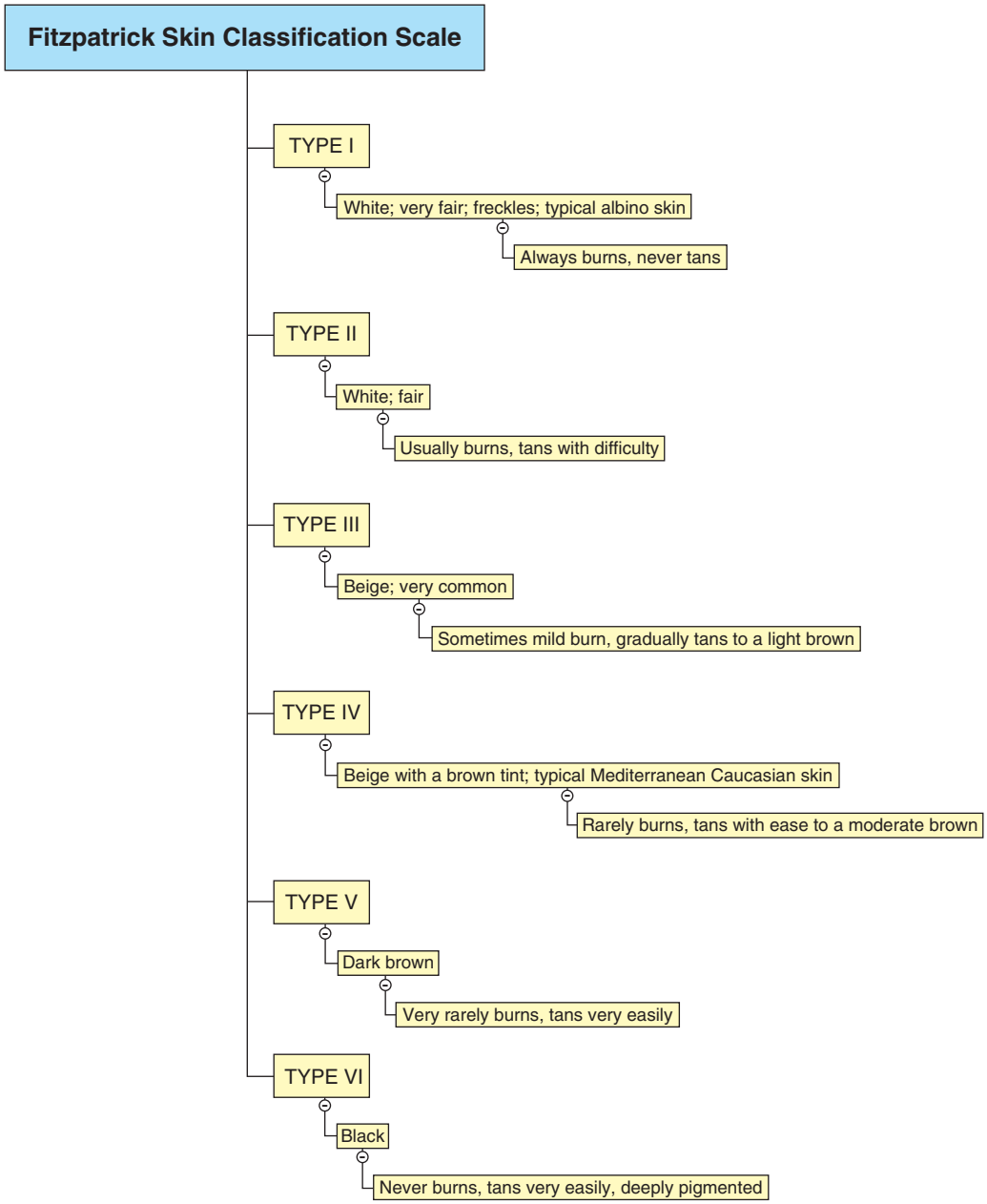
A younger patient with mild to moderate submental fullness may respond quite nicely to submental liposuction. This procedure removes the superficial adipose compartment above the platysma muscle (Fig. 27.6). It does not include removal of any excess skin and completely relies on the contraction of the skin after removal of excess fat (Fig. 27.7). Because the actual amount of fat between all individuals is identical (only the size of the fat cells differs between a thin and obese patient), removal of the fatty deposit should create a long-lasting result.[2]

An older patient who shows evidence of skin laxity and submental fullness may benefit from more invasive procedures such as a formal neck lift. These patients almost always have laxity of the right and left platysma muscles, often manifested as platysmal redundancy or banding (Fig. 27.8). A neck lift, also referred to as a cervicoplasty or submentoplasty, can be combined with a formal face lift and comprehensively addresses all of the aging components of the lower face and neck, including removal of submental fat, removal of redundant platysma, and possible excess skin removal. This procedure uses an incision in the submental area and incisions around the ears to address the cosmetic deformity (Fig. 27.9).[3,4]

Evaluation of the chin is also a critical component of lower face and neck rejuvenation. Obviously, occlusion plays an important role in the appearance of the chin. However, chin deficiencies, in an anterior/posterior vector as well as laterally, can certainly exist without an obvious malocclusion. Bone resorption and descent of soft tissue can certainly lead to the appearance of a "weak" chin. Augmentation of the chin can occur via a genioplasty in which

TABLE 27.1 Glogau Classification (Photoaging)

Group	Classification	Age (y)	Description	Characteristics
I	Mild	28–35	No wrinkles	Early photoaging; no keratosis
II	Moderate	35–50	Wrinkles in motion	Early to moderate photoaging
III	Advanced	50–65	Wrinkles at rest	Advanced photoaging
IV	Severe	60–75	Only wrinkles	Severe photoaging; cannot wear make up



• **Fig. 27.5** Fitzpatrick skin classification scale.

the chin button is cut away from the remaining aspects of the mandible and simply repositioned into a more favorable location (described in Chapter 26). Chin augmentation can also be accomplished by placing alloplastic implants. Chin augmentation using an implant can be performed from inside the oral cavity or from a percutaneous approach from the submental region (Figs. 27.10 and 27.11).[5,6]

Face and Midface

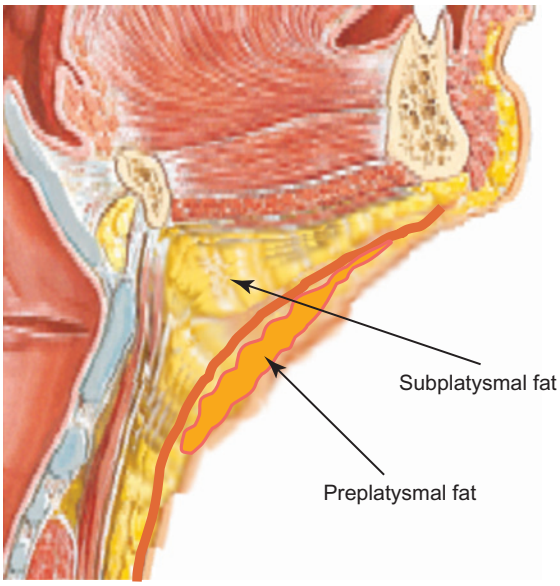
This region, bounded by the inferior border of the mandible all the way up to cheek bones and zygomatic arches, is one of the largest areas that can show manifestations of the aging process. Surgical options to rejuvenate this area include face lift, midface lift, and cheek augmentation.

The aging process in the middle aspect of the face includes laxity and ptosis of the facial soft tissue envelope (skin, fat, fascia, and muscle), formation of prominent folds (nasolabial folds, melolabial folds), loss of definition of the jaw border, and development of jowls (accumulation of ptotic facial fascia and fat along the anterior aspects of the mandible).

One of the most striking surgical procedures is a face lift operation. Often combined with a neck lift, this operation rejuvenates the face by repositioning the ptotic soft tissue envelope in a more posterior and superior direction, thus effacing prominent facial folds, eliminating jowls, and removing excess skin. This operation involves making an incision around the ears, extending into the frontal sideburns and posterior hairline (Fig. 27.12). After elevating a skin flap, the superficial fascia of the face (superficial musculoaponeurotic system) is repositioned appropriately to re-drape the

soft tissue envelope. When combined with a neck lift, the entire facial and neck subunits are effectively rejuvenated (Fig. 27.13).

If the aging process is limited only to the cheek region of the face, then a midface lift or cheek augmentation can be entertained. A midface lift is performed with two incisions inside the mouth (right and left maxillary vestibular incisions), whereby the musculature of the midface is completely degloved from the underlying bone. A separate incision in the temple area is then performed and a tunnel is created between the temples and the oral cavity by dividing the connecting periosteum and fascia. The ptotic midface tissue is then suspended in an upward and posterior direction and repositioned on the temple with sutures or resorbable anchor devices (Figs. 27.14 and 27.15). Alternatively, the midface can simply be rejuvenated by placing alloplastic cheek implants, often via an intraoral approach. These implants come in a variety of materials including silicone and polyethylene (Fig. 27.16).[7]



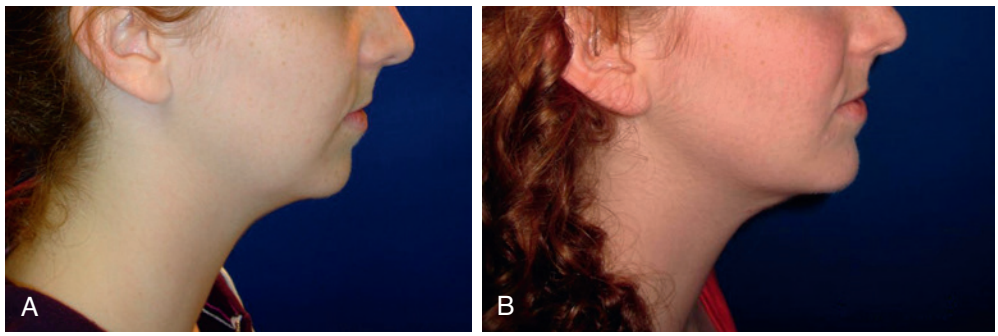
• **Fig. 27.6** Fat compartment removed during submental liposuction.

Forehead and Brows

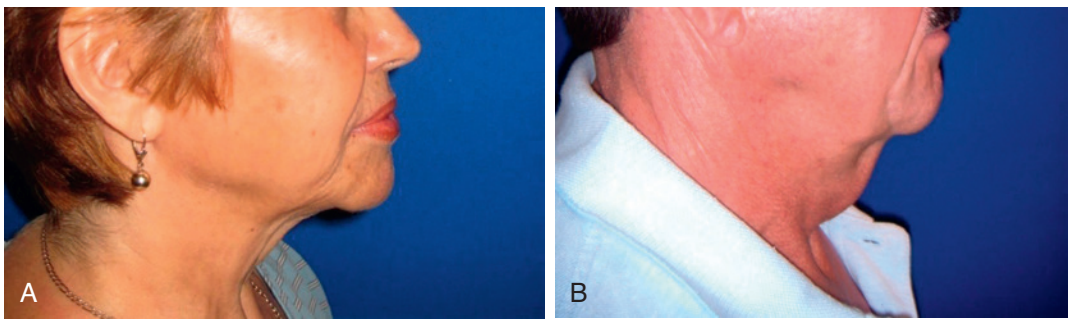
Another powerful rejuvenative procedure is the elevation of an aged and ptotic forehead and brows. This procedure "opens up" the eyes by repositioning the brows and surrounding fat pads in a more superior and youthful position. Evidence of forehead ptosis includes descent of the brows when examined in a neutral gaze. In females, an ideal brow sits above the supraorbital rims, reaches a peak, and gently descends (Fig. 27.17). In males, an ideal brow sits rather flat at/or within 1 to 2 mm of the supraorbital rims. In addition, the presence of wrinkles across the forehead and/or in a vertical fashion in the glabellar areas also signals forehead aging. There are multiple different methods of forehead lifting. The two most common methods include the endoscopic approach and the pretricheal approach. The endoscopic approach uses an endoscopic camera and other specifically modified instruments to elevate the brows in a more youthful direction (Fig. 27.18). The pretricheal approach includes an incision just within the hairline (Fig. 27.19). After elevation of an appropriate forehead flap, excess muscle, fascia, and skin are excised and the eyebrows and forehead elevated (Fig. 27.20).[8–10]

Eyelids

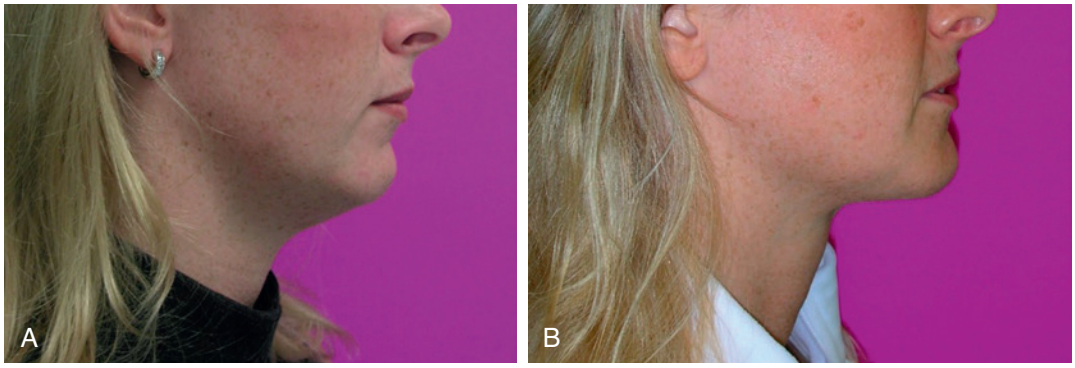
In a younger patient, or in someone who does not have forehead and brow ptosis, rejuvenation of the eyelid region can include



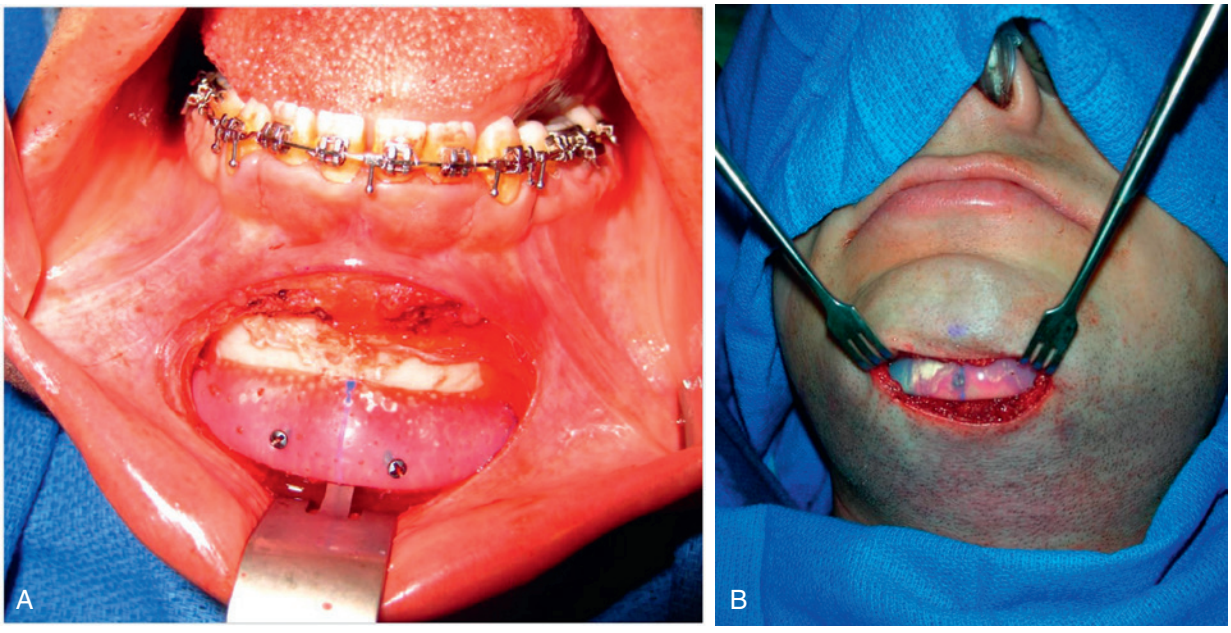
• **Fig. 27.7** (A) Before and (B) after photos of submental liposuction.



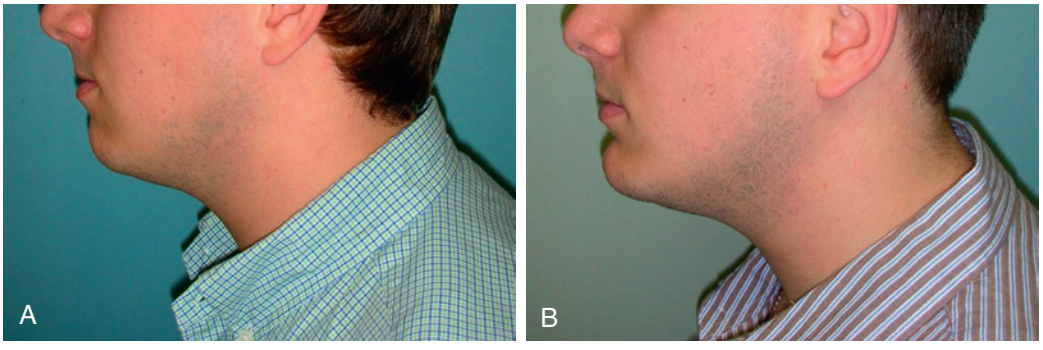
• **Fig. 27.8** (A) Platysmal bands versus (B) platysmal redundancy.



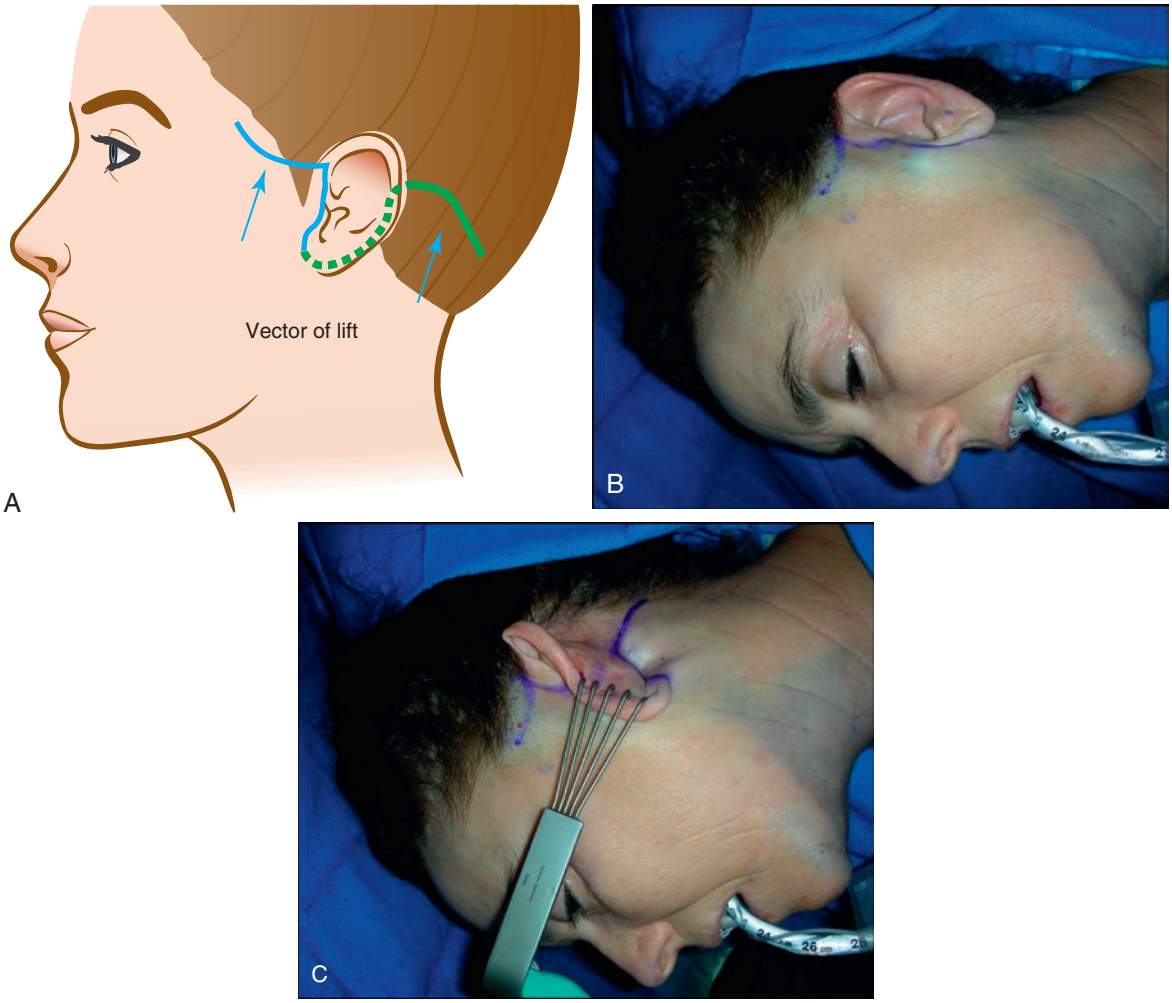
• **Fig. 27.9** (A) Before and (B) after photos of a neck lift.



• **Fig. 27.10** (A) Intraoral versus (B) transcervical approaches for placement of chin implants.



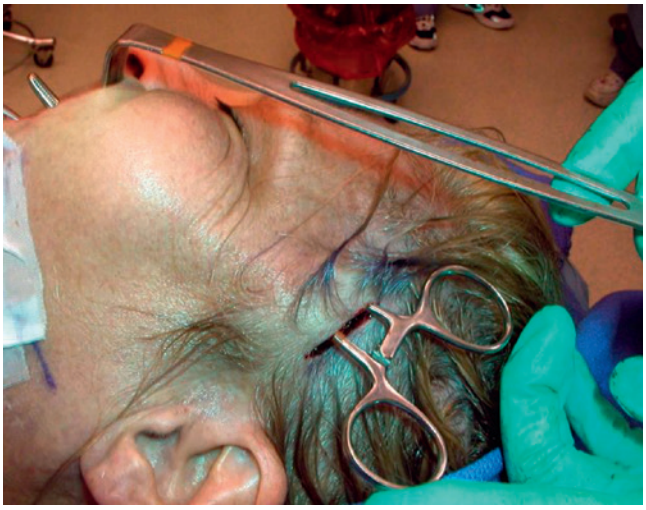
• **Fig. 27.11** (A) Before and (B) after photos of chin augmentation.



• **Fig. 27.12** (A–B) Outline of incisions for a face lift. (C) Vector of lift.

• **Fig. 27.13** (A) Before and (B) after photos of a face and neck lift.

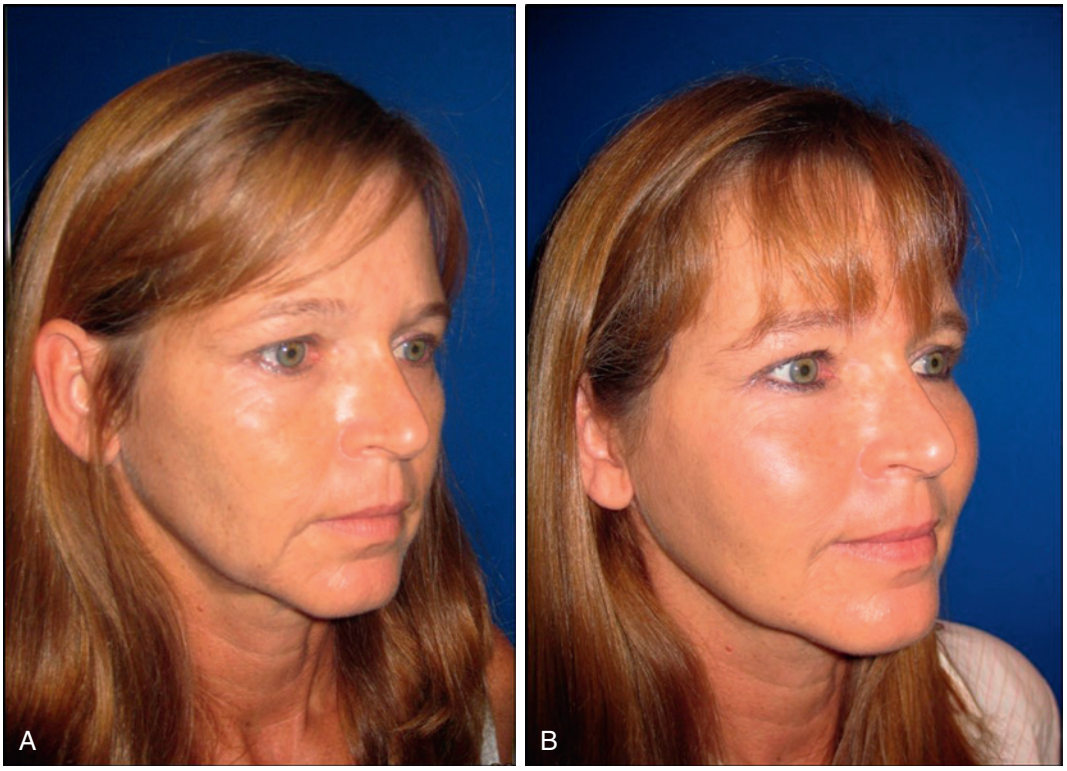
upper and lower blepharoplasty. Blepharoplasty includes removal of excess skin and eyelid muscle, as well as repositioning or removal of eyelid fat pads. There are two distinct fat pads in the upper eyelid and three in the lower lid. If the clinician determines that the fat pads are pronounced and contributing to a "bulge" in the lower or upper lid, a conservative removal and repositioning of the fats pads might be indicated. Fullness of upper and lower lids can also stem from ptotic skin and orbicularis oculi muscle. This fullness in the upper eyelid is referred to as "hooding" and, if severe, can actually interfere with vision in the lateral gaze (Fig. 27.21). Special attention must be paid when performing lower eyelid blepharoplasty to avoid the complication of lower eyelid rounding or malpositioning. Upper eyelid blepharoplasty includes removal of skin, muscle, and indicated fat pads by an external skin incision (Fig. 27.22). Lower eyelid blepharoplasty can be performed via an external approach (skin) or internal approach (transconjuctival) and can remove skin, muscle, and fat pads (Fig. 27.23). Tightening the lower lid must be performed when performing a lower lid transcutaneous approach (Fig. 27.24).[11]



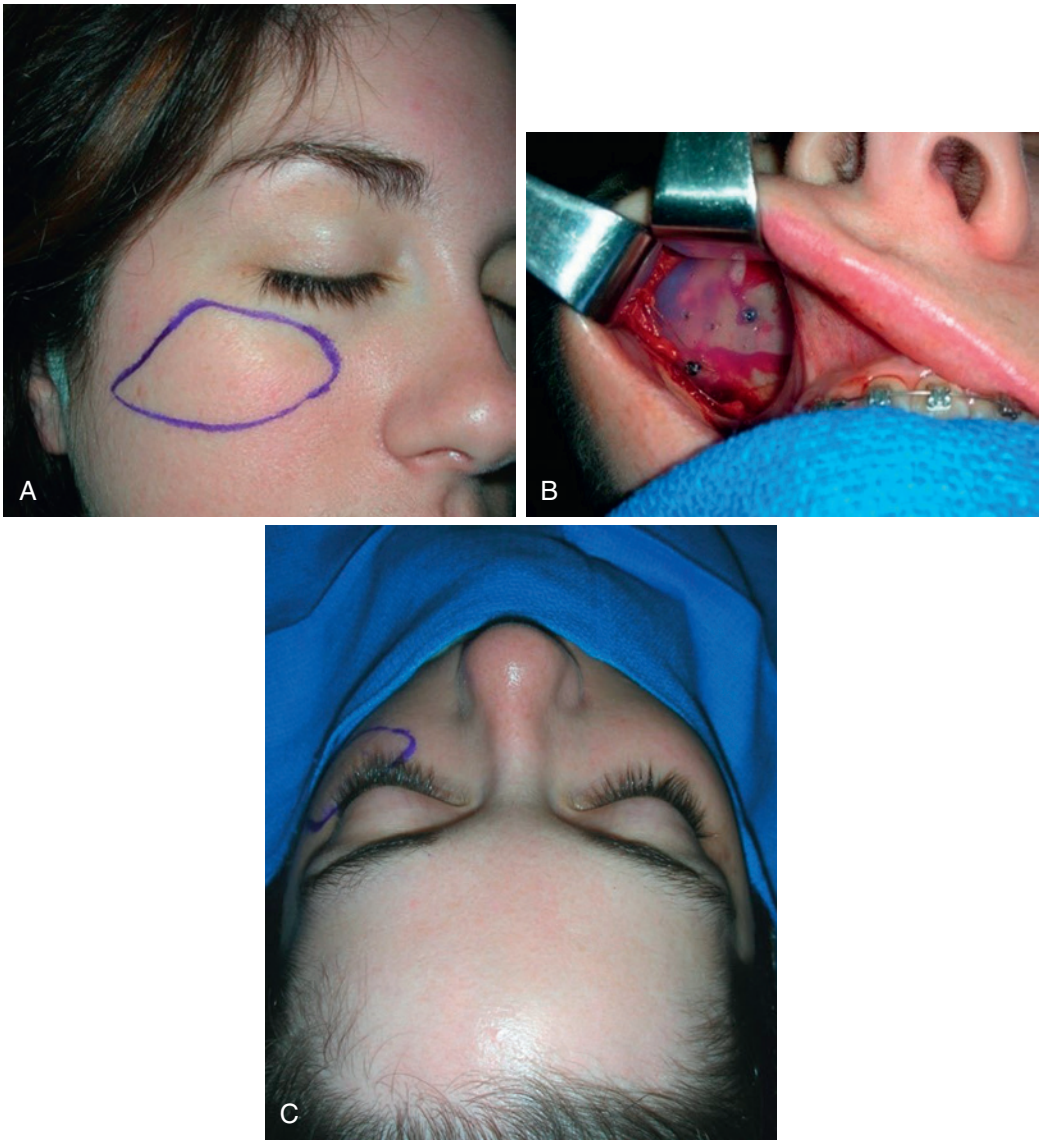
• **Fig. 27.14** Combination of an intraoral incision and temple incision to achieve a midface lift.

Rhinoplasty

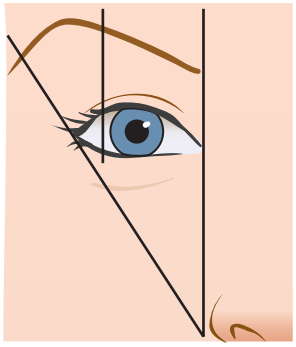
Considered the most difficult aesthetic surgical procedure, rhinoplasty is also one of the more commonly performed facial cosmetic procedures. Prior to performing a rhinoplasty, a thorough understanding of the entire nasal complex is necessary. Deformities of the nose include both cartilaginous and bony issues, as well as the soft tissue envelope overlying the nose. A nose can be too big, too small, twisted, deviated, or wide, as well as exhibiting a myriad of other deformities, including functional (breathing) issues. After a clear understanding of the underlying cosmetic and functional deformities is gained, a comprehensive treatment plan is created to address each issue. The nasal cavity can be approached through an internal (endonasal) or external (transcutaneous) approach (Fig. 27.25). Once the underlying structures are exposed, a methodical approach is taken to address the nose in a systematic manner (typically from top to bottom) (Fig. 27.26). Septoplasty, commonly performed at the time of a rhinoplasty, can address a twisted or deviated septum (common cause of a twisted nose) and can allow harvesting of cartilage to be used to "rebuild" or "restructure" specific aspects of a nose (Figs. 27.27 to 27.29). This is especially useful when addressing functional issues such as collapse of nasal



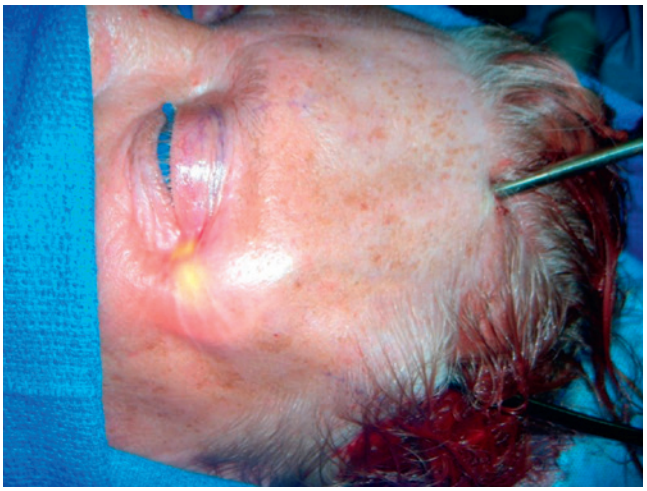
• **Fig. 27.15** (A) Before and (B) after photos of a midface lift.



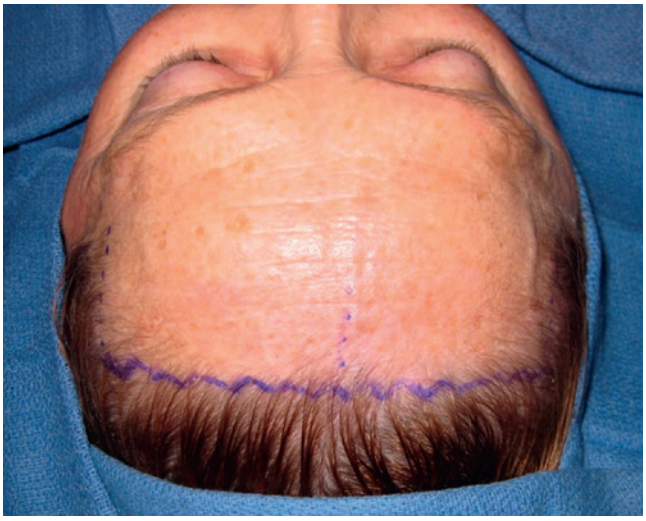
• **Fig. 27.16** (A) Outline of proposed silicone cheek implant. (B) Placement of a silicone cheek implant via a transoral incision. (C) Note the difference between cheek projection on the right side (implant in place) compared with the left side.



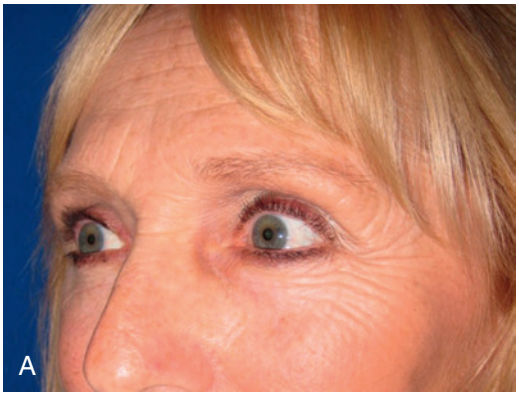
• **Fig. 27.17** The "ideal" female brow. The medial aspect of the brow begins tangential to a line drawn from the alar base vertically through the medial canthus. The tail of the brow ends tangential to an oblique line drawn from the alar base through the lateral canthus. The apex of the brow falls somewhere between the lateral limbus and the lateral canthus. The brow gently tapers as it arches laterally and superiorly.

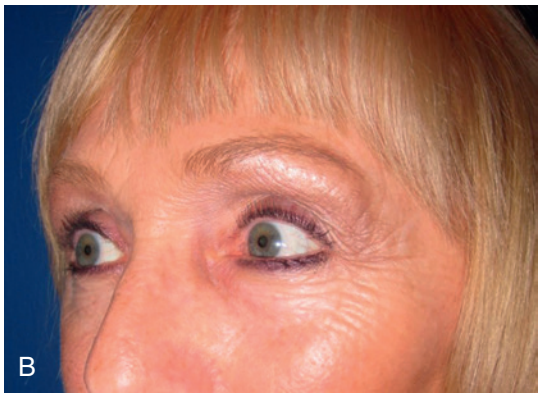


• **Fig. 27.18** Endoscopic instruments in place during an endoscopic forehead lift.

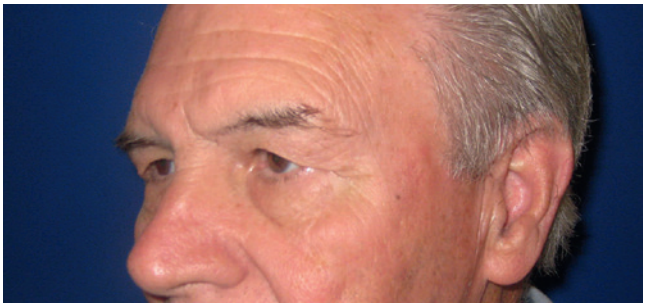


• **Fig. 27.19** Outline of a pretrichial brow lift.

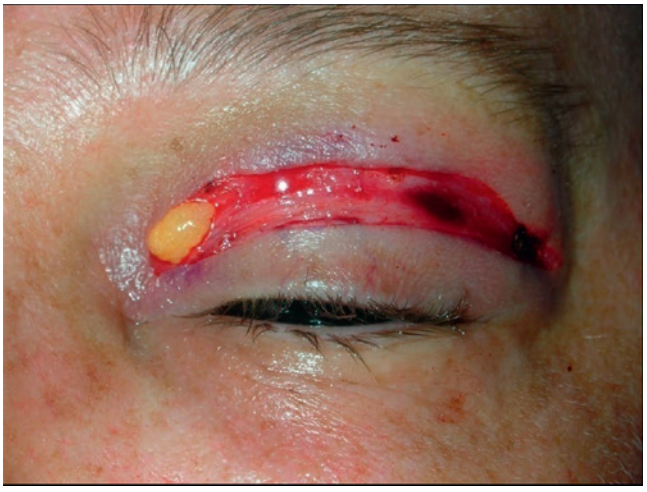




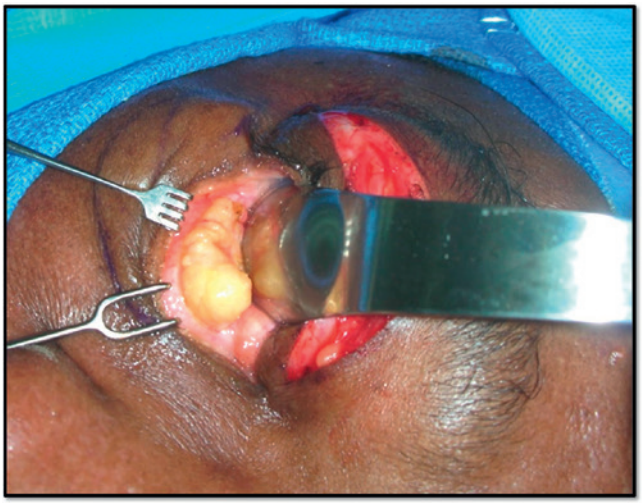
• **Fig. 27.20** (A) Before and (B) after photos of a pretrichial brow lift.



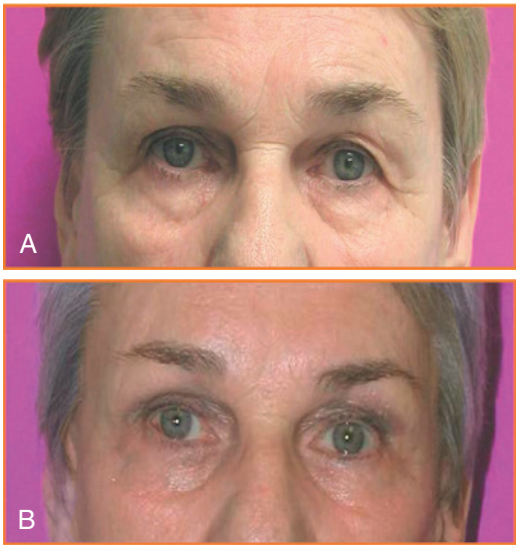
• **Fig. 27.21** Excessive "hooding" of upper eyelid skin, interfering with vision.



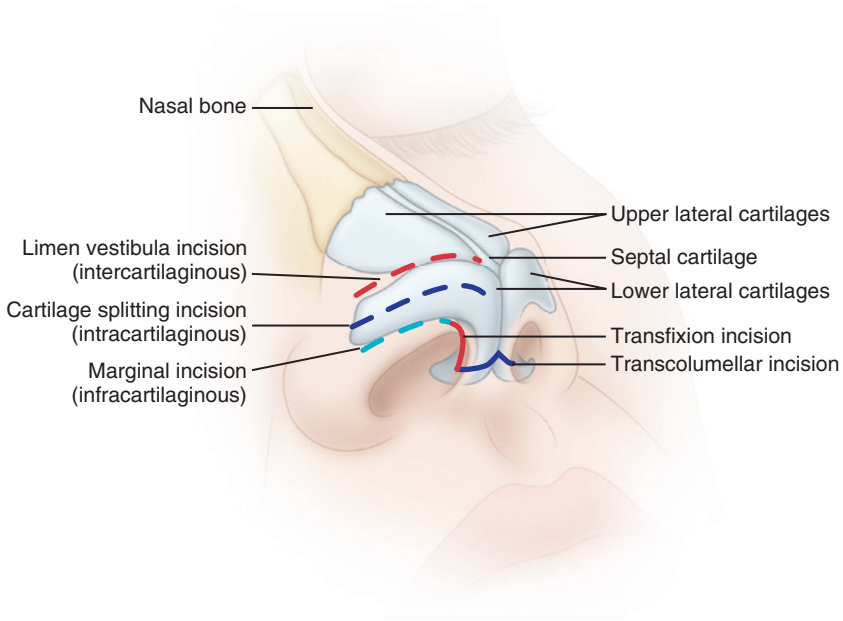
• **Fig. 27.22** Right upper eyelid blepharoplasty.



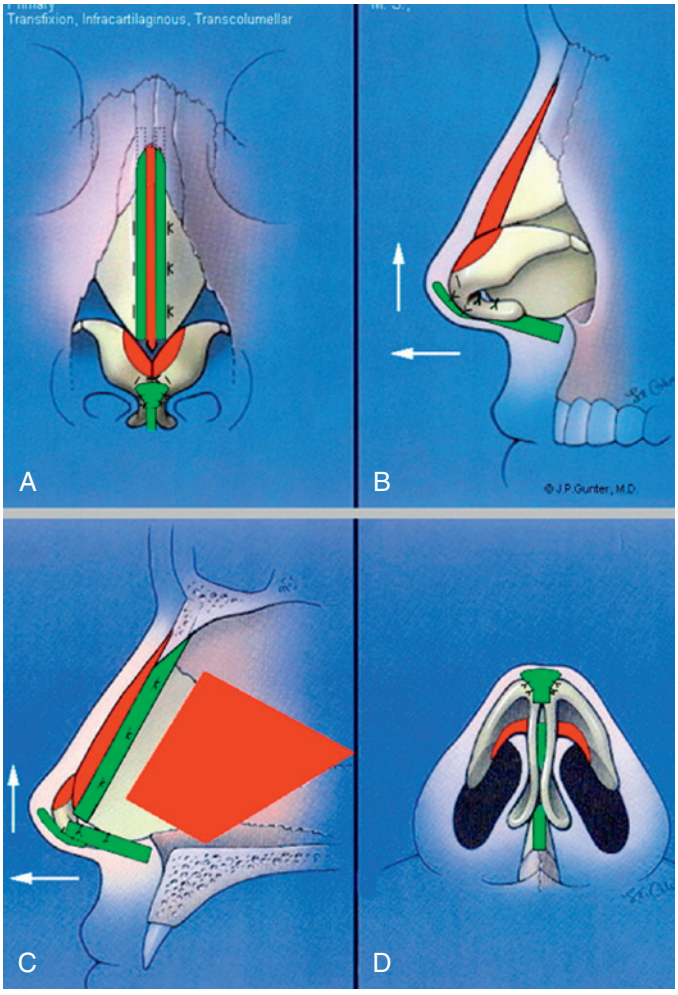
• **Fig. 27.23** Right lower eyelid transconjuctival blepharoplasty.



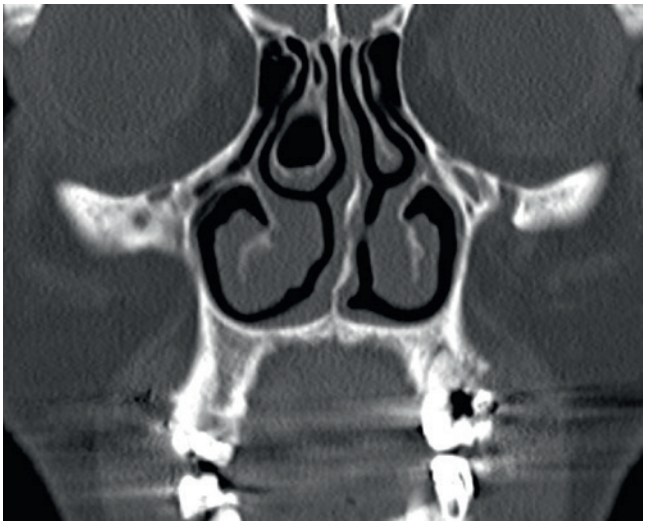
• **Fig. 27.24** (A) Before and (B) after photos of a blepharoplasty patient.



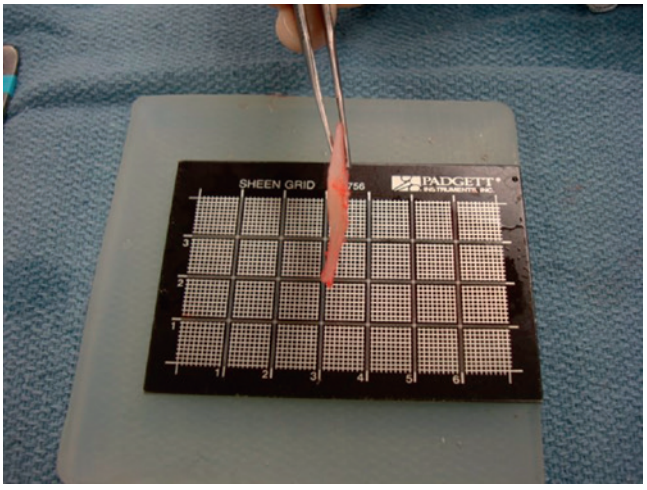
• **Fig. 27.25** Typical incision lines for open and closed rhinoplasty.



• **Fig. 27.26** Rhinoplasty worksheet demonstrating harvesting of the septum (in red) and placement of additional grafts (in green). (From Rohrich RJ, Adams WP, Ahmad J, Gunter JP. *Dallas Rhinoplasty: Nasal Surgery by the Masters*. 3rd ed. Boca Raton, FL: CRC Press; 2014.)



• **Fig. 27.27** Computed tomography demonstrating a deviated septum and enlarged right-sided inferior turbinate.

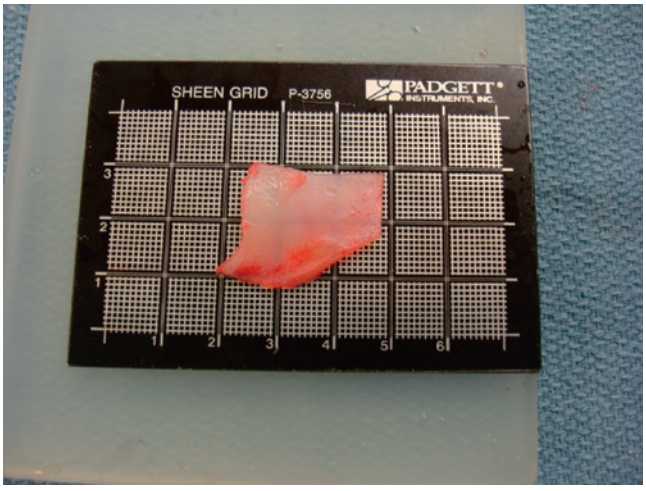


• **Fig. 27.28** Cadaveric specimen showing internal anatomy of nose (overlying skin removed).

valves involved in breathing or hypertrophic inferior turbinates that can also obstruct nasal air flow. Rhinoplasty allows the surgeon to reduce a prominent nasal hump by reducing the bony components, the cartilaginous components, or both. The procedure is often combined with bone osteotomies to refine the nasal tip through trimming the nasal tip cartilages, suture techniques, or both; alter the tip rotation and projection; and even change the shape of the nostril. When both functional and aesthetic concerns of the nose are addressed appropriately, the results can be quite gratifying (Fig. 27.30).[12–16]

Nonsurgical Procedures

One of the fastest growing cosmetic modalities in our country is nonsurgical or sometimes called "minimally invasive" procedures. These treatments typically are less expensive, less time consuming, and require little or no recovery time for the patient. These attractive features allow the clinician to incorporate nonsurgical procedures within a full-scope cosmetic practice. The main focus of the nonsurgical procedures is the top layers of the skin (epidermis and dermis).



• **Fig. 27.29** Harvested septum following a septoplasty.

Topical Skin Care

Topical skin care includes products that are formulated to be used on skin surfaces for rejuvenation purposes. These include prescribed and nonprescribed ointments, lotions, creams, and medications. Examples of this type of therapy include vitamin A derivatives such as tretinoic acid (Retin A), vitamin C topical ointments, botanicals, and antioxidants. Growth factor derivatives, collagen creams, moisturizers, cleansers, and bleaching creams are other examples of topical modalities. Most patients can benefit from topical skin care even if they are interested in more invasive surgical options. In fact, topical therapy is often times initiated prior to formal surgical intervention.

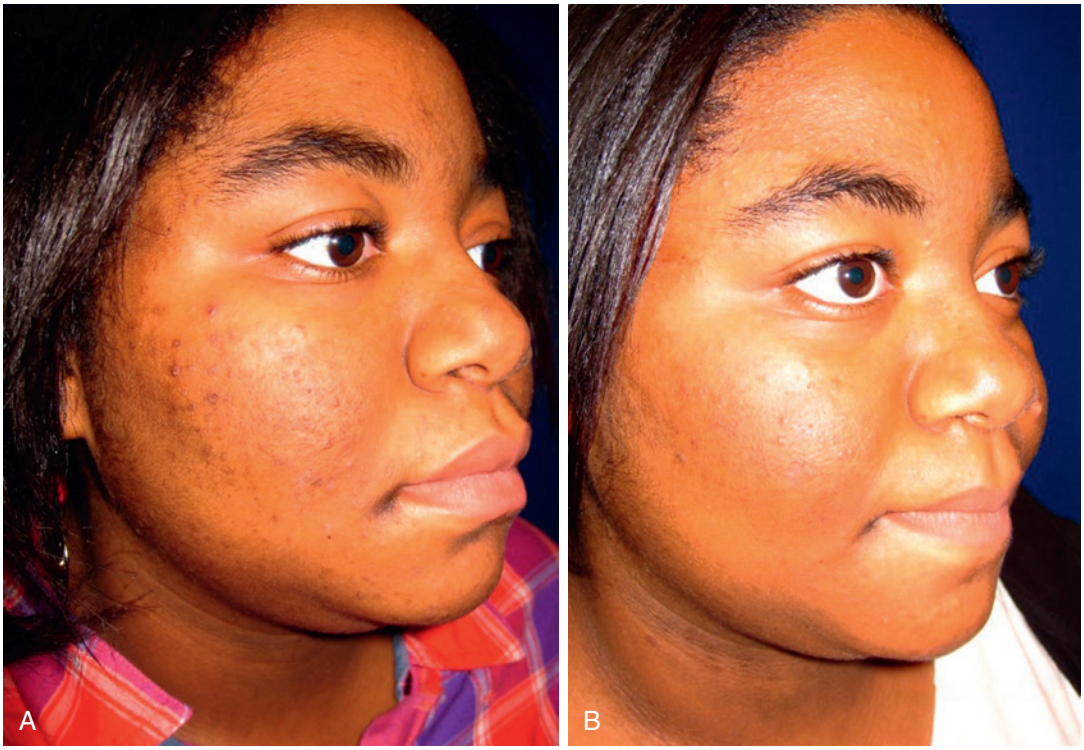
Chemical Peels

One of the most effective skin therapy modalities is chemical peeling. This procedure goes back thousands of years when the ancient Egyptians used sour milk and pumice to "lighten" skin and improve its texture. Today, chemical peels are quite popular in most aesthetic practices. There are different types of chemical peels based on the strength or concentration of the peeling agent, as well as its mode of action. Chemical peels are derivatives of alpha hydroxyl acids or tricholoroacetic acids. Chemical peels increase the turnover of skin cells (shorten the life cycle), increase collagen formation, brighten up skin, decrease acne breakouts, and improve skin texture and tone. Common examples of chemical peels are glycolic acids, Jessner solution, and phenols. Peels are often performed in the office as part of a comprehensive skin care regimen. Patients tolerate these procedures quite easily and most will experience some skin peeling over the subsequent few days following application of the chemical peel. Once performed over a few appointments, results can be quite pleasing and effective (Fig. 27.31).

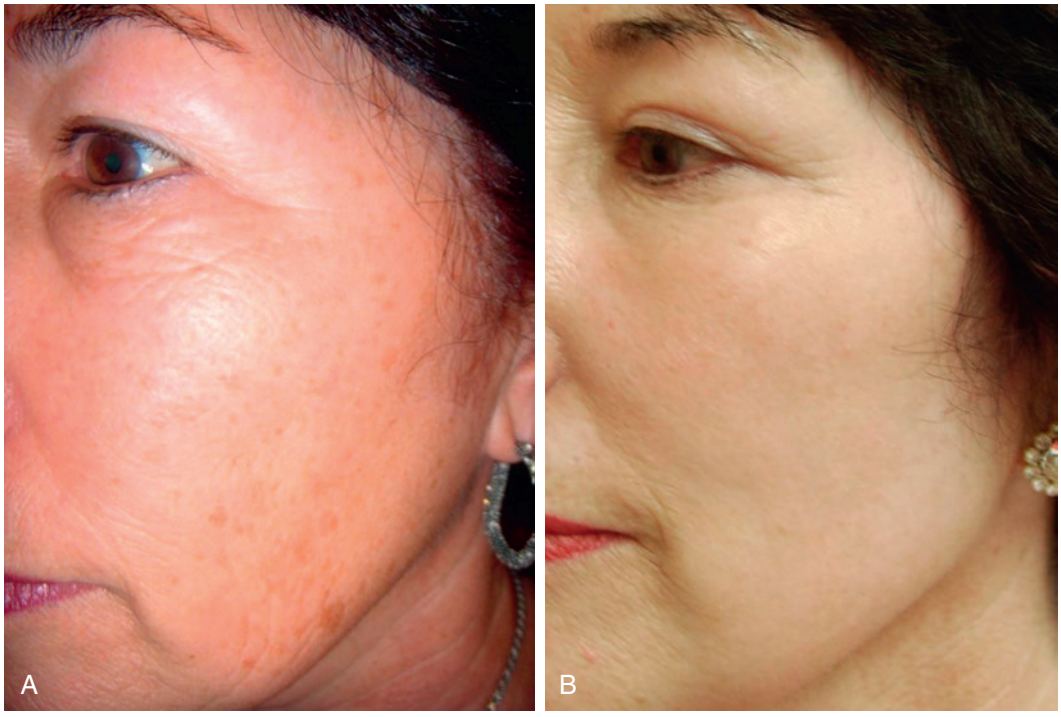
Laser Resurfacing

Use of lasers in medicine goes back many decades. Lasers use a source of energy (CO_2, xenon, etc.), a pump, and an optical cavity to create a visible or nonvisible light with tremendously high energy and focus. Depending on the desired outcome or goal, a specific type of laser is used. For example, using a laser to perform facial

• **Fig. 27.30** (A) Before and (B) after photos of rhinoplasty.



• **Fig. 27.31** (A) Before and (B) after results following three chemical peels.



• **Fig. 27.32** (A) Before and (B) after results following laser resurfacing.

skin rejuvenation would require a laser whose target is water (60% of skin cells are made up of water), whereas using a laser to remove a tattoo would require a laser whose target is pigments and dyes. The two most commonly used lasers in facial resurfacing are CO_2 and erbium YAG (yttrium-aluminum-garnet). These lasers target water within skin cells, leading to removal of all epidermis and most of the dermis components. In doing so, the body recognizes that an "injury" has occurred and attempts to heal itself by creating new collagen and elastin fibers, thereby rejuvenating itself. Not only does the body create new epidermis and dermis, but unsightly scars from previous surgeries, aging spots, and photoaged skin are all eliminated via the resurfacing procedure. Unlike chemical peels, laser treatments require a longer recovery time; however, the results are much more attractive and long lasting (Fig. 27.32).

Dermal Fillers

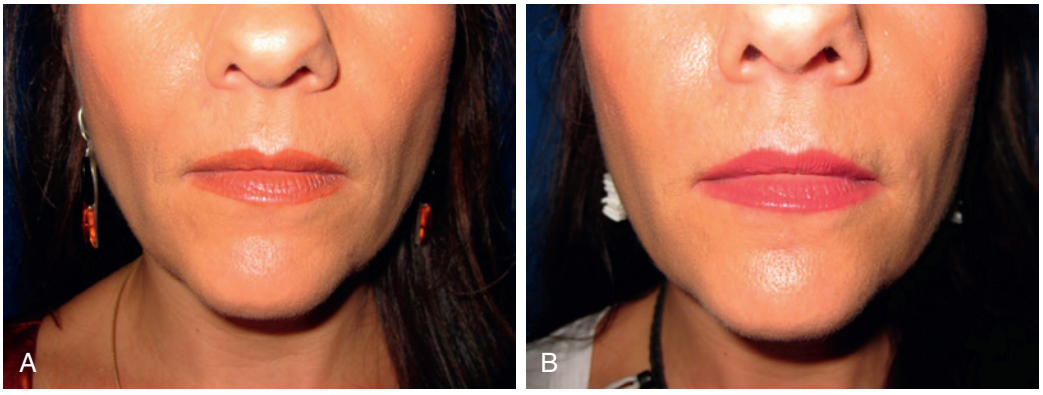
Dermal fillers have been around since the late 1970s. Fillers, irrespective of the composition, are intended to restore volume to an area of skin by "filling" a void or a wrinkle. Early versions of dermal fillers were derived from bovine collagen and required skin testing to rule out allergic reactions. The newer versions include hyaluronic acid (HA) fillers, injectable silicone, polymethyl methacrylate, and other materials. HA fillers are certainly the most popular variety. HA is a component of skin and subcutaneous tissues and is abundantly found in joint spaces and in eyes. It is a hydrophilic material that, by nature, can maintain hydration within the specific tissue. It has been routinely used in orthopedic surgery and ophthalmology before becoming formulated in a soft gel-like consistency, which makes it ideal as an injectable into skin. Fillers are ideal in nonsurgical facial rejuvenation by augmenting nasolabial folds, lips, lower lid areas, acne scars, cheeks, and any other region that is devoid of adequate volume. Fillers are easily performed in the office setting. After administration of a local anesthetic block or topical anesthetic, through a series of transcutaneous injections, fillers are placed within the dermal layer of the skin, causing an immediate augmentation. It is quick and relatively inexpensive with almost no recovery time for patients, hence the popularity of dermal fillers (Fig. 27.33). Because the HA molecules are synthetically formulated, the injected particles slowly dissolve within 6 to 9 months, depending of the viscosity of the material. Another advantage of HA fillers is the availability of an antidote to address any complications. Hyaluronidase is an injectable enzyme that immediately begins to break down HA particles within skin. This is of significant clinical importance because untoward reactions, such as formation of skin granulomas, allergic reactions, and topical infections, can easily be addressed via the application of the antidote. Currently, HA fillers are the only injectable dermal fillers with a reversing agent.

Neurotoxins

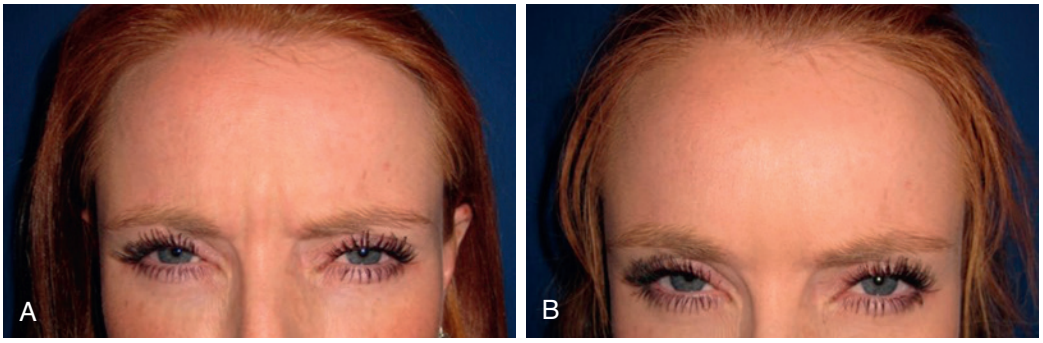
Neurotoxins are the most popular nonsurgical cosmetic item. Because wrinkling can be attributed to constant muscle contraction, administration of a drug (such as a neurotoxin) can stop the muscle from contracting and thereby improve or eliminate the appearance of wrinkles. Derived from the bacteria *Clostridium botulinum,* cosmetic neurotoxins are purified exotoxins sold under the trade names Botox, Xeomin, and Dysport. All neurotoxins work in a similar fashion; because acetylcholine (ACH) is required for a muscle fiber action potential, neurotoxins block the release of ACH at the postsynaptic cleft, thereby preventing muscle contraction. After a few months, the body creates new ACH molecules and receptors, and the effect of the neurotoxin is worn off. One of the most commonly used areas for cosmetic application of neurotoxins is the forehead. Appropriate injection of selective muscles in the forehead can relax forehead wrinkles, produce a smooth appearance, and even elevate the brows, which is especially pleasing in females. There are numerous noncosmetic applications of neurotoxins in the management of headaches, body movement disorders (dystonia or torticollis), excessive sweat production, and myofascial pain, such as temporomandibular pain. Neurotoxins are easily injected in the office without any local anesthetic. Results are evident for up to 3 months (Fig. 27.34).

Conclusion

The field of cosmetic surgery is a booming area of medicine. It is popular with patients of all ages, young and old. The utilization



• **Fig. 27.33** (A) Before and (B) after photos following injection of dermal fillers into nasolabial folds.



• **Fig. 27.34** (A) Before and (B) after photos following injection of Botox into forehead.

trend continues to increase. Oral and maxillofacial surgeons play a significant role in the safe and effective performance of surgical and nonsurgical cosmetic options for the facial region. Appropriate level of training, proper diagnosis and assessment, and understanding of the aging process are imperative.

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28

Management of Patients With Orofacial Clefts

EDWARD ELLIS III

CHAPTER OUTLINE

A cleft is a congenital abnormal space or gap in the upper lip, alveolus, or palate. The colloquial term for this condition is *harelip*. The use of this term should be discouraged because it carries demeaning connotations. The more appropriate terms are *cleft lip, cleft palate,* or *cleft lip and palate.*

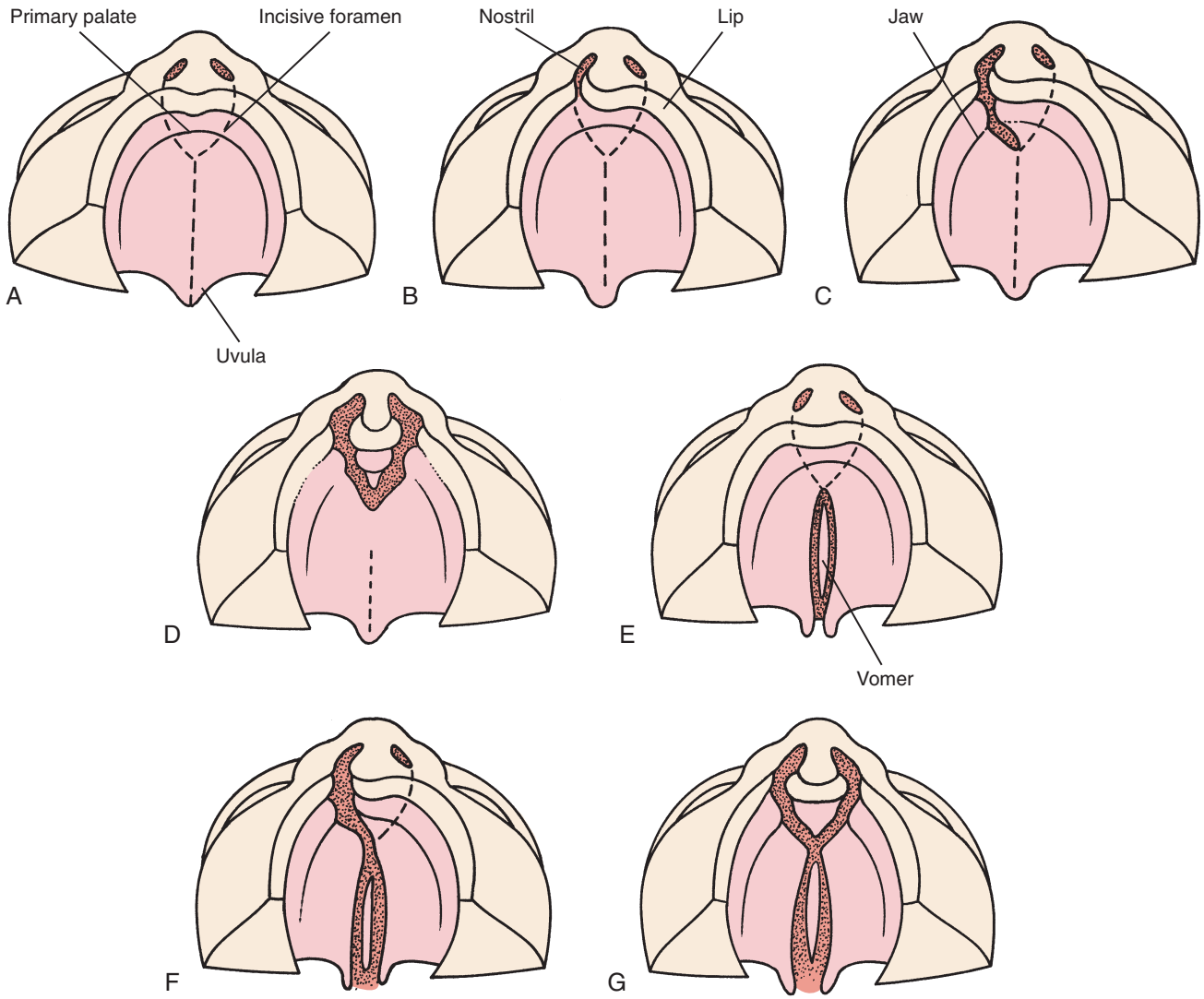
Clefts of the lip and palate are the most common serious congenital anomalies to affect the orofacial region. The initial appearance of clefts may be grotesque. Because clefts are deformities that can be seen, felt, and heard, they constitute a serious affliction to those who have them. Because of their location, clefts are deformities that involve the dental specialties throughout their protracted course of treatment. The general dentist will become involved in managing these patients' special dental needs because these patients may have partial anodontia and supernumerary teeth. Malocclusion is usually present, and orthodontic therapy with or without corrective jaw surgery is frequently indicated.

The occurrence of a cleft deformity is a source of considerable shock to the parents of an afflicted baby, and the most appropriate approach to these parents is one of informed explanation and reassurance. Parents should be told that the defects are correctable and need not adversely affect the child's future. However, parents should be prepared for a protracted course of therapy to correct the cleft deformities and to allow the individual to function.

The problems encountered in the rehabilitation of patients with cleft deformities are unique. The treatment must address patient appearance, speech, hearing, mastication, and deglutition. Most children affected with orofacial clefts are managed by a team of professionals. Cleft teams are found in most cities of at least moderate size. These teams commonly are comprised of a general or pediatric dentist, an orthodontist, a prosthodontist, an oral-maxillofacial surgeon, a cosmetic surgeon, an audiologist, an otorhinolaryngologist, a pediatrician, a speech pathologist, a psychologist or psychiatrist, and a social worker. The number of specialists required reflects the number and complexity of the problems faced by individuals with orofacial clefts.

The occurrence of oral clefts in the United States has been estimated as 1 in 700 births.[1] Clefts exhibit interesting racial predilections, occurring less frequently in blacks but more so in Asians. Boys are affected by orofacial clefts more often (at a ratio of 3:2) than girls. Cleft lip and palate (together) occur approximately twice as often in boys as in girls, whereas isolated clefts of the palate (without cleft lip) occur slightly more often in girls.

Oral clefts commonly affect the lip, alveolar ridge, and hard and soft palates. Three-fourths of clefts are unilateral deformities; one-fourth are bilateral. The left side is involved more often than the right when the defect is unilateral. The cleft may be incomplete; that is, it may not extend the entire distance from the lip to the soft palate. Cleft lip may occur without clefting of the palate, and isolated cleft palate may occur without clefting of the lip (Fig. 28.1). A useful classification divides the anatomy into primary and secondary palates. The primary palate involves those structures anterior to the incisive foramen (the lip and the alveolus); the secondary palate consists of those structures posterior to the incisive foramen (the hard and soft palates).[2] Thus an individual may have clefting of the primary palate, the secondary palate, or both (Fig. 28.2).



• **Fig. 28.1** Ventral view of palate, lip, and nose showing variability of cleft lip and palate deformity. (A) Normal. (B) Unilateral cleft lip extending into the nose. (C) Unilateral cleft involving the lip and alveolus, extending to the incisive foramen. (D) Bilateral cleft involving the lip and alveolus. (E) Isolated cleft palate. (F) Cleft palate combined with unilateral cleft of the alveolus and lip. (G) Bilateral complete cleft of lip and palate. (Modified from Langman J. *Medical Embryology*. 3rd ed. Baltimore: Williams & Wilkins; 1975.)

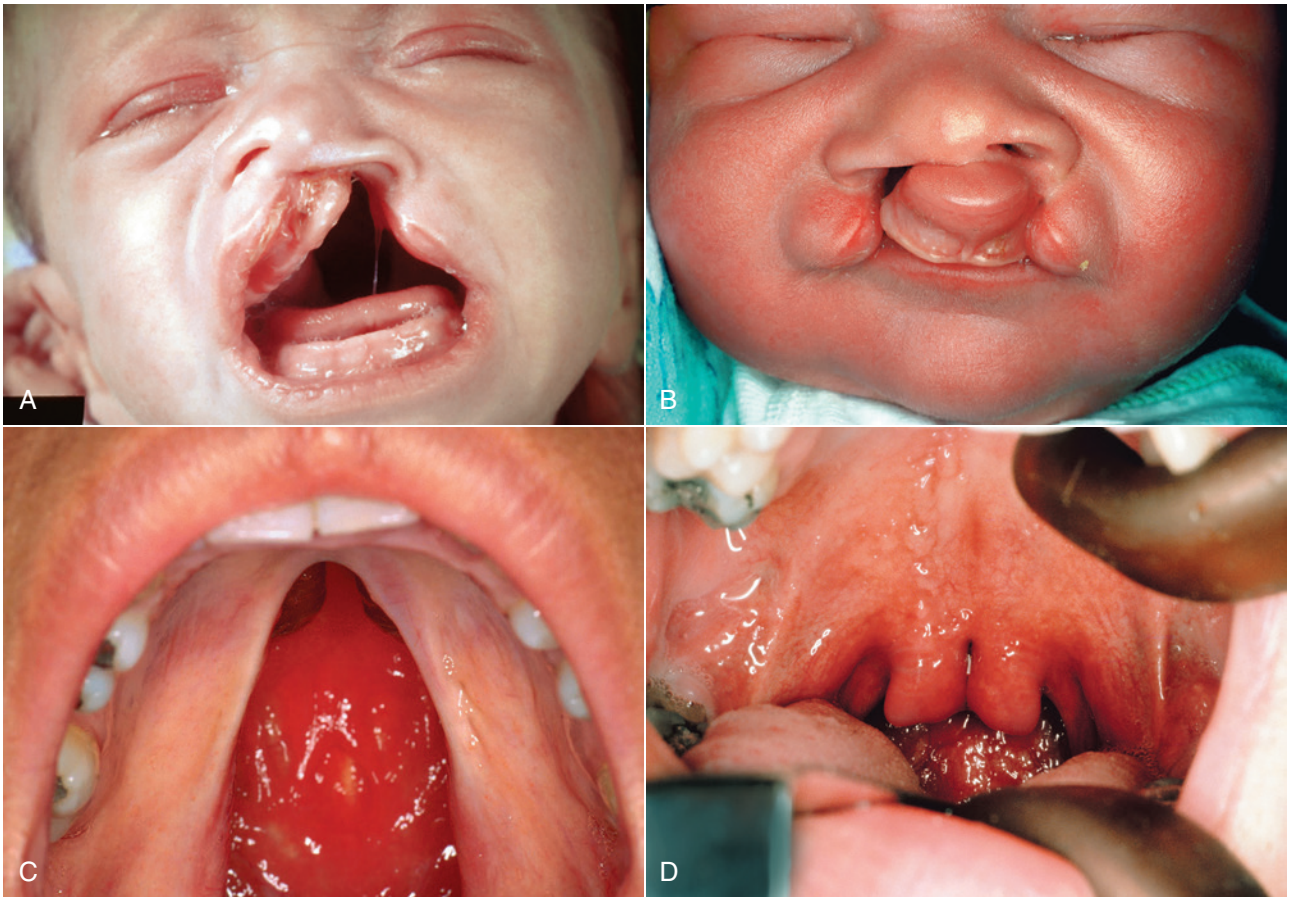
Clefts of the lip may range from a minute notch on the edge of the vermilion border to a wide cleft that extends into the nasal cavity and thus divides the nasal floor. Clefts of the soft palate may also show wide variations from a bifid uvula (see Fig. 28.2D) to a wide inoperable cleft. The bifid uvula is the most minor form of cleft palate in which only the uvula is cleft. Submucosal clefts of the soft palate are occasionally seen. These clefts are also called *occult clefts* because they are not readily seen on cursory examination. The defect in such a cleft is a lack of continuity in the musculature of the soft palate. However, the oronasal mucosa is continuous and covers the muscular defect. To diagnose such a defect, the dentist inspects the soft palate while the patient says "ah." This action lifts the soft palate, and in individuals with submucosal palatal clefts, a furrow in the midline is seen where the muscular discontinuity is present. The dentist can also palpate the posterior aspect of the hard palate to detect the absence of the posterior nasal spine, which is characteristically absent in submucosal clefts. If a patient shows hypernasal speech without an obvious soft palatal cleft, the dentist should suspect a submucosal cleft of the soft palate.

Embryology

To understand the causes of oral clefts, a review of nose, lip, and palate embryology is necessary. The entire process takes place between the fifth and tenth weeks of fetal life.[3]

During the fifth week, two fast-growing ridges, the lateral and medial nasal swellings, surround the nasal vestige (Fig. 28.3). The lateral swellings form the alae of the nose; the medial swellings give rise to four areas: (1) the middle portion of the nose, (2) the middle portion of the upper lip, (3) the middle portion of the maxilla, and (4) the entire primary palate. Simultaneously, the maxillary swellings approach the medial and lateral nasal swellings but remain separated from them by well-marked grooves.

During the next 2 weeks, the appearance of the face changes considerably. The maxillary swellings continue to grow in a medial



• **Fig. 28.2** Various types of cleft deformities. Nasal deformities are also apparent. (A) Unilateral complete cleft of lip and palate. (B) Bilateral cleft lip and palate, complete on right, incomplete on left. (C) Palatal view of isolated cleft palate. (D) Bifid uvula.

direction and compress the medial nasal swellings toward the midline. Subsequently, these swellings simultaneously merge with each other and with the maxillary swellings laterally. Hence the upper lip is formed by the two medial nasal swellings and the two maxillary swellings.

The two medial swellings merge not only at the surface but also at the deeper level. The structures formed by the two merged swellings are known together as the *intermaxillary segment* (Fig. 28.4), which is composed of three components: (1) a labial component, which forms the philtrum of the upper lip; (2) an upper jaw component, which carries the four incisor teeth; and (3) a palatal component, which forms the triangular primary palate. Above, the intermaxillary segment is continuous with the nasal septum, which is formed by the frontal prominence.

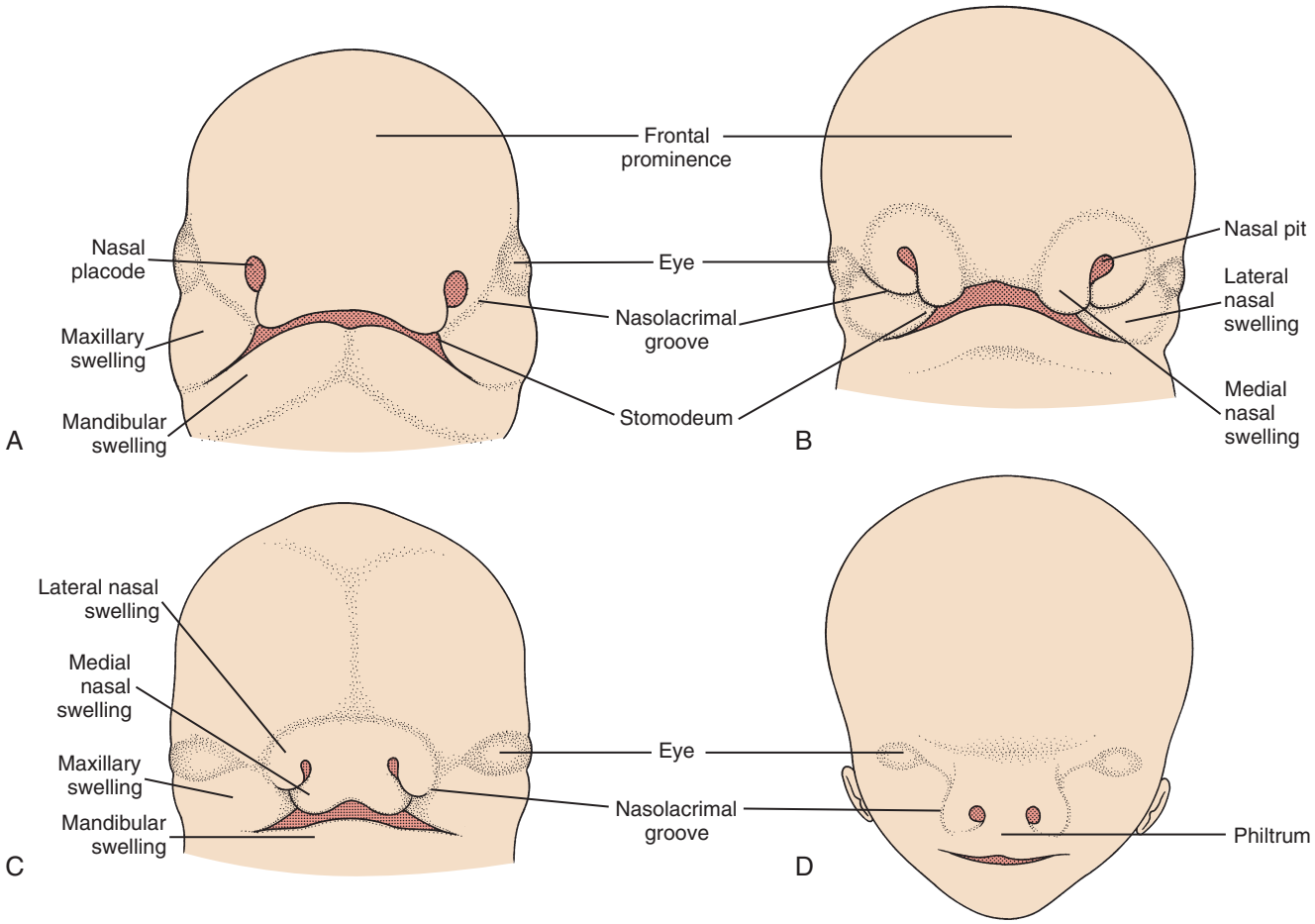
Two shelflike outgrowths from the maxillary swellings form the secondary palate. These palatine shelves appear in the sixth week of development and are directed obliquely downward on either side of the tongue. However, in the seventh week the palatine shelves ascend to attain a horizontal position above the tongue and fuse with each other, thereby forming the secondary palate. Anteriorly, the shelves fuse with the triangular primary palate, and the incisive foramen is formed at this junction. At the same time, the nasal septum grows down and joins the superior surface of the newly formed palate. The palatine shelves fuse with each other and with the primary palate between the seventh and tenth weeks of development.

Clefts of the primary palate result from a failure of the mesoderm to penetrate into the grooves between the medial nasal and maxillary processes, which prohibits their merging with one another. Clefts of the secondary palate are caused by a failure of the palatine shelves to fuse with one another. The causes for this are speculative and include failure of the tongue to descend into the oral cavity.

Causative Factors

The causes of facial clefting have been extensively investigated. The exact cause of clefting is unknown in most cases. For most cleft conditions, no single factor can be identified as the cause. However, it is important to distinguish between isolated clefts (in which the patient has no other related health problem) and clefts associated with other birth disorders or syndromes. A *syndrome* is a set of physical, developmental, and sometimes behavioral traits that occur together. Clefts have been identified as a feature in more than 300 syndromes, most of which are rare.[1] Syndromes account for approximately 15% of the total number of cases of cleft lip and cleft palate but nearly 50% of cases of isolated cleft palate. Medical geneticists are usually asked to consult with the family of children born with syndromes to identify the specific syndrome and to provide information to the parents about the likelihood of another child being affected.

For nonsyndromic clefts, it was initially thought that heredity played a significant role in the causation. However, studies have



• **Fig. 28.3** Frontal aspect of the face. (A) Five-week-old embryo. (B) Six-week-old embryo. Nasal swellings are gradually separated from maxillary swelling by deep furrows. At no time during normal development does this tissue break down. (C) Seven-week-old embryo. (D) Ten-week-old embryo. Maxillary swellings gradually merge with nasal folds, and furrows are filled with mesenchyme. (Modified from Langman J. *Medical Embryology*. 3rd ed. Baltimore: Williams & Wilkins; 1975.)

been able to implicate genetics in only 20% to 30% of patients with cleft lip or palate. Even in those individuals whose genetic backgrounds may verify familial tendencies for facial clefting, the mode of inheritance is not completely understood. The cause is not a simple case of mendelian dominant or recessive inheritance but is multigenetic. The majority of nonsyndromic clefts appear to be caused by an interaction between the individual's genes (i.e., genetic predisposition) and certain factors in the environment that may or may not be specifically identified.

Environmental factors seem to play a contributory role at the critical time of embryologic development, when the lip and palatal halves are fusing. A host of environmental factors have been shown in experimental animals to result in clefting. Nutritional deficiencies, radiation, several drugs, hypoxia, viruses, and vitamin excesses or deficiencies can produce clefting in certain situations.

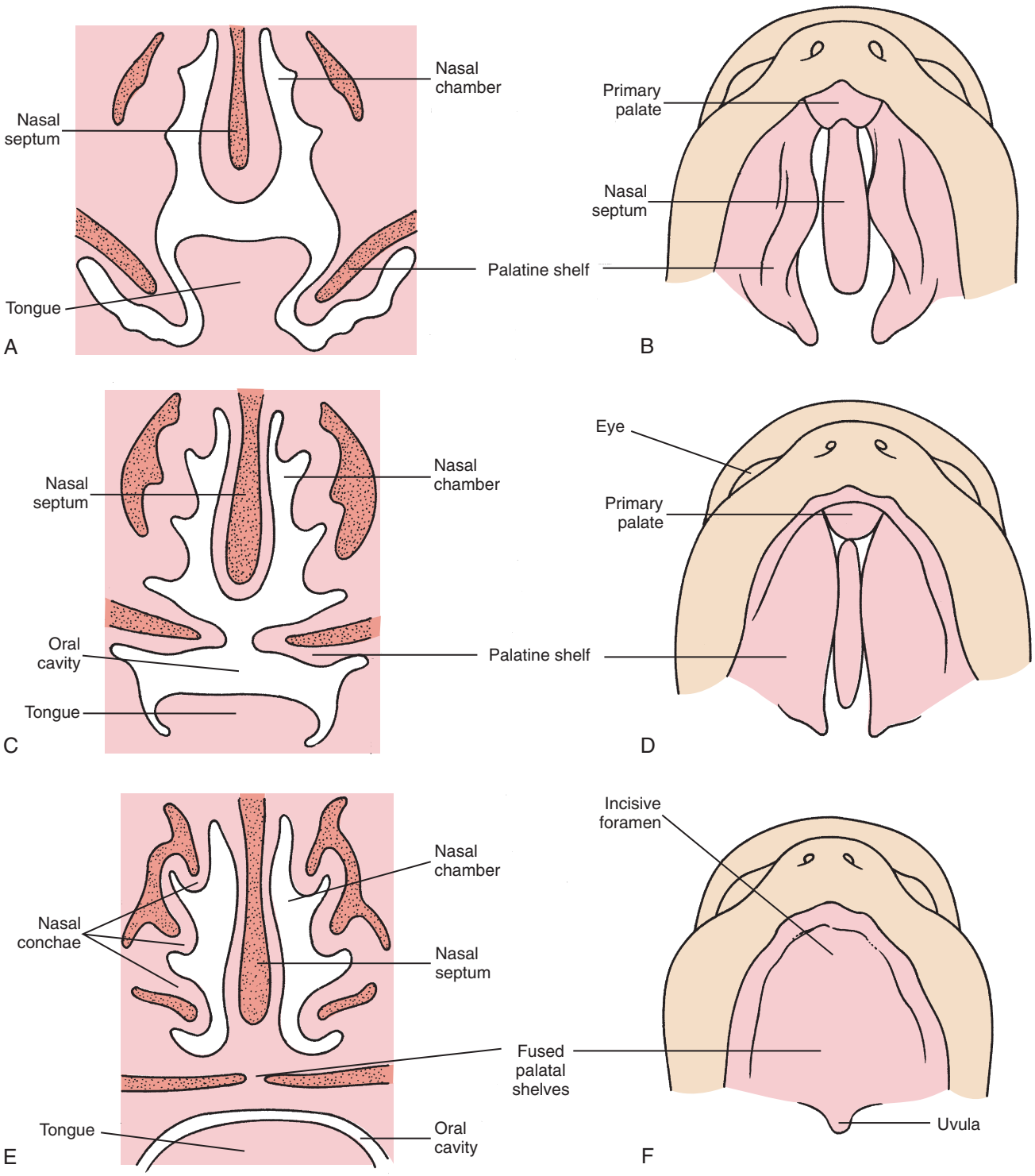
The risk for having another child with a cleft is based on a number of factors that are often unique in a particular family. These factors include the number of family members with clefts, how closely they are related, the race and sex of the affected individuals, and the type of cleft each person has. After a syndrome or complex disorder is excluded, recurrence risk counseling for a cleft can be offered to families. No genetic test can determine a person's individual chance of having a child with a cleft.

Every parent has approximately a 1 in 700 risk of having a child with a cleft. Once parents have a child with a cleft, the risk that the next child (and each succeeding child) will be affected is 2% to 5% (i.e., 2 to 5 chances in 100).[1] If more than one person in the immediate family has a cleft, the risk rises to 10% to 12% (i.e., approximately 1 chance in 10). A parent who has a cleft has a 2% to 5% chance that his or her child will have a cleft. If the parent with a cleft also has a close relative with a cleft, the risk increases to 10% to 12% for their child being born with a cleft. The unaffected siblings of a child with a cleft have an increased risk of having a child with a cleft (1%, or 1 in 100, compared with 1 in 700 when no history of cleft exists). If a syndrome is involved, the risk for recurrence within a family can be as high as 50%.[1] Genetic counselors may be consulted for parents of children with clefts or for persons with clefts who would like to obtain more information on the relative risks for their offspring.

Problems of Individuals With Clefts

Dental Problems

A cleft of the alveolus can often affect the development of the primary and permanent teeth and the jaw itself.[4] The most common



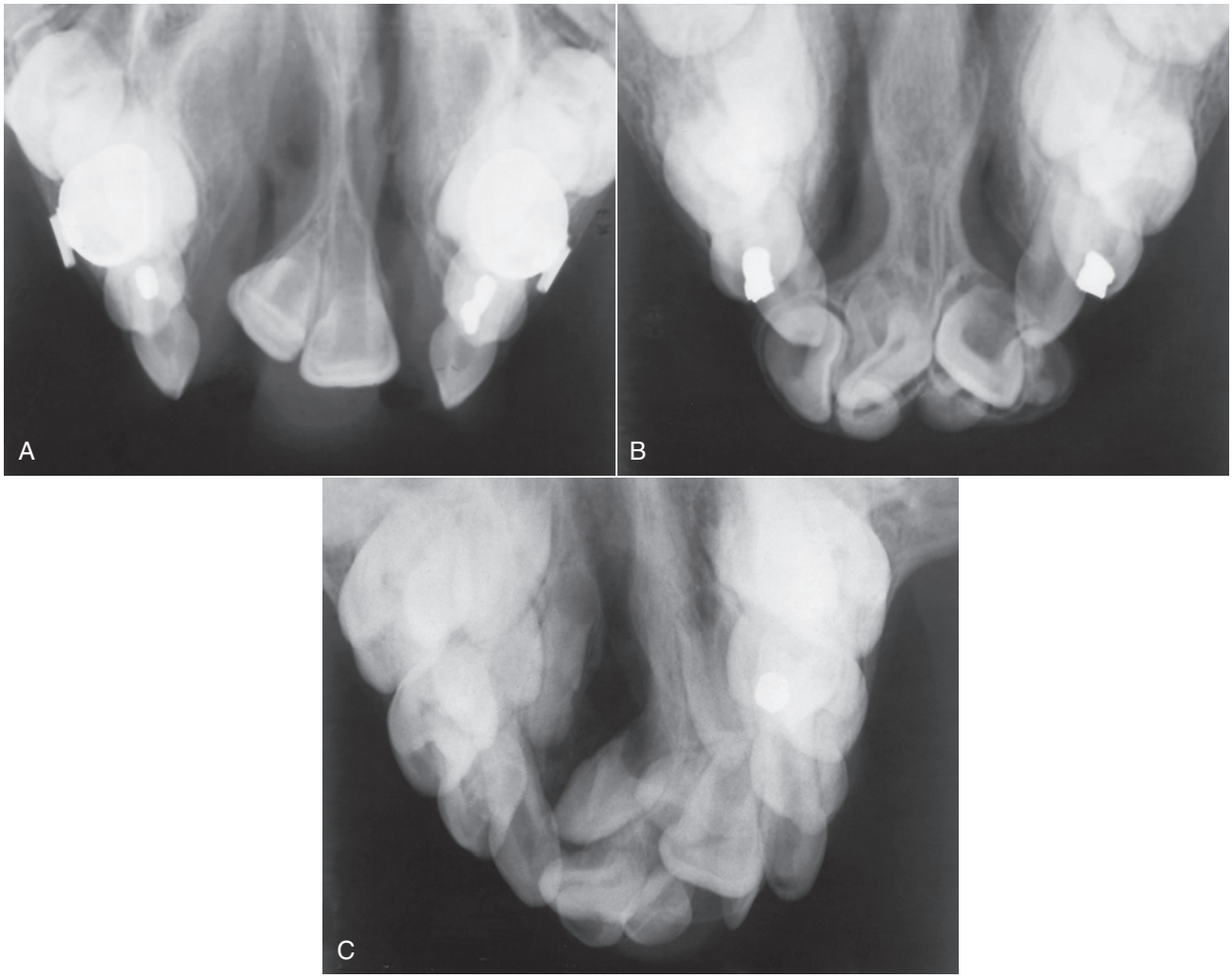
• **Fig. 28.4** (A) Frontal section through head of 6½-week-old embryo. Palatine shelves are located in the vertical position on each side of the tongue. (B) Ventral view. Note the clefts between the primary triangular palate and the palatine shelves, which are still in the vertical position. (C) Frontal section through the head of 7½-week-old embryo. The tongue has moved downward, and the palatine shelves have reached horizontal position. (D) Ventral view. Shelves are in the horizontal position. (E) Frontal section through the head of 10-week-old embryo. Two palatine shelves have fused with each other and with the nasal septum. (F) Ventral view. (Modfiied from Langman J. *Medical Embryology*. 3rd ed. Baltimore, MD: Williams & Wilkins; 1975.)

problems may be related to congenital absence of teeth and, ironically, supernumerary teeth (Fig. 28.5). The cleft usually extends between the lateral incisor and the canine area. These teeth may be absent because of their proximity to the cleft; when present, they may be severely displaced so that eruption into the cleft margin is common. These teeth may also be morphologically deformed or hypomineralized. Supernumerary teeth occur frequently, especially around the cleft margins. These teeth usually must be removed at some point during the child's development. However, these teeth may be retained if they can furnish any useful function in the patient's overall dental rehabilitation. Frequently, supernumerary teeth of the permanent dentition are left until 2 to 3 months before alveolar cleft bone grafting because these teeth, although nonfunctional, maintain surrounding alveolar bone. If extracted earlier, this bone may resorb, making the alveolar cleft larger.

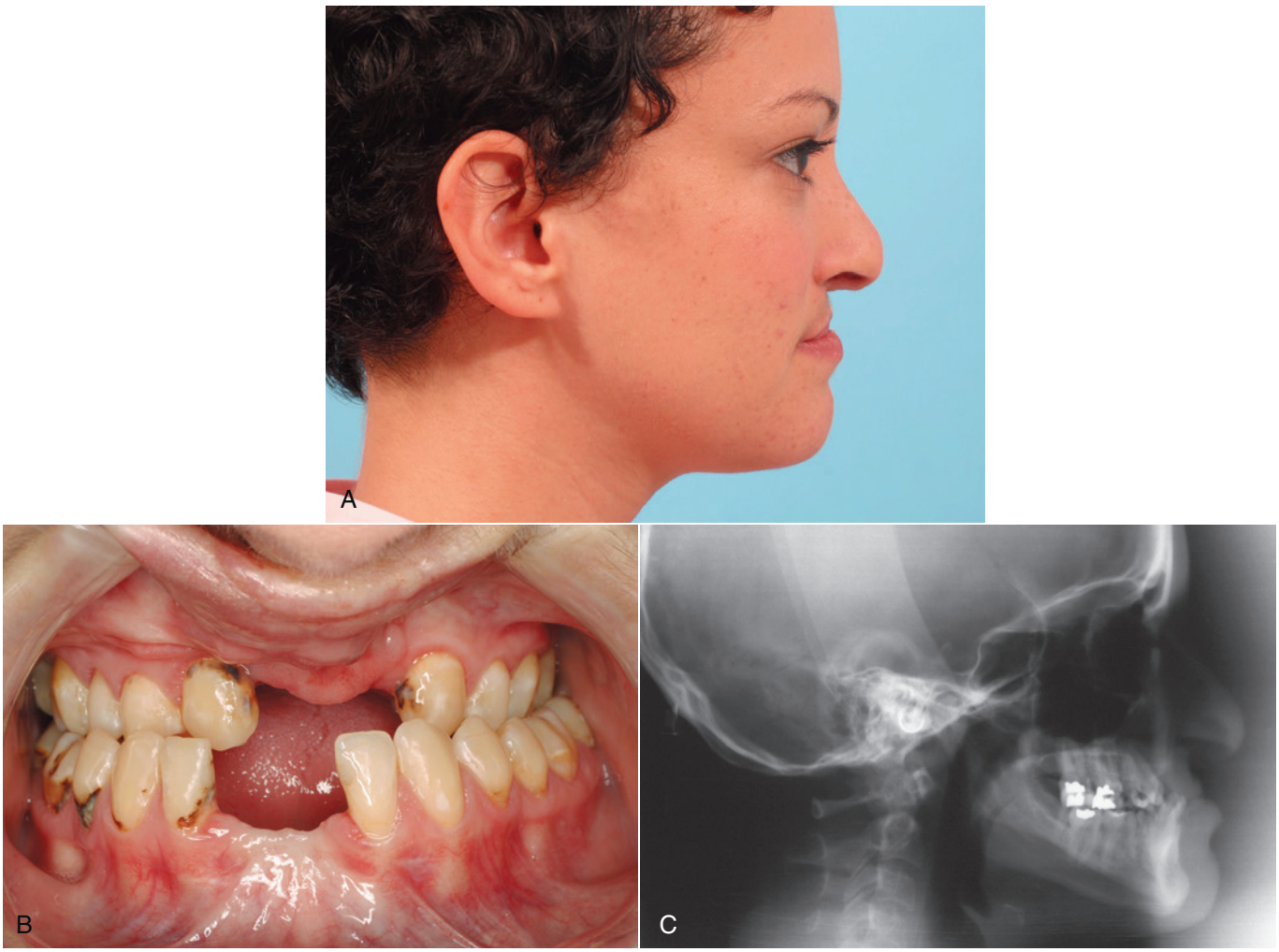
Malocclusion

Individuals affected with cleft deformities, especially those of the palate, show skeletal discrepancies between the size, shape, and position of their jaws. Class III malocclusion, seen in most cases, is caused by many factors. A common finding is mandibular prognathism, which is frequently relative and is caused more by the retrusion of the maxilla than by protrusion of the mandible (i.e., pseudoprognathism; Fig. 28.6). Missing or extra teeth may partially contribute to the malocclusion. However, retardation of maxillary growth is the factor most responsible for the malocclusion. In general, the operative trauma of the cleft closure and the resultant fibrosis (i.e., scar contracture) severely limit the amount of maxillary growth and development that can take place. The maxilla may be deficient in all three planes of space, with retrusion, constriction, and vertical underdevelopment common. Unilateral palatal clefts show collapse of the cleft side of the maxilla (i.e., the lesser segment) toward the center of the palate, which produces a narrow dental arch. Bilateral palatal clefts show collapse of all three segments or may have constriction of the posterior segments and protrusion of the anterior segment.

Orthodontic treatment may be necessary throughout the individual's childhood and adolescent years. Space maintenance and control is instituted during childhood. Appliances to maintain



• **Fig. 28.5** Occlusal radiographs of various types of cleft deformities. (A) Bilateral complete cleft of the alveolus and palate. Note the absence of the permanent lateral incisors. (B) Bilateral complete cleft of the alveolus and palate. Note the absence of the permanent lateral incisor on the patient's left side. (C) Unilateral complete cleft of the alveolus and palate. Note the supernumerary teeth within the clefted area.



• **Fig. 28.6** (A) Facial profile of typical patient with a cleft. Note the pseudoprognathic appearance of the mandible. (B) Occlusal relationship showing Angle class III relationship with anterior crossbite. (C) Lateral cephalogram showing maxillary skeletal sagittal deficiency contributing to class III occlusal relationship.

or increase the width of the dental arch are frequently used. This treatment is usually begun with the eruption of the first maxillary permanent molars.

Comprehensive orthodontic care is deferred until later, when most of the permanent teeth have erupted. Consideration for orthognathic surgical intervention for correction of skeletal discrepancies and occlusal disharmonies is frequently necessary at this time.

Nasal Deformity

Deformity of normal nasal architecture is commonly seen in individuals with cleft lips (see Fig. 28.2). If the cleft extends into the floor of the nose, the alar cartilage on that side is flared and the columella of the nose is pulled toward the side without the cleft. A lack of underlying bony support to the base of the nose compounds the problem.

Surgical correction of nasal deformities should usually be deferred until all clefts and associated problems have been corrected, because correction of the alveolar cleft defect and the maxillary skeletal retrusion alters the osseous foundation of the nose. Therefore improved changes in the nasal form result from these osseous procedures. Thus nasal revision may be the last corrective surgical procedure undergone by the individual affected by a cleft.

Feeding

Babies with cleft palates can swallow normally once the material being fed reaches the hypopharynx but have extreme difficulty producing the necessary negative pressure in their mouth to allow sucking breast milk or bottle milk. When a nipple is placed in the baby's mouth, he or she starts to suck just like any other newborn because the sucking and swallowing reflexes are normal. However, the musculature is undeveloped or not properly oriented to allow the sucking to be effective. This problem is easily overcome through the use of specially designed nipples that are elongated and extend further into the baby's mouth. The opening should be enlarged because the suck will not be as effective as in a normal baby. Other satisfactory methods are the use of eyedroppers or large syringes with rubber extension tubes connected to them. The tube is placed in the baby's mouth, and a small amount of solution is injected. These methods of feeding, although adequate for sustenance, require more time and care. Because the child will swallow a considerable amount of air when these feeding methods

are used, the child is not usually fed in the recumbent position, and more frequent burping is necessary.

Ear Problems

Children with a cleft of the soft palate are predisposed to middle ear infections. The reason for this becomes clear on review of the anatomy of the soft palate musculature. The levator veli palatini and the tensor veli palatini, which are normally inserted into the same muscles on the opposite side, are left unattached when the soft palate is cleft. These muscles have their origins directly on or near the auditory tube. These muscles allow opening of the ostium of this tube into the nasopharynx. This action is demonstrated when middle ear pressures are equalized by swallowing during changes in atmospheric pressure, as when ascending or descending in an airplane.

When this function is disrupted, the middle ear is essentially a closed space, without a drainage mechanism. Serous fluid may then accumulate and result in serous otitis media. Should bacteria find their way from the nasopharynx into the middle ear, an infection can develop (i.e., suppurative otitis media). To make matters worse, the auditory tube in infants is at an angle that does not promote dependent drainage. With age, this angulation changes and allows more dependent drainage of the middle ear.

Children with cleft palate frequently need to have their middle ear "vented." The otorhinolaryngologist, who creates a hole through the inferior aspect of the tympanic membrane and inserts a small plastic tube, performs this procedure, which drains the ear to the outside instead of the nasopharynx (myringotomy).

Chronic serous otitis media is common among children with cleft palate, and multiple myringotomies are frequently necessary. Chronic serous otitis media presents a serious threat to hearing.

Because of the chronic inflammation in the middle ear, hearing impairments are common in patients with cleft palate. The type of hearing loss experienced by the patient with cleft palate is conductive (i.e., the neural pathway to the brain continues to function normally). The defect in these instances is simply that sound cannot reach the auditory sensory organ as efficiently as it should because of the chronic inflammatory changes in the middle ear. However, if the problem is not corrected, permanent damage to the auditory sensory nerves (i.e., sensory neural loss) can also result. This type of damage is irreparable. The range of hearing impairment found in individuals with cleft palates is vast. The loss can be great enough so that normal-sounding speech is heard at less than one-half of expected volume. In addition, certain sounds of speech (called *phonemes*), such as the "s," "sh," and "t" sounds, may be heard poorly. Audiograms are useful tools and are performed repeatedly on patients with cleft palates to monitor hearing ability and performance.

Speech Difficulties

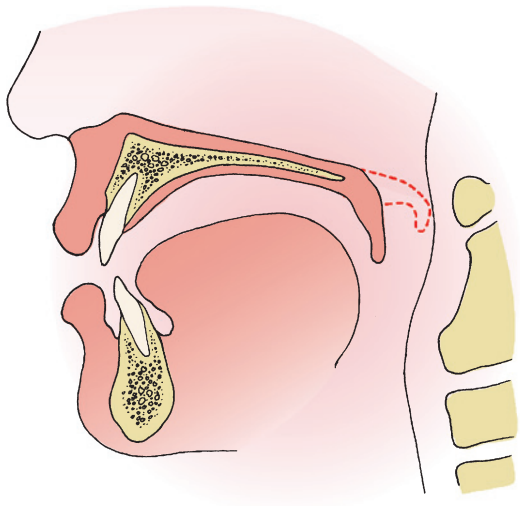
Four speech problems are usually created by cleft lip and palate deformity. Retardation of consonant sounds (i.e., "p," "b," "t," "d," "k," and "g") is the most common finding. Because consonant sounds are necessary for the development of early vocabulary, much language activity is omitted. As a result, good sound discrimination is lacking by the time the palate is closed. Hypernasality is usual in the patient with a cleft of the soft palate and may remain after surgical correction. Dental malformation, malocclusion, and abnormal tongue placement may develop before the palate is closed and thus produce an articulation problem. Hearing problems contribute significantly to the many speech disorders common in patients with oral clefts.

In the normal individual, speech is created by the following scheme. Air is allowed to escape from the lungs, pass through the vocal cords, and enter the oral cavity. The position of the tongue, lips, lower jaw, and soft palate working together in a highly coordinated fashion results in the sounds of speech being produced. If the vocal cords are set into vibration while the airstream is passing between them, then voice is superimposed on the speech sounds that result from the relationships of the oral structures. The soft palate is raised during speech production, preventing air from escaping through the nose.

For clear speech, it is necessary for the individual to have complete control of the passage of air from the oropharynx to the nasopharynx. The hard palate provides the partition between the nasal and oral cavities. The soft palate functions as an important valve to control the distribution of escaping air between the oropharynx and nasopharynx (Fig. 28.7). This is called the *velopharyngeal mechanism* ("velo" means soft palate). As the name implies, the two main components are (1) the soft palate and (2) the pharyngeal walls. When passive, the soft palate hangs downward toward the tongue, but during speech the muscles of the soft palate elevate it and draw it toward the posterior pharyngeal wall, which happens to the normal individual's soft palate when he or she is asked to say "ah." In normal speech, this action takes place rapidly and with an unbelievable complexity so that the valving mechanism can allow large amounts of air to escape into the nasopharynx or can limit or eliminate the escape.

In individuals whose soft palate is cleft, the velopharyngeal mechanism cannot function because of the discontinuity of the musculature from one side to the other. Thus the soft palate cannot elevate to make contact with the pharyngeal wall. The result of this constant escape of air into the nasal cavity is hypernasal speech.

Individuals with cleft palate have compensatory velopharyngeal, tongue, and nasal mechanisms in an attempt to produce intelligible speech. The posterior and lateral pharyngeal walls obtain great mobility and attempt to narrow the passageway between the oropharynx and the nasopharynx during speech. A muscular bulge of the pharyngeal wall actually develops during attempts at closure



• **Fig. 28.7** Upward and backward movement of the soft palate during normal speech. Soft palate contact with the posterior pharyngeal wall is shown.

of the passageway in some individuals with cleft palate and is known as *Passavant ridge* or *bar*. Individuals with cleft palates develop compensatory tongue postures and positions during speech to help valve the air coming from the larynx into the pharyngeal areas. Similarly, the superficial muscles around the nose involved in facial expression are recruited to help limit the amount of air escaping from the nasal cavity. In this instance, the valving is at the other end of the nasal cavity from the velopharyngeal mechanism. However, in an uncorrected cleft of the soft palate, it is literally impossible for compensatory mechanisms to produce a satisfactory velopharyngeal mechanism. Unfortunately, in surgically corrected soft palates, velopharyngeal competence is not always achieved with one operation, and secondary procedures are frequently necessary.

Speech pathologists are well versed in assisting children with cleft deformities to develop normal articulation skills. The earlier in life speech training is started in patients with cleft deformities, the better is the eventual outcome. The patient may need to undergo speech counseling for several years to produce acceptable speech.

When hearing problems are also present, the speech problems are compounded. Hearing loss at an early age is especially detrimental to the development of normal speech skills. The child who is unable to hear is unable to imitate normal speech. Thus the parents must be cognizant of their child's development and ensure that regular visits to the pediatrician are undertaken.

Associated Anomalies

Although the child with an oral cleft is 20 times more likely to have another congenital anomaly than a normal child, no correlation is evident with specific anatomic zones of additional anomaly involvement.[2] Of those children who have associated anomalies, 38% have isolated cleft palate, and 21% have cleft lip, with or without cleft palate. In the overall cleft-afflicted population, approximately 30% have other anomalies in addition to the facial cleft, ranging from clubfoot to neurologic disturbances. Of the overall cleft-afflicted population, 10% have congenital heart disease and 10% have some degree of mental retardation. Thus the child with a facial cleft may require additional care beyond the scope of the cleft team.

Treatment of Cleft Lip and Palate

The aim of treatment of cleft lip and palate is to correct the cleft and associated problems surgically and thus hide the anomaly so that patients can lead normal lives. This correction involves surgically producing a face that does not attract attention, a vocal apparatus that permits intelligible speech, and a dentition that allows optimal function and aesthetics. Operations begin early in life and may continue for several years. In view of the gross distortion of tissues surrounding the cleft, it is amazing that success is ever achieved. However, with modern anesthetic techniques, excellent pediatric care centers, and surgeons who have had a wealth of experience because of the frequency of the cleft deformity, acceptable results are becoming commonplace.

Timing of Surgical Repair

The timing of the surgical repair has been and remains one of the most debated issues among surgeons, speech pathologists, audiologists, and orthodontists. It is tempting to attempt to correct all of the defects as soon as the baby is able to withstand the surgical procedure. The parents of a child born with a facial cleft would certainly desire this mode of treatment, eliminating all of the baby's clefts as early in life as possible. Indeed, the cleft lip is usually corrected as early as possible. Most surgeons adhere to the proven "rule of 10" as determining when an otherwise healthy baby is fit for surgery (i.e., age 10 weeks, 10 lb body weight, and at least 10 g/dL hemoglobin in blood). However, because surgical correction of the cleft is an elective procedure, if any other medical condition jeopardizes the health of the baby, the cleft surgery is postponed until medical risks are minimal.

Unfortunately, each possible advantage for closing a palatal cleft early in life has several possible disadvantages for the individual later in life. The six advantages for early closure of palatal defects are (1) better palatal and pharyngeal muscle development once repaired, (2) ease of feeding, (3) better development of phonation skills, (4) better auditory tube function, (5) better hygiene when the oral and nasal partition is competent, and (6) improved psychological state for parents and baby. Closing palatal clefts early in life also has several disadvantages, the two most important being (1) more difficulty with surgical correction in younger children with small structures and (2) scar formation resulting from the surgery, which causes maxillary growth restriction.

Although different cleft teams time the surgical repair differently, a widely accepted principle is compromise. The lip is corrected as early as is medically possible. The soft palatal cleft is closed between 8 and 18 months of age, depending on a host of factors. Closure of the lip as early as possible is advantageous because it performs a favorable "molding" action on the distorted alveolus. Lip closure also assists the child in feeding and is of psychological benefit. The palatal cleft is closed next to produce a functional velopharyngeal mechanism when or before speech skills are developing. The hard palatal cleft occasionally is not repaired at the time of soft palate repair, especially if the cleft is wide. In such cases the hard palate cleft is left open as long as possible so that maxillary growth proceeds as unimpeded as possible. Closure of the hard palatal cleft can be postponed at least until all of the deciduous dentition has erupted. This postponement facilitates the use of orthodontic appliances and allows more maxillary growth to occur before scarring from the surgery is induced. Because a significant portion of maxillary growth has already occurred by ages 4 to 5 years, closure of the hard palate at this time is usually performed before the child's enrollment in school. Removable palatal obturators can be fitted and worn in the meantime to partition the oral and nasal cavities.

The largest problem in evaluation of treatment regimens is the fact that the final results of surgical repair of clefts can be judged conclusively only when the individual's growth is complete. A surgical method used today cannot be put to careful scrutiny for 10 to 20 years, which, unfortunately, may allow many individuals with cleft deformities to be treated with procedures that may later be discarded when follow-up examinations and studies show unsatisfactory or poor effects.

Cheilorrhaphy

Cheilorrhaphy is the surgical correction of the cleft lip deformity; this term is derived from *cheilo,* meaning "lip," and *rhaphy,* meaning "junction by a seam or suture." Cheilorrhaphy is usually the earliest operative procedure used to correct cleft deformities and is undertaken as soon as medically possible.

The cleft of the upper lip disrupts the important circumoral orbicularis oris musculature. The lack of continuity of this muscle allows the developing parts of the maxilla to grow in an uncoordinated

manner so that the cleft in the alveolus is accentuated. At birth, the alveolar process on the unaffected side may appear to protrude from the mouth. The lack of sphincteric muscle control from the orbicularis oris causes a bilateral cleft lip to exhibit a premaxilla that protrudes from the base of the nose and produces an unsightly appearance. Thus restoration of this muscular sphincter with lip repair has a favorable effect on the developing alveolar segments.

Objectives

The objectives of cheilorrhaphy are twofold: (1) functional and (2) aesthetic. The cheilorrhaphy should restore the functional arrangement of the orbicularis oris musculature to reestablish the normal function of the upper lip. If muscle continuity is not restored across the area of the cleft, an aesthetically unpleasing depression will result when the lip is brought into function. The second objective of cheilorrhaphy is to produce a lip that displays normal anatomic structures, such as a vermilion tubercle, Cupid's bow, and philtrum. The lip must be symmetric, well contoured, soft, and supple, and the scars must be inconspicuous. Another aesthetic necessity is to correct (at least partially) the nasal deformity resulting from the cleft lip.

Despite the skill of the surgeon, these ideal objectives are rarely achieved. Hindrances are the poor quality of tissues in the cleft margins and the distortion of structures before surgical intervention. Several surgical techniques reproduce normal appearance immediately but do not maintain this appearance with growth. However, with careful selection of surgical technique, satisfactory results are obtainable.

Surgical Techniques

Each cleft is unique and so must be the surgical procedure. Countless techniques can be used for cheilorrhaphy, each designed to elongate the cleft margins to facilitate closure (Figs. 28.8 and 28.9). In unilateral cases the unaffected side serves as a guide for lip length and symmetry. A key point in design is to break up the lines of the scar so that, with fibrosis and contracture, deformity of the lip is minimized. In lips closed in a linear fashion, scar contracture causes a characteristic notching of the upper lip. Attention to reorienting and reuniting the musculature of the lip is of paramount importance if normal function is to be established.

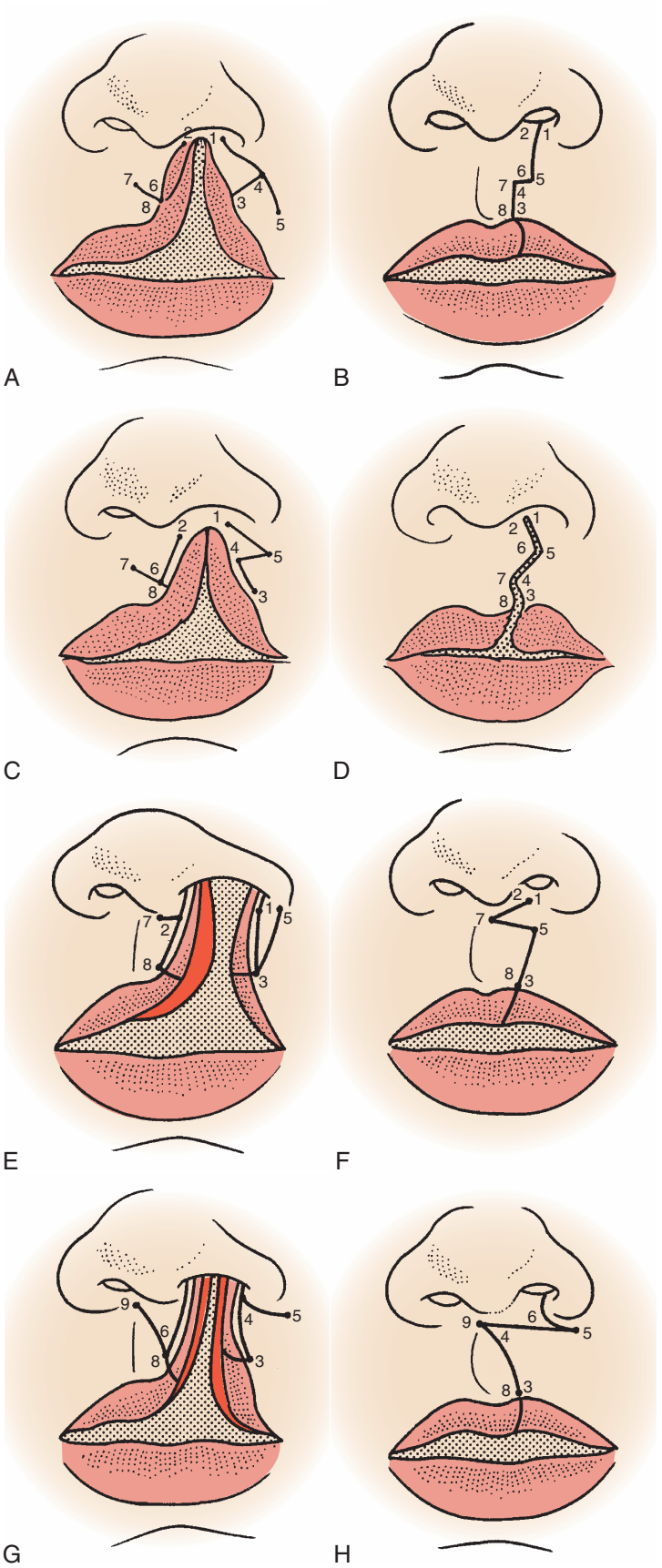
Cheilorrhaphy procedures serve to restore symmetry not only to the lip but also to the nasal tip. With the cleft extending through the floor of the nose, the continuity of the nasal apparatus is disrupted. Without the bony foundation for the alar cartilage, a collapse of the lateral aspect of the nose occurs. When the lip is closed, it is necessary to advance this laterally displaced tissue toward the midline. Thus cheilorrhaphy is the first and one of the most important steps in correcting the nasal deformity so common in patients with clefts.

Palatorrhaphy

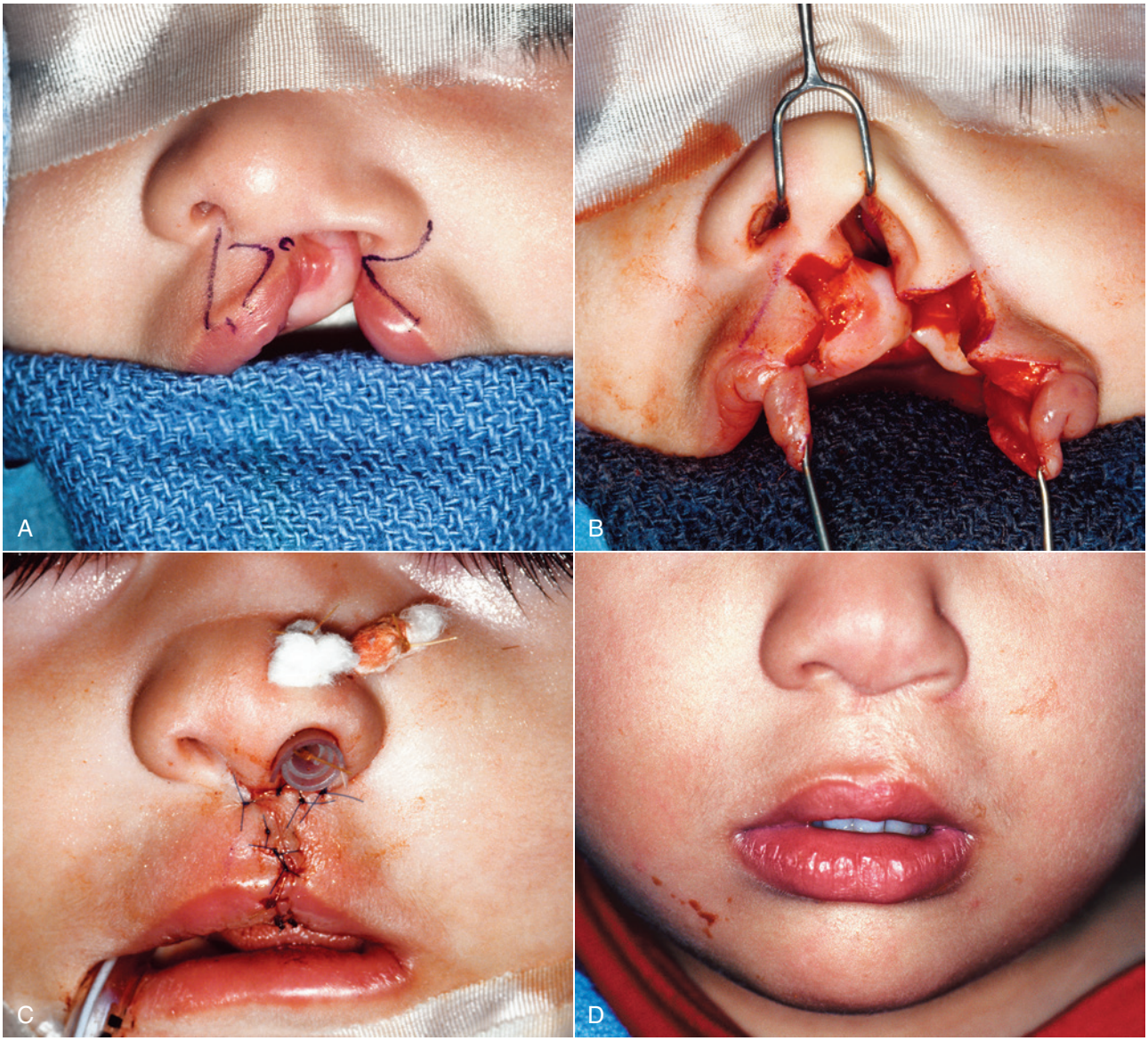
Palatorrhaphy is usually performed in one operation and occasionally in two. In two operations, the soft palate closure (i.e., staphylorrhaphy) is usually performed first and the hard palate closure (i.e., uranorrhaphy) is performed second.

Objectives

The primary purpose of the cleft palate repair is to create a mechanism capable of speech and deglutition without significantly interfering with subsequent maxillary growth. Thus creation of a competent velopharyngeal mechanism and partitioning of the nasal



• **Fig. 28.8** Several cheilorrhaphy techniques. (A–B) LeMesurier technique for incomplete unilateral cleft. (C–D) Tennison operation. (E–F) Wynn operation. (G–H) Millard operation (i.e., rotation advancement technique).



• **Fig. 28.9** Millard cheilorrhaphy technique. (A) Incisions outlined. (B) Flaps rotated. (C) Closure. (D) Result seen a few years later.

and oral cavities are prerequisites to achieving these goals. The aim is to obtain a long and mobile soft palate capable of producing normal speech. Extensive stripping of soft tissues from bone creates more scar formation, which adversely affects maxillary growth. The precarious nature of the problem indicates the complexity of the surgical procedures designed and the ages at which they are instituted.

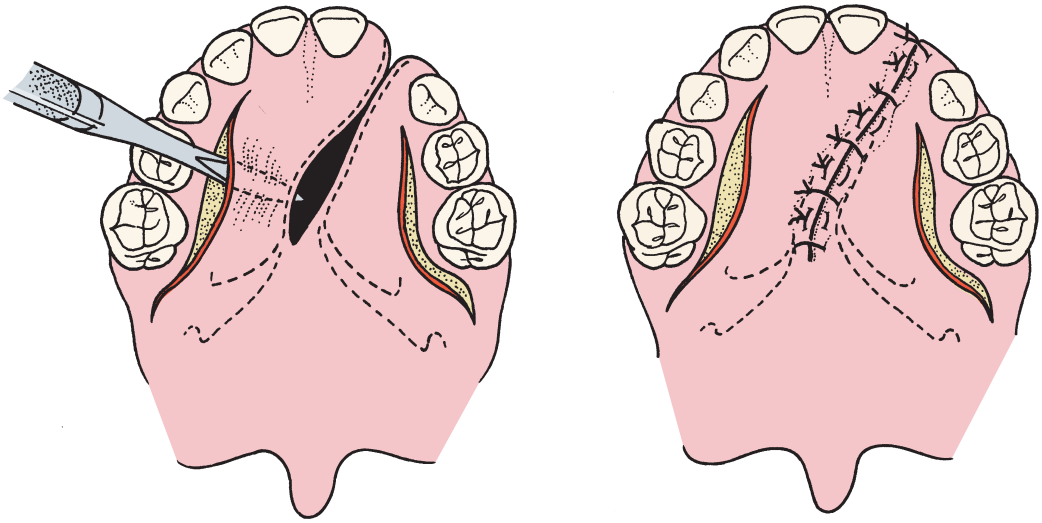
Surgical Techniques

Operative procedures for palatorrhaphy are as varied as techniques for cleft lip repair. Each cleft of the palate is unique. Repairs vary in width, completeness, amount of hard and soft tissues available, and palatal length. Thus the surgical techniques used to close cleft palate deformities are extremely varied, not just from one surgeon to another but from one patient to the next.

Hard Palate Closure

The hard palate is closed with soft tissues only. Usually, no effort is made to create an osseous partition between the nasal and oral cavities. The soft tissues extending around the cleft margin vary in quality. Some tissues are atrophic and not particularly useful. Other tissues appear healthy and readily lend themselves to dissection and suture integrity. In the most basic sense, soft tissues are incised along the cleft margin and are dissected from the palatal shelves until approximation over the cleft defect is possible. This procedure frequently necessitates the use of lateral relaxing incisions close to the dentition (Fig. 28.10). Soft tissues are then sutured in a watertight manner over the cleft defect and are allowed to heal. The areas of bone exposed by lateral relaxing incisions are allowed to heal by secondary intention. The superior aspect of the palatal flaps also reepithelializes with respiratory epithelium because this surface is now the lining of the nasal floor. When possible, it is advisable to obtain a two-layer closure of the hard palatal cleft (Fig. 28.11), which necessitates that the nasal mucosa from the floor, lateral wall, and septal areas of the nose be mobilized and sutured together before the oral closure.

When the vomer is long and attached to the palatal shelf opposite the cleft, a mucosal flap can be raised from it and sutured to the



• **Fig. 28.10** Von Langenbeck operation for closure of the hard palate using lateral releasing incisions. This technique is a one-layer closure. Nasal (i.e., superior) aspect of palatal flaps will epithelialize, as will denuded areas of the palatal bone.

palatal tissues on the cleft side (Fig. 28.12). This procedure (i.e., vomer flap technique) requires little stripping of palatal mucoperiosteum and produces minimal scar contraction. The denuded areas of vomer and the opposite sides of the flap where no epithelium is present will reepithelialize. The vomer flap technique is useful in clefts that are not wide and where the vomer is readily available for use. The technique is a one-layer closure.

Soft Palate Closure

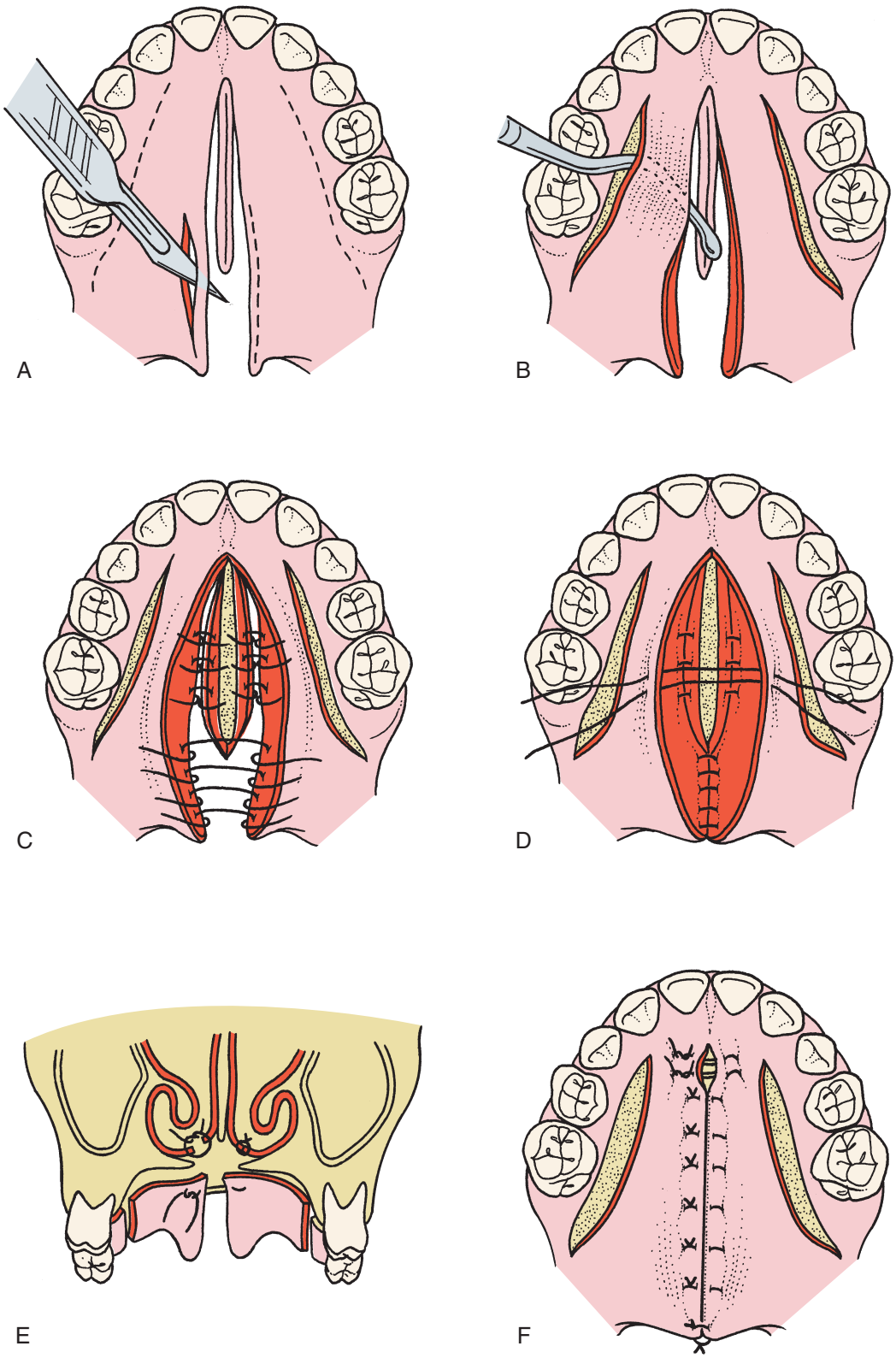
The closure of the soft palate is technically the most difficult of the operations yet discussed. Access is the largest problem because the soft palate is toward the back of the oral cavity. The combination of difficulty with light, retraction, and the fact that the clinician can work only from the oral side and yet must correct the oral and nasal sides of the soft palate leads to difficulties. In addition, the clinician may have to work with extremely thin, atrophic tissues and yet produce a closure that will hold together under function while healing is progressing. To help accomplish this goal, the soft palate is always closed in three layers and in the same order: (1) nasal mucosa, (2) muscle, and (3) oral mucosa (Fig. 28.13). The margins of the cleft are incised from the posterior end of the hard palate to at least the distal end of the uvula (some surgeons carry the incision and closure down the palatopharyngeal fold to elongate the soft palate). The nasal mucosa is then dissected free from the underlying musculature and sutured to the nasal mucosa of the opposite side. The muscular layer requires special care. The musculature of the cleft soft palate is not inserted across to the opposite side but instead is inserted posteriorly and laterally along the margins of the hard palate. These muscular insertions must be released from their bony insertions and reapproximated to those of the other sides. Only then will the velopharyngeal mechanism have a chance to perform properly. If the quantity of muscular tissue is inadequate for approximation of the musculature in the midline, the pterygoid hamular processes can be infractured, thus releasing the tensor palatini muscles toward the midline. This maneuver is frequently necessary, especially in wide clefts.

Occasionally, the soft palate is found to be short, and articulation with the pharyngeal wall is impossible. This situation is especially prevalent in incomplete palatal clefts—those of the soft palate only. In these cases the palate can be closed in a manner that not only brings the two lateral halves together in the midline but also gains palatal length (Fig. 28.14). The so-called *W-Y push-back procedure (Wardill)* and *U-shaped push-back procedure (Dorrance and Brown)* are commonly used. The mucoperiosteum of the hard palate is incised and elevated in a manner that allows the entire soft tissue elements of the hard and soft palate to extend posteriorly, thus gaining palatal length.

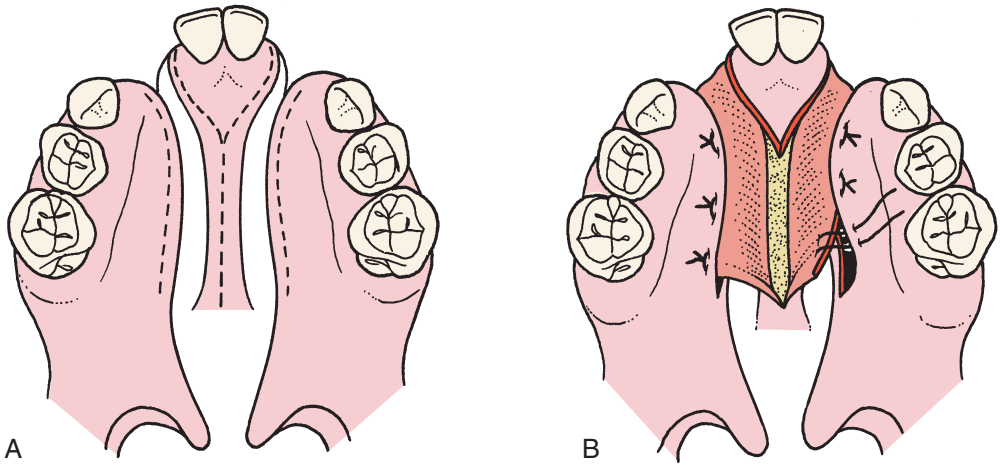
Alveolar Cleft Grafts

The alveolar cleft defect is usually not corrected in the original surgical correction of the cleft lip or the cleft palate (Fig. 28.15). As a result the individual may have residual oronasal fistulae in this area, and the maxillary alveolus will not be continuous because of the cleft. Because of this, five problems commonly occur: (1) oral fluids escape into the nasal cavity; (2) nasal secretions drain into the oral cavity; (3) teeth erupt into the alveolar cleft; (4) the alveolar segments collapse; and (5) if the cleft is large, speech is adversely affected.

Alveolar cleft bone grafts provide several advantages. First, they unite the alveolar segments and help prevent collapse and constriction of the dental arch, which is especially important if the maxilla has been orthodontically expanded. Second, alveolar cleft bone grafts provide bone support for teeth adjacent to the cleft and for those that will erupt into the area of the cleft. Frequently, the bone support on the distal aspect of the central incisor is thin, and the height of the bone support varies. These teeth may show slight mobility because of this lack of bone support. Increasing the amount of alveolar bone for this tooth helps ensure its periodontal maintenance, especially if bone grafting occurs before the early stages of eruption of the tooth. The canine tends to erupt into the cleft site and, with healthy bone placed into the cleft, will maintain good periodontal support during eruption and thereafter. The third benefit of alveolar cleft grafts is closure of the oronasal fistula, which will partition the oral and nasal cavities and prevent the escape of fluids between them. Augmentation of the alveolar ridge in the area of the cleft is a fourth advantage because it facilitates the use of dental prostheses by creating a more suitable supporting



• **Fig. 28.11** Variation of von Langenbeck operation for concomitant hard and soft palate closure. The operation uses three-layer closure for the soft palate (i.e., nasal mucosa, muscle, and oral mucosa) and two-layer closure for the hard palate (i.e., flaps from vomer and nasal floor to produce nasal closure and palatal flaps for oral closure). (A) Removing mucosa from the margin of the cleft. (B) Mucoperiosteal flaps on the hard palate are developed; note the lateral releasing incisions. (C) Sutures placed into the nasal mucosa after development of nasal flaps from the vomer and nasal floor. Sutures are placed so that knots will be on the nasal side. (D) Nasal mucosa has been closed. (E) Frontal section showing repair of the nasal mucosa. (F) Closure of the oral mucoperiosteum.



• **Fig. 28.12** Vomer flap technique for closure of a hard palate cleft (bilateral in this case). (A) Incisions through the nasal mucosa on the underside of the nasal septum (i.e., vomer) and mucosa of cleft margins. (B) The mucosa of the nasal septum is dissected off the nasal septum and inserted under the palatal mucosa at the margins of the cleft. This is a one-layer closure only. The connective tissue undersurface of the nasal mucosa will epithelialize. This technique, because it does not require extensive elevation of palatal mucoperiosteum, produces less scarring with attendant growth restriction.

base. A fifth benefit is the creation of a solid foundation for the lip and alar base of the nose. It has become evident that the alveolar cleft-grafting procedure itself creates a favorable change in the nasal structure because the tissues at the base of the nose become supported after alveolar cleft grafting, whereas they had no solid osseous foundation before the graft. Therefore the alveolar graft should be performed before nasal revisions.

Timing of Graft Procedure

The alveolar cleft graft is usually performed when the patient is between ages 6 and 10 years. By this time, a major portion of maxillary growth has occurred, and the alveolar cleft surgery should not adversely affect the future growth of the maxilla. It is important to have the graft in place before the eruption of the permanent canines into the cleft, thus ensuring their periodontal support. Ideally, the grafting procedure is performed when one-half to two-thirds of the unerupted canine root has formed. Some surgeons advocate that alveolar grafting be performed nearer to the time when the maxillary central incisors are erupting.

Orthodontic expansion of the arch before or after the procedure is equally effective; however, some surgeons prefer to expand before bone grafting to facilitate access into the cleft area at surgery.

Surgical Procedure

Intact mucoperiosteal flaps on each side must cover bone grafts placed into the alveolar cleft. This means that flaps of nasal mucosa, palatal mucosa, and labial mucosa must be developed and sutured in a tension-free, watertight manner to prevent infection of the graft. The soft tissue incisions for alveolar cleft grafts vary, but in each procedure, these conditions are met (Fig. 28.16).

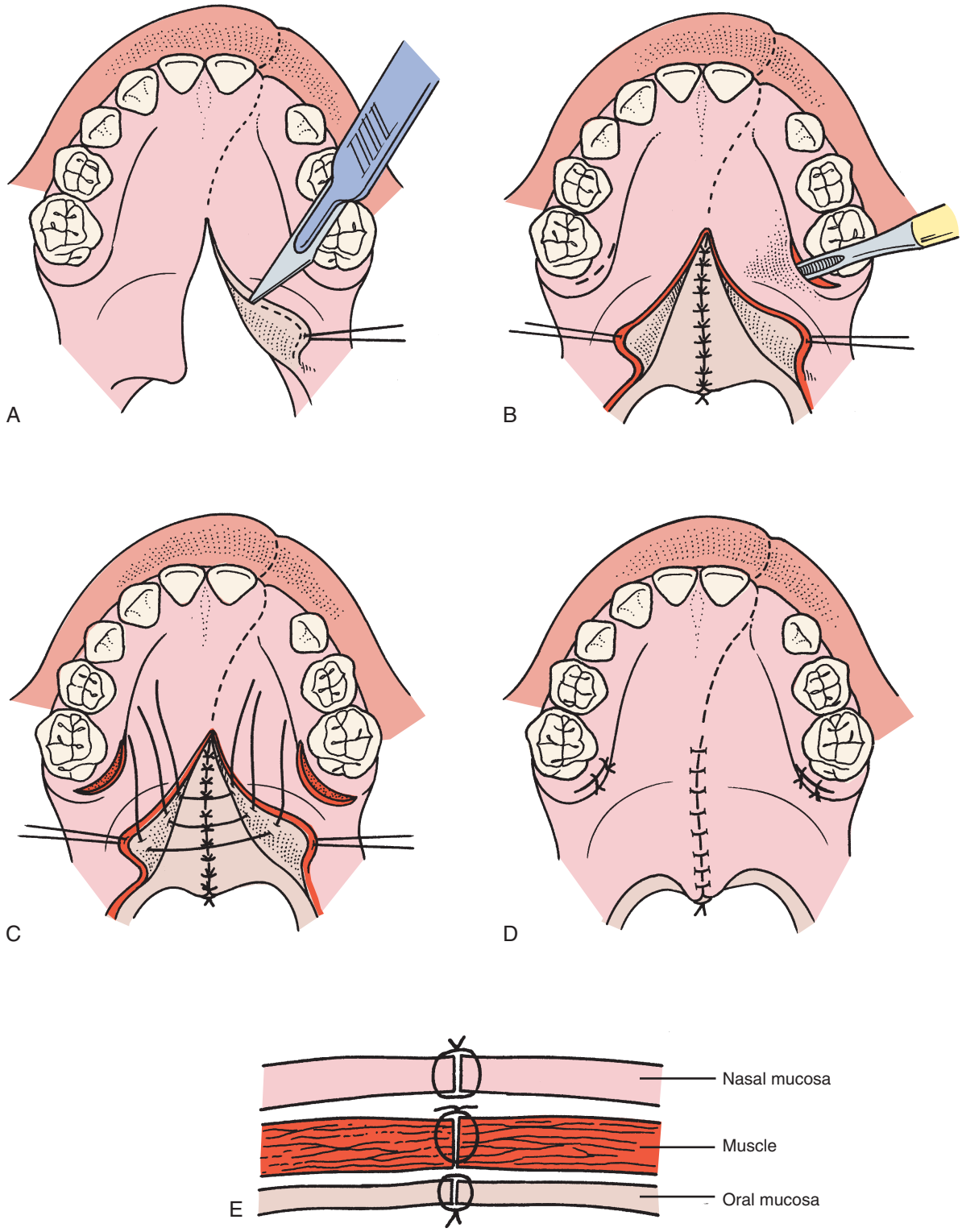
The bone placed into the alveolar cleft is usually obtained from the patient's ilium or cranium; however, some surgeons are using allogeneic bone (i.e., homologous bone from another individual) and recently bone morphogenetic proteins have been used for this purpose.[5–8] The grafts are made into a particulate consistency and are packed into the defect once the nasal and palatal mucosa has been closed. The labial mucosa is then closed over the bone graft. In time, these grafts are replaced by new bone that is indistinguishable from the surrounding alveolar process (see Fig. 28.15). Orthodontic movement of teeth into the graft sites is possible, and eruption of teeth into them usually proceeds unimpeded. Implants may also be placed.

Correction of Maxillomandibular Disharmonies

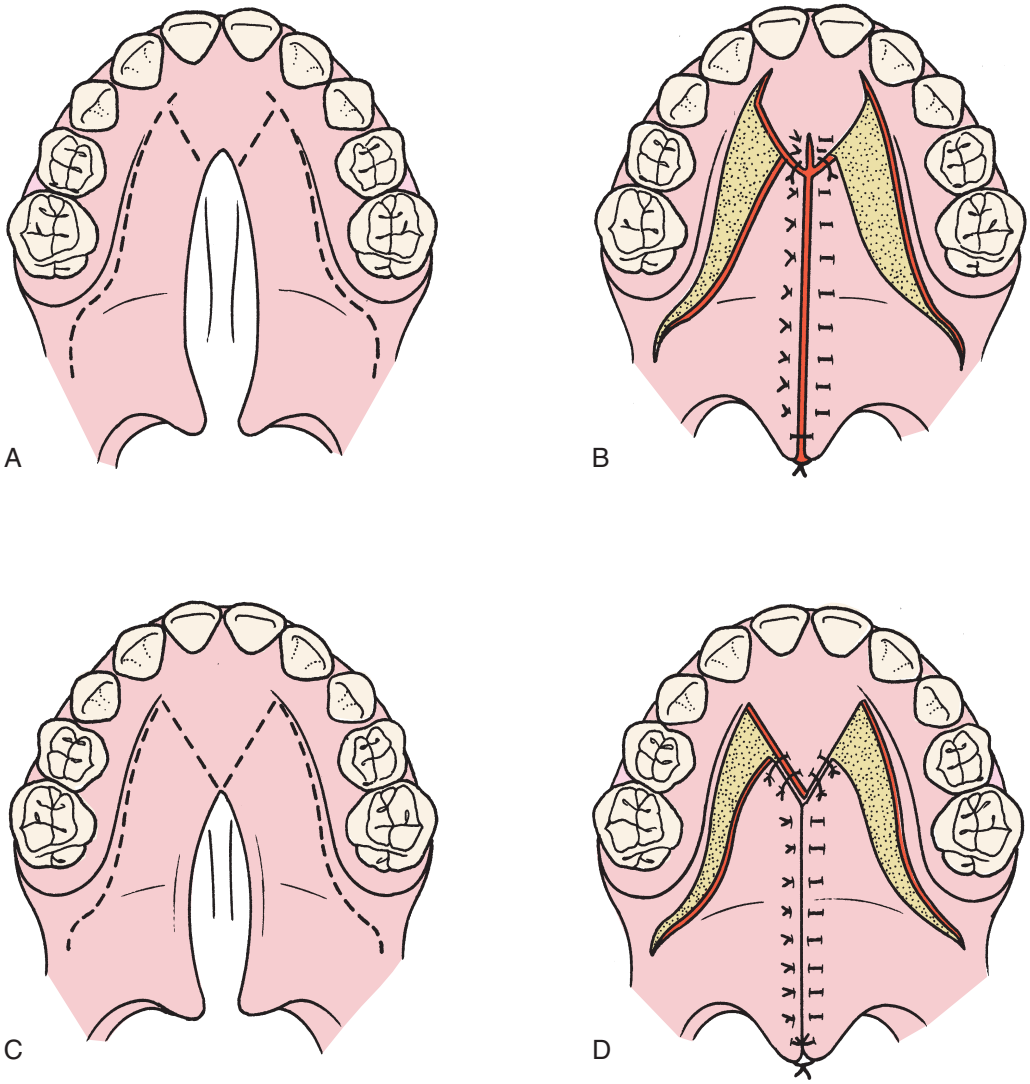
The individual with a cleft deformity usually exhibits maxillary retrusion and a transverse maxillary constriction resulting from the cicatricial contraction of previous surgeries. In many instances, the associated malocclusion is beyond the scope of orthodontic treatment alone. In these cases, orthognathic surgery similar to the procedures outlined in Chapter 26 is indicated to correct the underlying skeletal malrelationships.

However, some differences exist in the technical aspects of maxillary surgery because of the other deformities and scarring that are present in the maxilla of individuals with clefts. In general, total maxillary osteotomies are necessary to advance and sometimes widen the maxilla. Closure of some of the space in the alveolar cleft area by bringing the alveolus of the cleft side anteriorly is also performed in several instances. These latter procedures necessitate the segmentation of the maxilla, which, because of the nature of the cleft, usually already has occurred. However, the differences between patients with or without clefts are the scar present across the palate and the decreased blood supply to the maxilla. Scarring from previous surgeries makes widening of the maxilla difficult, and frequently excision of some of this tissue is necessary. The clinician should try to be diligent and to maintain as much mucoperiosteum to the maxilla as possible because of the poor blood supply that the cleft maxilla receives. Care must also be taken not to create another oronasal fistula.

If the alveolar cleft had not been grafted previously, this can be done in the same operation. However, in bilateral clefts, the blood supply to the prolabial segment is very poor. It may be more prudent in these instances to perform the alveolar cleft grafts first and then perform a one-piece maxillary osteotomy after sufficient time has passed for revascularization of the prolabial segment.



• **Fig. 28.13** Triple-layered soft palate closure. (A) Excision of the mucosa at the cleft margin. (B) Dissection of the nasal mucosa from the soft palate to facilitate closure. Nasal mucosa is sutured together with knots tied on the nasal (i.e., superior) surface. Note the small incision made to insert the instrument for the hamular process fracture. This maneuver releases the tensor veli palatini and facilitates approximation in the midline. (C) Muscle is dissected from the insertion into the hard palate, and sutures are placed to approximate the muscle in the midline. (D) Closure of the oral mucosa is accomplished last. (E) Layered closure of the soft palate. (Modfiied from Hayward JR. *Oral Surgery*. Springfield, IL: Charles C. Thomas; 1976.)



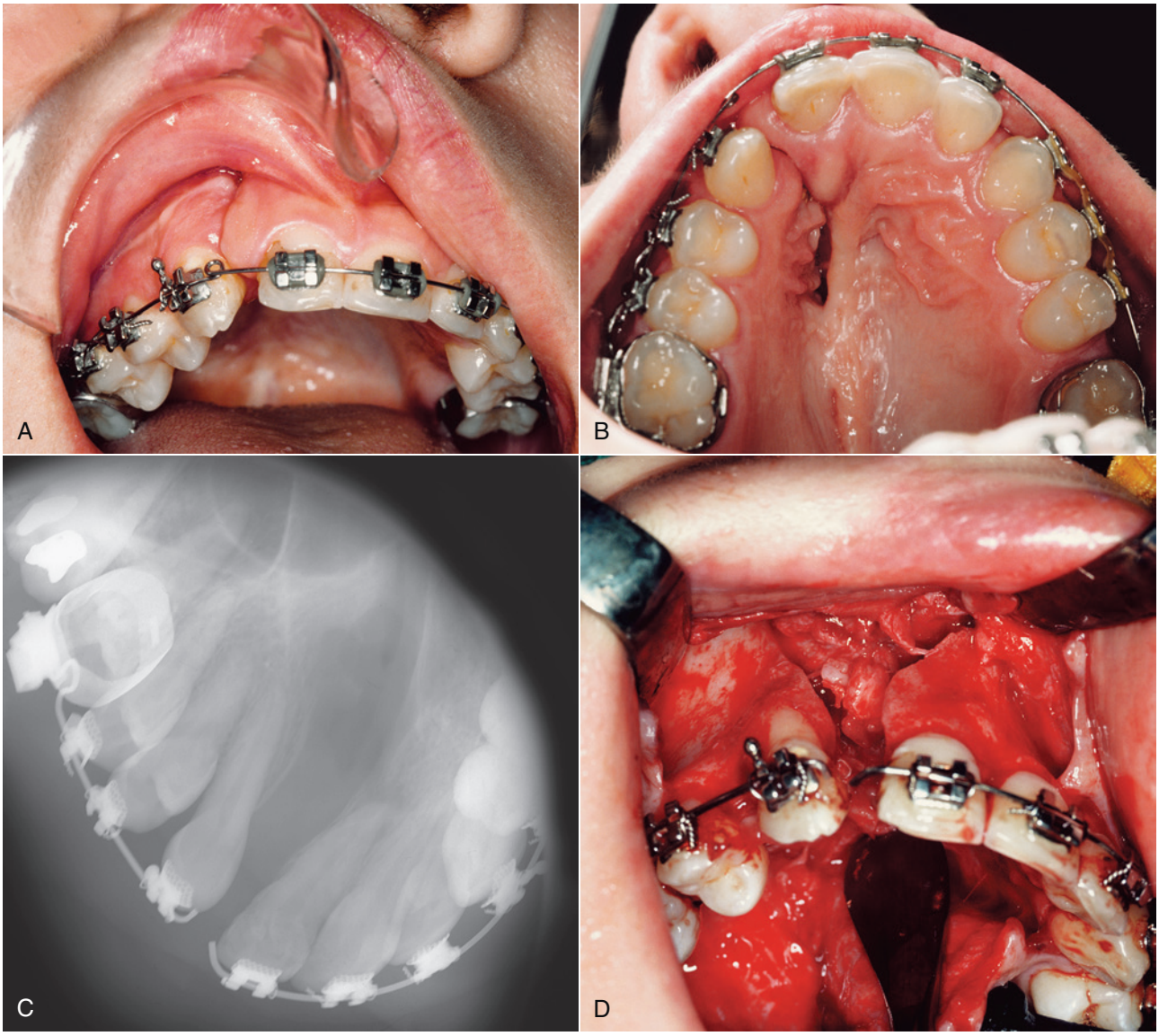
• **Fig. 28.14** Wardill operations for palatal lengthening on closure. (A–B) Four-flap operation for an extensive cleft. (C–D) Three-flap operation for a shorter cleft. Note the amount of denuded palatal bone left after these operations.

One problem faced by the patient with a cleft palate when maxillary advancement procedures are planned is the effect this may have on the velopharyngeal mechanism. When the maxilla is brought forward, the soft palate is also drawn forward. A patient's preoperative marginal competence of the velopharyngeal mechanism may become incompetent in the postoperative period. Determination of which patients will have this problem is difficult. However, because of the possibility of this incompetence, secondary palatal or pharyngeal surgical procedures to increase velopharyngeal competence are discussed with the patient. These procedures can be performed later, if necessary.

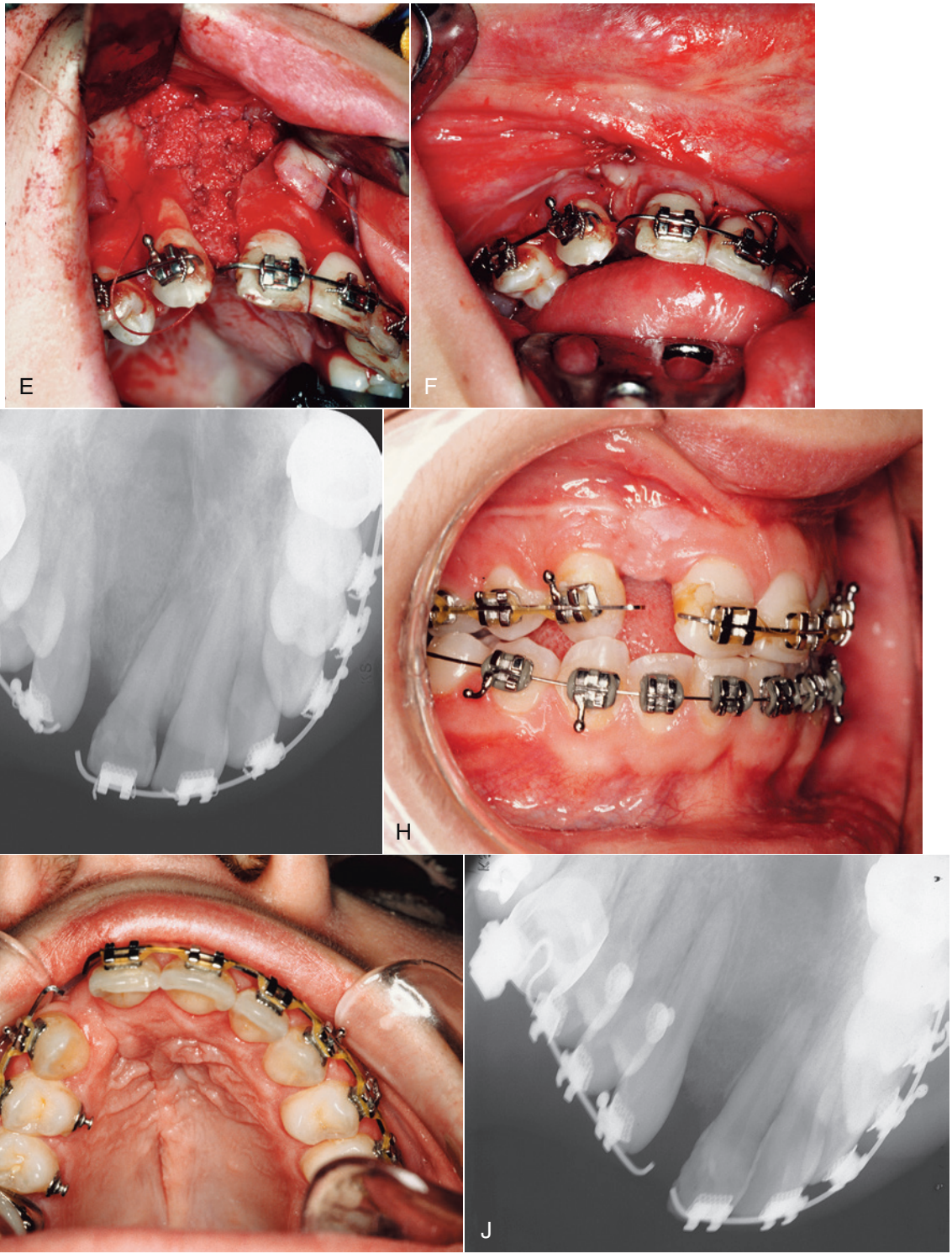
Secondary Surgical Procedures

Secondary surgical procedures are procedures performed after the initial repair of the cleft defects in an effort to improve speech or correct residual defects. The most commonly used technique to improve velopharyngeal competence secondarily is the pharyngeal flap procedure (Fig. 28.17). In this procedure, a wide vertical strip of pharyngeal mucosa and musculature is raised from the posterior pharyngeal wall and inserted into the superior aspect of the soft palate. These flaps are most often based superiorly. The defect left in the posterior pharyngeal wall from elevation of the pharyngeal flap can be closed primarily or left to heal by secondary intention. Once inserted into the soft palate, the pharynx and the soft palate are joined, leaving two lateral ports as the opening between the oropharynx and nasopharynx, which reduces the airstream between the oropharynx and the nasopharynx. The velopharyngeal mechanism then consists of raising the soft palate somewhat and medial constriction of the lateral pharyngeal walls.

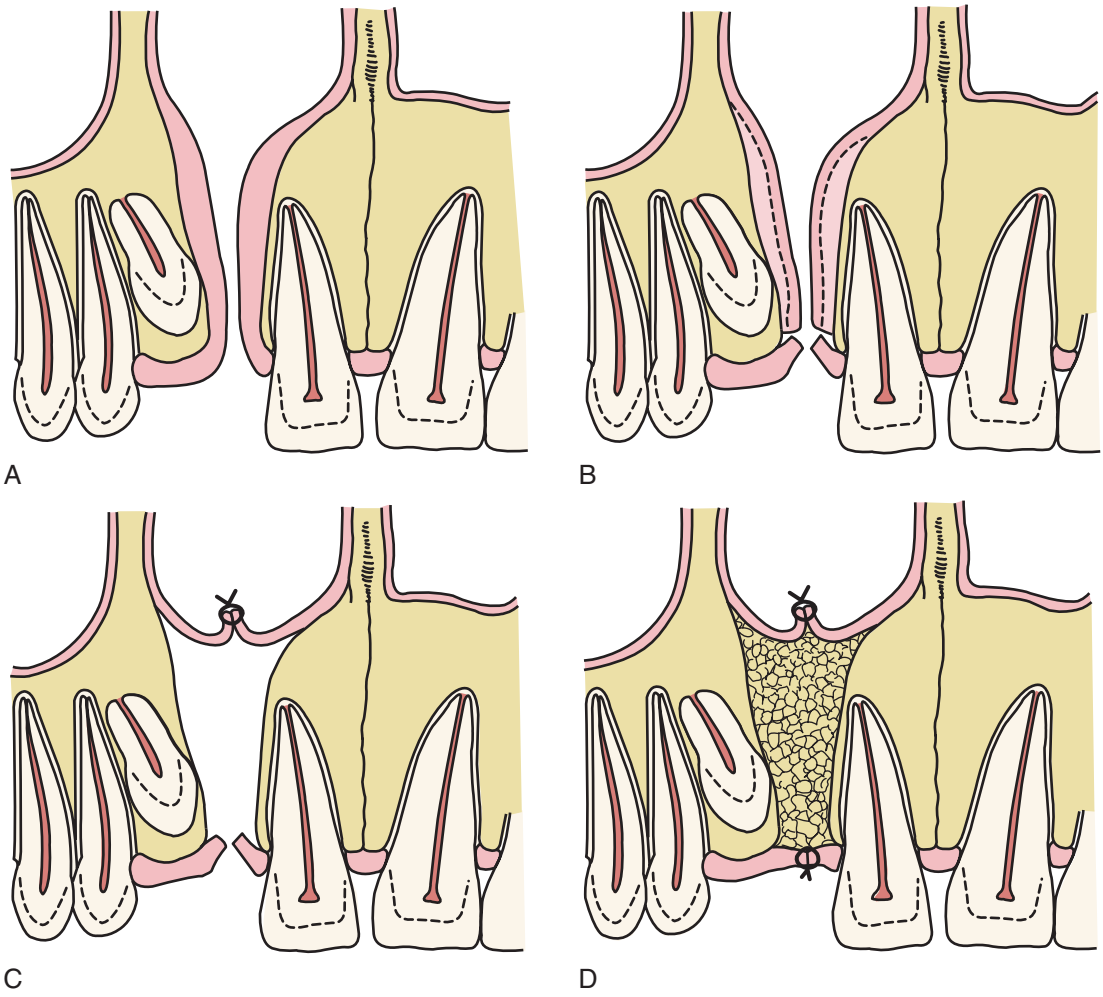
Another technique that has recently had a resurgence of interest because of new biocompatible material is the placement of an implant behind the posterior pharyngeal wall to bring it anteriorly (Fig. 28.18). Thus the soft palate has less distance to traverse to close off the nasopharynx. The major problems with this technique in the past have been migration of the implant and infection, which usually results in the need for removal.



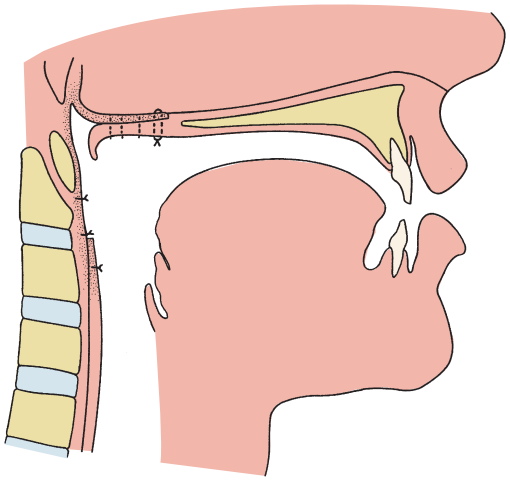
• **Fig. 28.15** (A–C) Labial, palatal, and radiographic views of a patent unilateral alveolar cleft that extends posteriorly along the hard palate. (D) Surgical closure of the nasal mucosa with inversion into the nasal cavity.



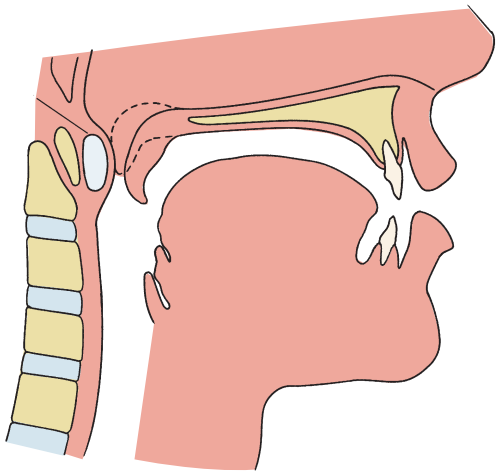
• **Fig. 28.15, cont'd** (E) Particulate bone graft is placed into the defect. (F) Closure of the palatal and labial mucosa over the bone graft. (G) Radiographic result is demonstrated 3 days after surgery. (H–I) Labial and palatal views 3 months after surgery showing healing of the soft tissues. (J) Radiograph taken 3 months after surgery showing consolidation of the bone graft.



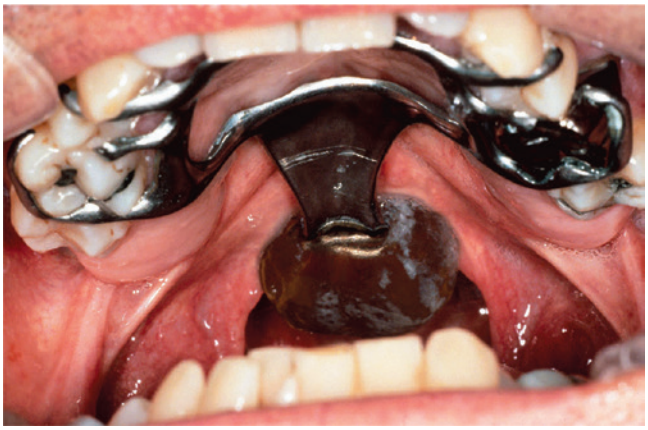
• **Fig. 28.16** Technique for alveolar cleft bone grafting. (A) Preoperative defect viewed from the labial aspect. The fistula extends into the nasal cavity. (B) The incision divides the mucosa fistula, which allows development of nasal and oral flaps. (C) The mucosal flap developed from the lining of the fistula is turned inward, up into nasal cavity, and sutured in a watertight manner. (D) Bone graft material is packed into the cleft, and the oral mucosa is closed in a watertight manner. Note the partially developed canine and the absence of a lateral incisor.



• **Fig. 28.17** Superiorly based pharyngeal flap. The flap is sutured to the superior aspect of the soft palate, thus partially partitioning the oral and nasal cavities from one another. The only nasal airway remaining after this operation is two lateral openings on each side of flap.



• **Fig. 28.18** Posterior pharyngeal wall implant. This makes the distance between the soft palate and pharyngeal wall smaller so that velopharyngeal closure is facilitated.



• **Fig. 28.19** Prosthetic speech aid appliance. The appliance can be designed to lift the soft palate and obturate oral and nasal cavities, if necessary.

Dental Needs of Individuals With Clefts

Dentists will have patients with clefts in their practice because of the relatively large number of persons so affected. These patients should not pose any great problems because their dental needs do not differ dramatically from those of other individuals. However, because of the presence of the cleft, corrected or uncorrected, these individuals have a few special needs of which the dentist should be cognizant.

Because of the interdisciplinary approach that patients with clefts require, it is important that the dentist be aware of the overall treatment plan formulated by the team for the patient's treatment. Awareness of this plan precludes the performance of any irreversible or costly procedures on teeth that may be charted for extraction in the future. For instance, placing a bridge to replace a congenitally missing lateral incisor before alveolar bone grafting and orthodontic therapy is unwise. Similarly, extracting supernumerary teeth that may be temporarily retained to maintain alveolar bone support is also disadvantageous. All fixed bridgework should be delayed until after the orthodontic, orthognathic, and alveolar grafting procedures have been completed. Only then will the dentist be able to determine accurately the exact space and ridge form available for pontics.

Furthermore, until the halves of the maxillary arch have been united with bone grafts, the halves will move independently and bridgework spanning the cleft margin may become loose. Therefore the dentist must communicate freely with the other professionals who are managing the patient's other cleft problems, and coordination of services is of paramount importance.

Teeth adjacent to the cleft margins not only may be malformed or absent but also may have poor periodontal support because of lack of bone and their position in the cleft margin. This situation predisposes teeth to periodontitis and early loss if not kept in an optimal state of health. Because teeth are frequently malaligned and rotated, oral hygienic measures may be more difficult; these individuals may need more frequent prophylaxis and special oral hygienic instructions with careful reinforcement. Otherwise, rampant caries with premature loss may occur. This is a special tragedy in the individual affected by cleft because he or she may have fewer teeth to serve vital functions (e.g., retaining orthodontic, orthopedic, or speech appliances).

Prosthetic Speech Aid Appliances

Prosthetic care for the patient with a cleft may be necessary for two reasons: First, the missing teeth should be replaced. Second, for patients who have failed to obtain velopharyngeal competence with surgical corrections, a speech aid appliance can be made by the dentist to decrease hypernasal speech. A speech aid appliance is an acrylic bulb attached to a toothborne appliance in the maxilla (Fig. 28.19). The bulb is fitted to project onto the undersurface of the soft palate and lifts the soft palate superiorly. If this bulb does not give adequate function, another projection of acrylic (i.e., bulb obturator) can be placed to extend to the posterior aspect of the palate. This narrows the pharyngeal isthmus, and the size can be adjusted for maximal effectiveness. The posterior pharyngeal wall then contacts this bulb in function. In many instances, the size of the bulb can be reduced as the pharyngeal musculature becomes more active. This type of appliance is used in two instances: (1) before a pharyngeal flap procedure to develop muscle action or (2) if the secondary surgical procedures are not successful in producing velopharyngeal competence. The speech aid appliance is also useful concomitantly to hold prosthetic dental replacements, to cover hard palate defects, and to support deficient upper lips by a flange extending into the labial sulcus. Obviously, the maintenance of the residual dentition in an optimal state is prerequisite for successful speech aid appliance therapy.

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29

Surgical Reconstruction of Defects of the Jaws

EDWARD ELLIS III

CHAPTER OUTLINE

Defects of the facial bones, especially the jaws, have a variety of causes, such as eradication of pathologic conditions, trauma, infections, and congenital deformities. The size of the defects that are commonly reconstructed in the oral-maxillofacial region varies considerably, from small alveolar clefts to mandibulectomy defects. Each defect poses a unique set of problems that reconstructive surgical intervention must address. In each of these instances, restoration of normal structure is usually possible, with resultant improvement in function and appearance.

When an osseous structure is defective in size, shape, position, or amount, reconstructive surgery can replace the defective structure. The tissue most commonly used to replace lost osseous tissue is bone. Bone grafting has been attempted for centuries with varying degrees of success. Recent advancements in the understanding of bone physiology, immunologic concepts, tissue-banking procedures, and surgical principles have made possible the successful reconstruction of most maxillofacial bony defects. As such, the biology and principles of transplantation of bone are presented in this chapter.

Biologic Basis of Bone Reconstruction

A tissue that is transplanted and expected to become a part of the host to which it is transplanted is known as a *graft*. Several types of grafts are available to the surgeon and are discussed later. A basic understanding of how a bone heals when grafted from one place to another in the same individual (i.e., autotransplantation) is necessary to understand the benefits of the various types of bone grafts available.

The healing of bone and bone grafts is unique among connective tissues because new bone formation arises from tissue regeneration rather than from simple tissue repair with scar formation.[1] Therefore this healing requires the element of cellular proliferation (i.e., osteoblasts) and the element of collagen synthesis. When bone is transplanted from one area of the body to another, several processes become active during the incorporation of the graft.

Two-Phase Theory of Osteogenesis

Two basic processes occur on transplanting bone from one area to another in the same individual.[1–5] The first process that leads to bone regeneration arises initially from transplanted cells in the graft that proliferate and form new osteoid. The amount of bone regeneration during this phase depends on the number of transplanted bone cells that survive the grafting procedure. Obviously, when the graft is first removed from the body, the blood supply has been severed. Thus the cells in the bone graft depend on diffusion of nutrients from the surrounding graft bed (i.e., the area where the graft is placed) for survival. A considerable amount of cell death occurs during the grafting procedure, and this first phase of bone regeneration may not lead to an impressive amount of bone regeneration when considered alone. Still, this phase is responsible for the formation of most of the new bone. The amount of bone that will form depends on the amount of viable cells that can be successfully transplanted with the graft.

The graft bed also undergoes changes that lead to a second phase of bone regeneration beginning in the second week. Intense angiogenesis and fibroblastic proliferation from the graft bed begin after grafting, and osteogenesis from host connective tissues soon begins. Fibroblasts and other mesenchymal cells differentiate into osteoblasts and begin to lay down new bone. Evidence shows that a protein (or proteins) found in the bone induces these reactions in the surrounding soft tissues of the graft bed.[6,7] This second phase is also responsible for the orderly incorporation of the graft into the host bed with continued resorption, replacement, and remodeling.

Immune Response

When a tissue is transplanted from one site to another in the same individual, immunologic complications usually do not occur. The immune system is not triggered because the tissue is recognized as "self." However, when a tissue is transplanted from one individual to another or from one species to another, the immune system may present a formidable obstacle to the success of the grafting procedure. If the graft is recognized as a foreign substance by the host, it will mount an intense response in an attempt to destroy the graft. The type of response the immune system mounts against "foreign" grafts is primarily a cell-mediated response by T-lymphocytes. However, the response may not occur immediately, and in the early period the incorporation of a bone graft into the host may appear to be progressing normally. The length of this latent period depends on the similarity between the host and the recipient. The more similar they are (antigenically), the longer it may take for an immunologic reaction to appear. This type of immunologic reaction is the most common reason for rejection of hearts, kidneys, and other organs transplanted to another individual. Tissue-typing procedures, in which a donor and recipient are genetically compared for similarities before transplantation, are currently commonplace for organ transplantation but never for bone grafts.

Because of the immunologic rejection of transplants between individuals or between species, methods have been devised to improve the success of grafting procedures in these instances. Two basic approaches are used clinically: The first is the suppression of the host individual's immune response. Immunosuppression with various medications is most commonly used in organ transplant recipients. This approach is not used routinely in oral-maxillofacial surgical bone grafting procedures because of the potential complications from immunosuppression.

Another approach that has been used extensively in oral and maxillofacial surgical procedures is the alteration of the antigenicity of the graft so that the host's immune response will not be stimulated. Several methods of treating grafts have been used, including boiling, deproteinization, use of thimerosal (Merthiolate), freezing, freeze-drying, irradiation, and dry heating. All of these methods, potentially helpful for use in bone grafts, are obviously not helpful in organ transplants.

Types of Grafts

Several types of bone grafts are available for use in reconstructive surgery. A useful classification categorizes the bone grafts according to their origin and thus their potential to induce an immunologic response. Because of their origins and the preparations used to help avoid an intense immune response, the grafts have different qualities and indications for use.

Autogenous Grafts

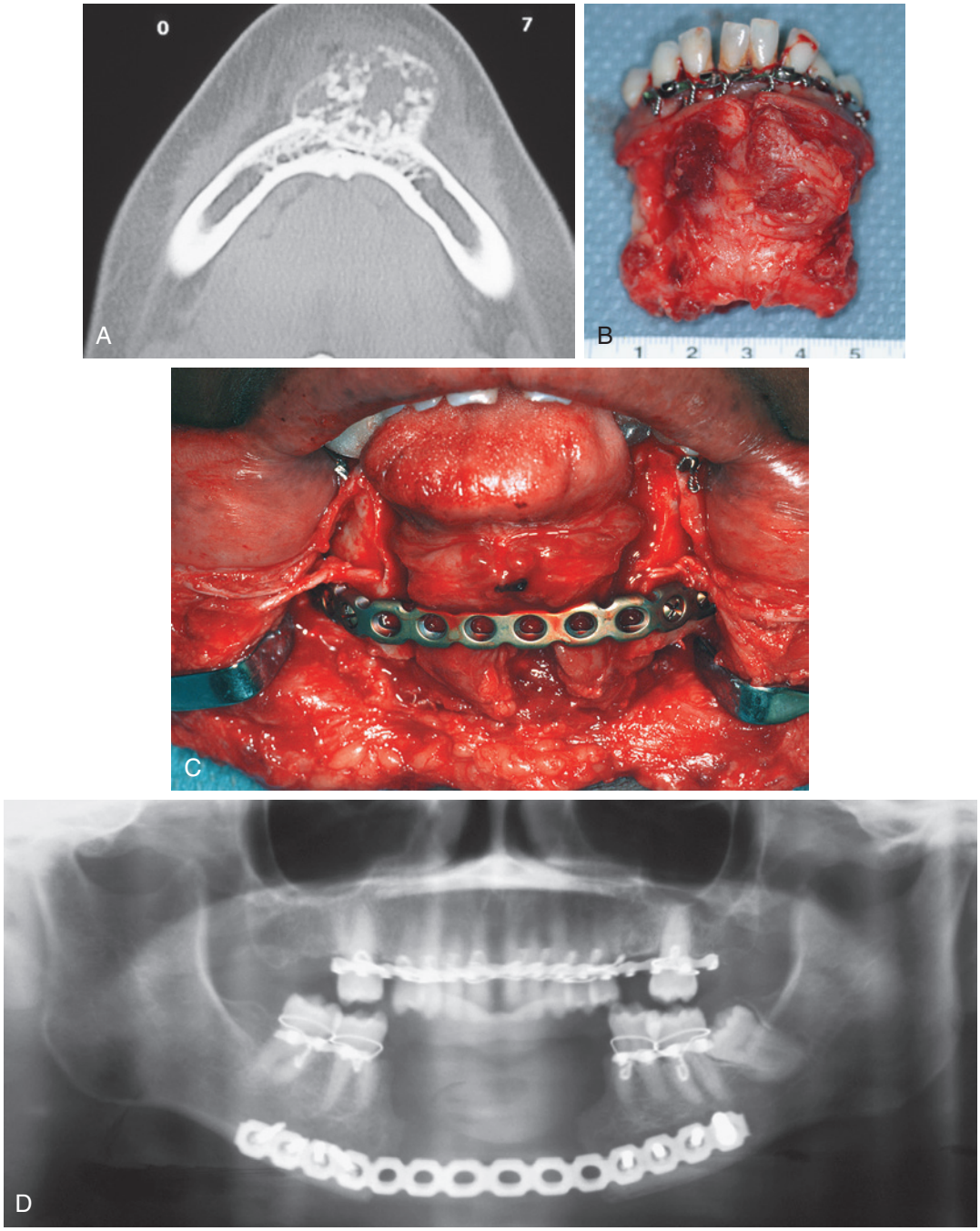
Also known as *autografts* or *self-grafts*, autogenous grafts are composed of tissues from the same individual. Fresh autogenous bone is the most ideal bone graft material. The autogenous graft is unique among bone grafts in that it is the only type of bone graft to supply living, immunocompatible bone cells essential to phase I osteogenesis. The larger the number of living cells transplanted, the more will be the osseous tissue produced.

Autogenous bone is the type used most frequently in oral-maxillofacial surgery. The bone to be transplanted can be obtained from a host of sites in the body and can be taken in several forms. *Block grafts* are solid pieces of cortical bone and underlying cancellous bone (Fig. 29.1). The iliac crest is often used as a source for this type of graft. The entire thickness of the ilium can be obtained, or the ilium can be split to obtain a thinner piece of block graft. Ribs also constitute a form of block graft. *Particulate marrow and cancellous bone grafts* are obtained by harvesting the medullary bone and the associated endosteum and hematopoietic marrow. Particulate marrow and cancellous bone grafts produce the greatest concentration of osteogenic cells, and because of the particulate nature, more cells survive transplantation because of the access they have to nutrients in the surrounding graft bed. The most common site for the procurement of this type of graft is the ilium. The iliac crest can be entered, and large volumes of particulate marrow and cancellous bone grafts can be obtained with large curettes. The diploic space of the cranial vault has recently been used as a site for obtaining this type of graft when small amounts of bone chips are needed (e.g., alveolar cleft grafts).

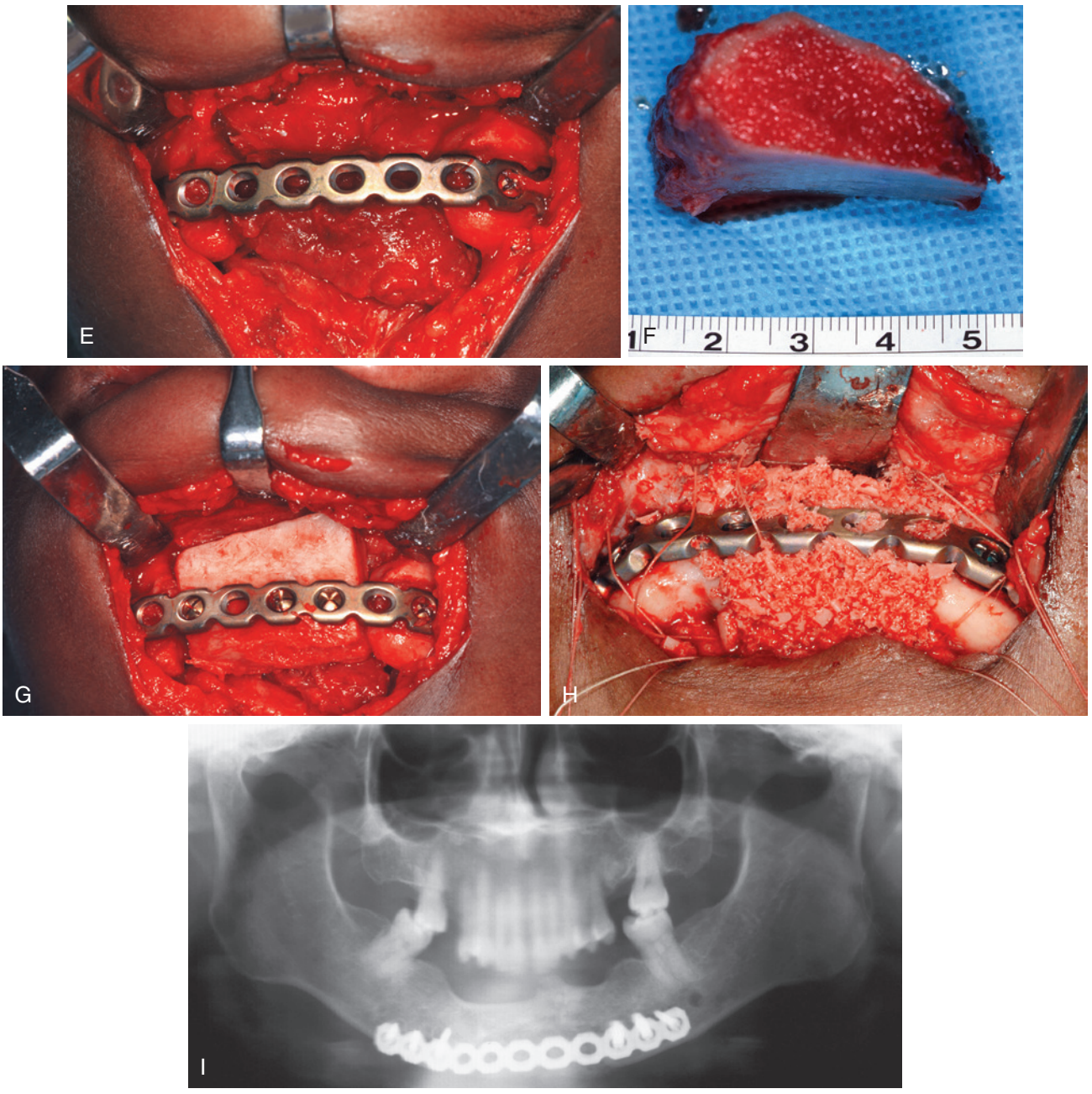
Autogenous bone may also be transplanted while maintaining the blood supply to the graft. Two methods can accomplish this: The first involves the transfer of a bone graft pedicled to a muscular (or muscular and skin) pedicle. The bone is not stripped of its soft tissue pedicle, preserving some blood supply to the bone graft. Thus the number of surviving osteogenic cells is potentially great. An example of this type of autogenous graft is a segment of the clavicle transferred to the mandible, pedicled to the sternocleidomastoid muscle. The second method by which autogenous bone can be transplanted without losing blood supply is by the use of microsurgical techniques. A block of ilium, tibia, rib, or other suitable bone is removed along with overlying soft tissue after dissecting free an artery and a vein that supply the tissue (Fig. 29.2). An artery and a vein are also prepared in the recipient bed. Once the bone graft is secured in place, the artery and veins are reconnected using microvascular anastomoses. In this way, the blood supply to the bone graft is restored.

Both of these types of autogenous grafts are known as *composite grafts* because they contain soft tissue and osseous elements. The first type described, in which the bone maintains a muscular origin, is a pedicled composite graft. The pedicle is the soft tissue remaining on it, which supplies the vasculature. The second type of composite graft is a free composite graft; that is, it is totally removed from the body and immediately replaced, and its blood supply is restored by reconnection of blood vessels.

Although these types of grafts may seem ideal, they have some shortcomings when used to restore defects of the jaws. Because soft tissues attached to the bone graft maintain the blood supply, minimal stripping of the soft tissue from the graft may occur during procurement and placement. Thus the size and shape of the graft cannot be altered to any significant degree. Frequently, inadequate bulk of bone is provided when these grafts are used to



• **Fig. 29.1** Use of autogenous corticocancellous block bone graft to replace a defect in the mandibular symphysis. This patient had an ameloblastoma of the anterior mandible. (A) Computed tomography scan showing expansion and irregularity of bone. (B) Specimen that was resected using an intraoral approach. (C) Bone plate used to span the resection gap, controlling the position of the right and left mandibular halves and allowing the patient to function postoperatively without the need for intermaxillary fixation. (D)



• **Fig. 29.1, cont'd** Panoramic radiograph taken immediately after resection. Three months later, the oral soft tissues have healed, and the patient is prepared for bone graft reconstruction of the symphysis. (E) Surgical exposure using an extraoral approach. (F) Full-thickness bone graft harvested from the ilium along with particulate marrow and cancellous bone to use as "filler" and to provide osteocompetent cells. (G) Bone graft attached to the bone plate. (H) Particulate bone is then packed around the area to promote bone healing. (I) Panoramic radiograph taken 2 years later showing bone fill and healing of graft to both mandibular halves.

restore mandibular continuity defects. Another problem is the morbidity to the donor site. Instead of just removing osseous tissue, soft tissues are also removed with composite grafts, which causes greater functional and cosmetic defects.

Advantages

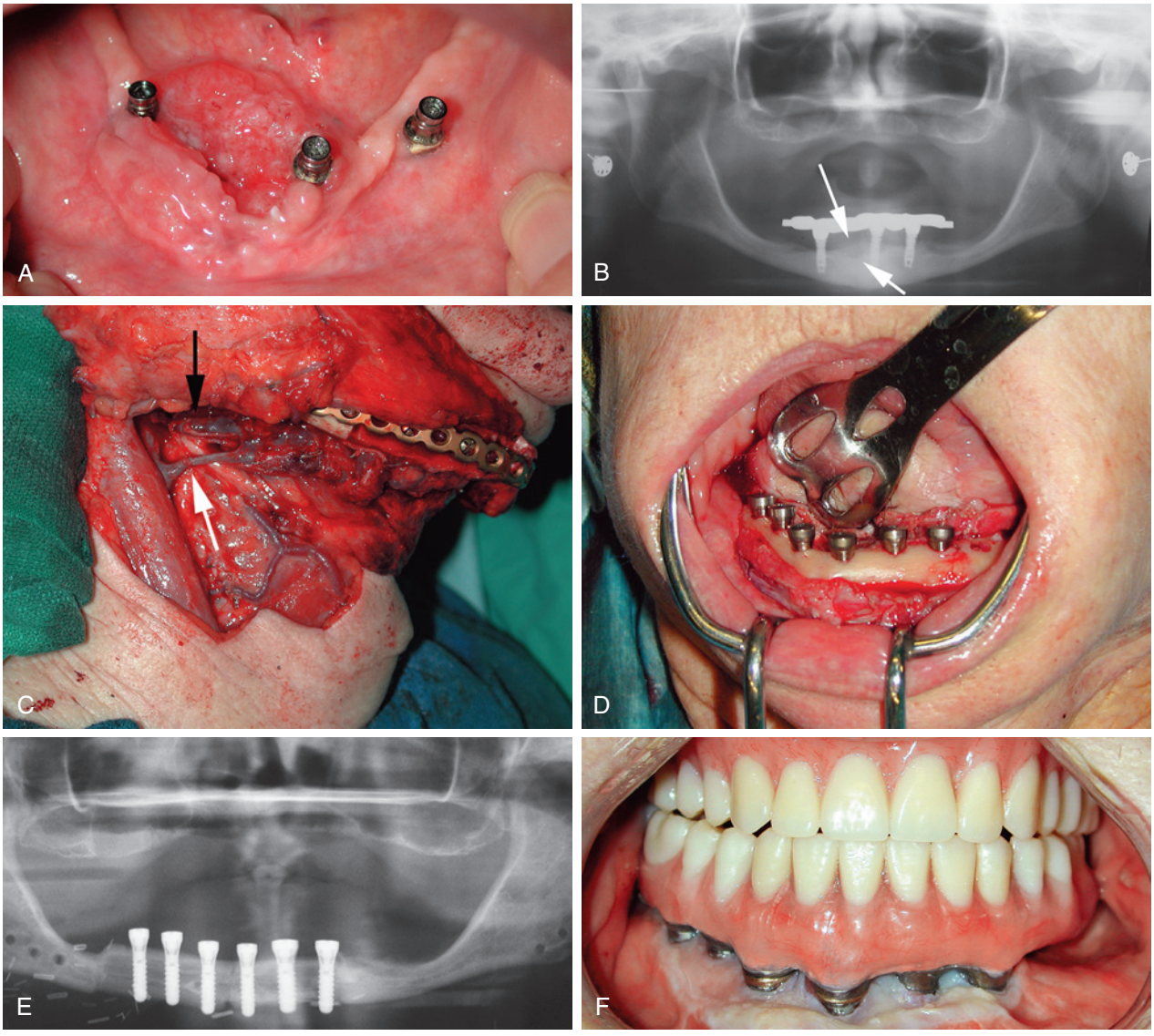
The advantages of autogenous bone are that it provides osteogenic cells for phase I bone formation and no immunologic response occurs.

Disadvantages

A disadvantage is that this procedure necessitates another site of operation for procurement of the graft.

Allogeneic Grafts

Also known as *allografts* or *homografts*, allogeneic grafts are grafts taken from another individual of the same species. Because the individuals are usually genetically dissimilar, treating the graft to



• **Fig. 29.2** Reconstruction with a vascularized free flap. (A) Squamous cell carcinoma located on the alveolar ridge and floor of mouth. (B) Panoramic radiograph showing erosion of lesion into bone *(arrows).* (C) Intraoperative image after the mandible and surrounding soft tissues were resected and a free fibular bone flap and reconstruction bone plate have been used to reconstruct the mandible. Note the venous anastomosis *(white arrow).* The arterial supply to the flap is also shown *(black arrow),* but the actual anastomosis is located more proximally, under the tissue, and is not visible. (D) After the bone graft has healed, dental implants are inserted. (E) Panoramic radiograph showing the reconstructed mandible after implants have been inserted. (F) Intraoral view of prosthetic reconstruction of dental implants. The white tissue surrounding the implants is skin that was transferred with the bone flap. (Courtesy Dr. Remy Blanchaert Jr.)

reduce the antigenicity is routinely accomplished. Today, the most commonly used allogeneic bone is freeze dried. All of these treatments destroy any remaining osteogenic cells in the graft, and therefore allogeneic bone grafts cannot participate in phase I osteogenesis. The assistance of these grafts to osteogenesis is purely passive; they offer a hard tissue matrix for phase II induction.

Thus the host must produce all of the essential elements in the graft bed for the allogeneic bone graft to become resorbed and replaced. Obviously, the health of the graft bed is much more important in this set of circumstances than it is if autogenous bone were to be used.

Advantages

The advantages are that allogeneic grafts do not require another site of operation in the host and that a similar bone or a bone of similar shape to that being replaced can be obtained (e.g., an allogeneic mandible can be used for reconstruction of a mandibulectomy defect).

Disadvantages

The disadvantage is that an allogeneic graft does not provide viable cells for phase I osteogenesis.

Xenogeneic Grafts

Also known as *xenografts* or *heterografts*, xenogeneic grafts are taken from one species and grafted to another. The antigenic dissimilarity of these grafts is greater than with allogeneic bone. The organic matrix of xenogeneic bone is antigenically dissimilar to that of human bone, and therefore the graft must be treated more vigorously to prevent rapid rejection of the graft. Bone grafts of this variety are rarely used in major oral-maxillofacial surgical procedures.

Advantages

The advantages are that xenografts do not require another site of operation in the host and a large quantity of bone can be obtained.

Disadvantages

The disadvantages are that xenografts do not provide viable cells for phase I osteogenesis and must be rigorously treated to reduce antigenicity.

Bone Morphogenetic Proteins

Bone morphogenetic proteins (BMPs) are a group of osteoinductive, sequentially arranged amino acids and polypeptides that are capable of stimulating mesenchymal cells within the body to become osteoblastic and to form bone. BMP was first described by Urist, who showed ectopic bone formation in rabbits and rats from extracted heterogeneous treated bone implants.[7] Subsequently, many BMPs have been characterized and cloned, providing the availability of recombinant BMPs for definitive use in a variety of recipient sites, including reconstruction of the jaws.

Advantages

The advantages are that BMPs do not require another site of operation in the host. They are useful when a donor site operation is not desired and when allogeneic or xenogeneic bone is not available.

Disadvantages

The disadvantages are that BMPs do not provide viable cells for phase I osteogenesis and must be used in a site where viable mesenchymal cells are located or in combination with the transplantation of viable mesenchymal stem cells. Another disadvantage is that, because BMP is a liquid, a carrier must be used to maintain the BMP at the site of implantation. Currently, a collagen sponge is used for this purpose. Unfortunately, the sponge does not have the physical properties that can maintain a large space within the tissue in which the new bone can form. Therefore other means of providing and maintaining this space are necessary. Currently, the use of BMP for mandibular reconstruction is not approved by the U.S. Food and Drug Administration and therefore is being used as an off-label application.

Combinations of Grafts

The ideal graft would have the structural characteristics of a block graft with the osteogenic potential of particulate marrow and cancellous bone grafts. However, a large block graft necessitates removal of a large portion of the patient's anatomy and does not provide the high concentration of osteogenic cells that the particulate marrow and cancellous bone graft does.

There are two graft combinations that have been successfully used to reconstruct the mandible. Both of these use allogeneic bone to provide the bulk and possibly shape that is desired. This graft is used for its structural strength and protein, which induces phase II bone formation from the surrounding tissues. The allogeneic graft is supplemented with osteocompetent cells to provide the development of new phase I bone.

Fig. 29.3 shows an allogeneic graft that has been hollowed out until only the cortical plates remain. Autogenous particulate marrow and cancellous bone is then obtained and packed into the shell to provide the osteogenic cells necessary for phase I bone formation. In this way, the ingredients necessary for both phases of osteogenesis are provided without necessitating the removal of a large portion of the individual's anatomy. The allogeneic portion of the graft acts as a biodegradable tray, which, in time, is completely replaced by host bone.

The advantages of this procedure are the same as those of autogenous and allogeneic grafts. The disadvantage is that this procedure necessitates a second site of operation in the host to obtain autogenous particulate marrow and cancellous bone graft.

The second combination of grafts that has been recently introduced is true tissue engineering and, like the aforementioned, uses allogeneic bone as a scaffold or to provide bulk. But rather than harvesting the patient's own particulate marrow to provide osteocompetent bone cells by a surgical procedure, bone marrow aspiration is used to provide such cells. This is much less invasive because a needle is used to aspirate the bone cells from the iliac crest—no surgical procedure is needed to obtain the osteocompetent bone cells. The bone marrow aspirate is concentrated in a centrifuge, and the fluid containing the bone cells is mixed with BMP to stimulate them (Fig. 29.4).

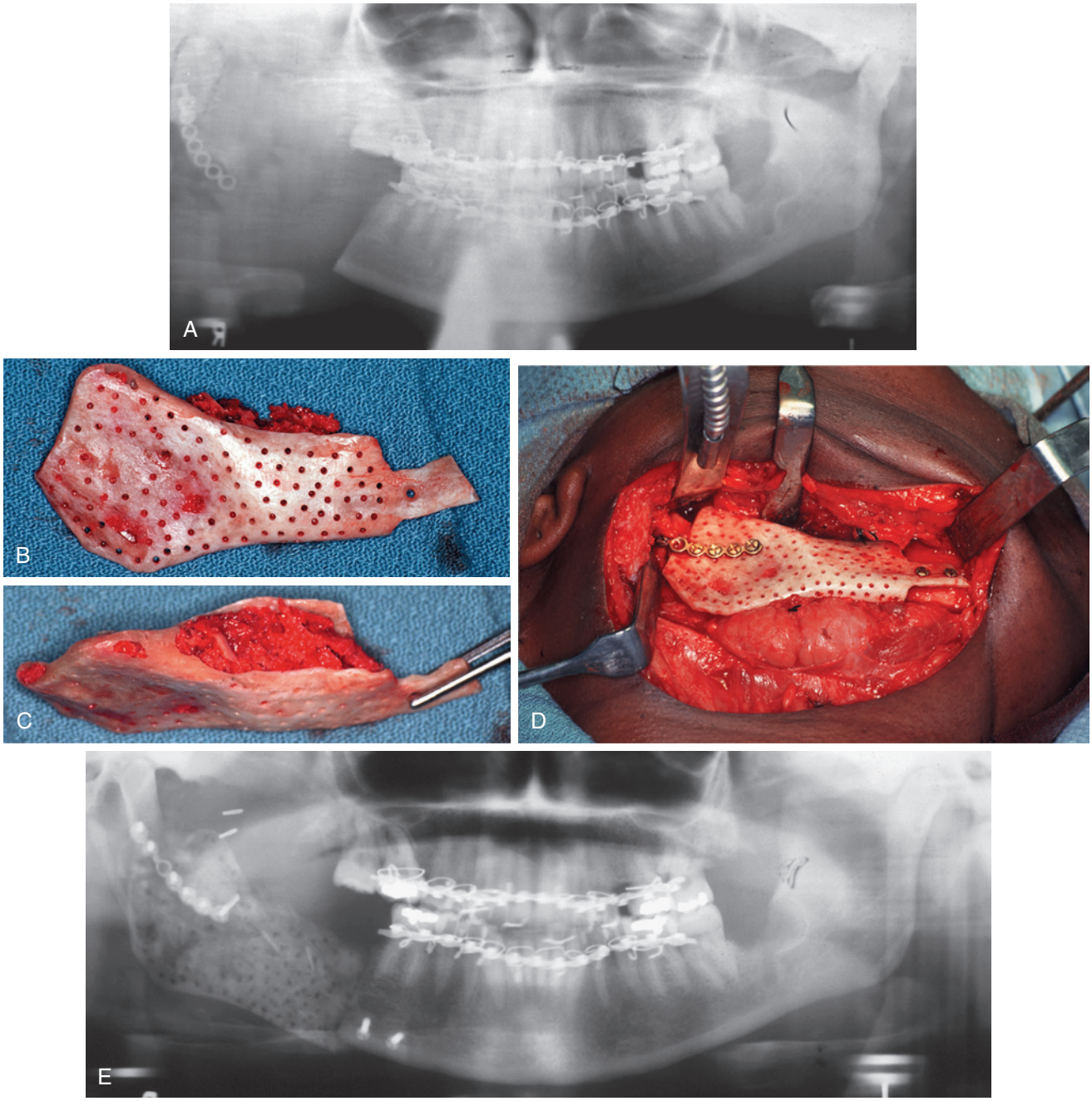
Assessment of Patient in Need of Reconstruction

Patients who have defects of the jaws can usually be treated surgically to replace the lost portion. However, each patient must be thoroughly evaluated because no two patients have the exact same problems. Analysis of the patient's problem must take into consideration the hard tissue defect, any soft tissue defects, and any associated problems that will affect treatment.

Hard Tissue Defect

Several factors concerning the actual osseous defect must be thoroughly assessed to formulate a viable treatment plan. Adequate radiographs are necessary to evaluate the full extent of the osseous defect. The site of the defect may be just as important as the size of the defect when dealing with mandibular osseous problems. For example, if the mandibular condyle is missing, treatment is relatively more difficult. A residual portion of the ramus with the condyle still attached makes osseous reconstruction easier because the temporomandibular articulation is difficult to restore.

The mandible has powerful muscles attached to it that usually direct functional movements. When the continuity of the mandible is broken, these muscles no longer work in harmony and may severely displace mandibular fragments into unnatural positions. Therefore the position of the residual mandibular fragments must be ascertained. For example, if a portion of the mandible in the area of the molars is missing, the muscles of mastication still attached to the mandibular ramus may rotate the ramus superiorly and medially, which may allow penetration into the oral cavity and compound the difficulty of planned treatment.

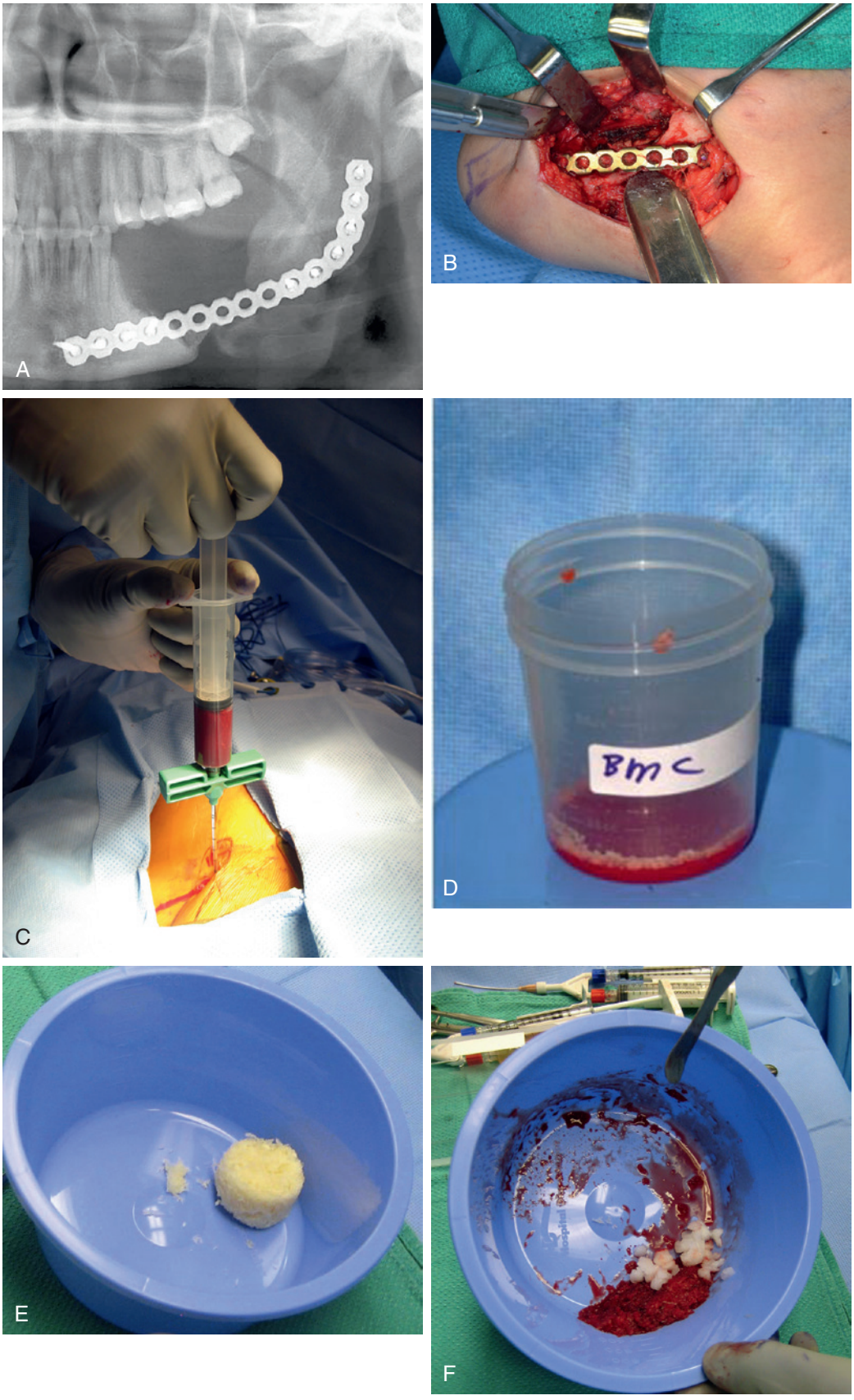


• **Fig. 29.3** Use of a combination of allogeneic and autogenous bone grafts to reconstruct the mandible after resection for ameloblastoma. (A) Panoramic radiograph showing the resected right mandibular ramus. A small bone plate was left attached to the condylar process to aid in later reconstruction. (B–C) Allogeneic right mandible has been hollowed out and packed with autogenous particulate cancellous bone and marrow and fashioned to fit into the defect. (D) The graft has been secured to the mandibular condylar process and body. (E) Postoperative panoramic radiograph showing graft in place.

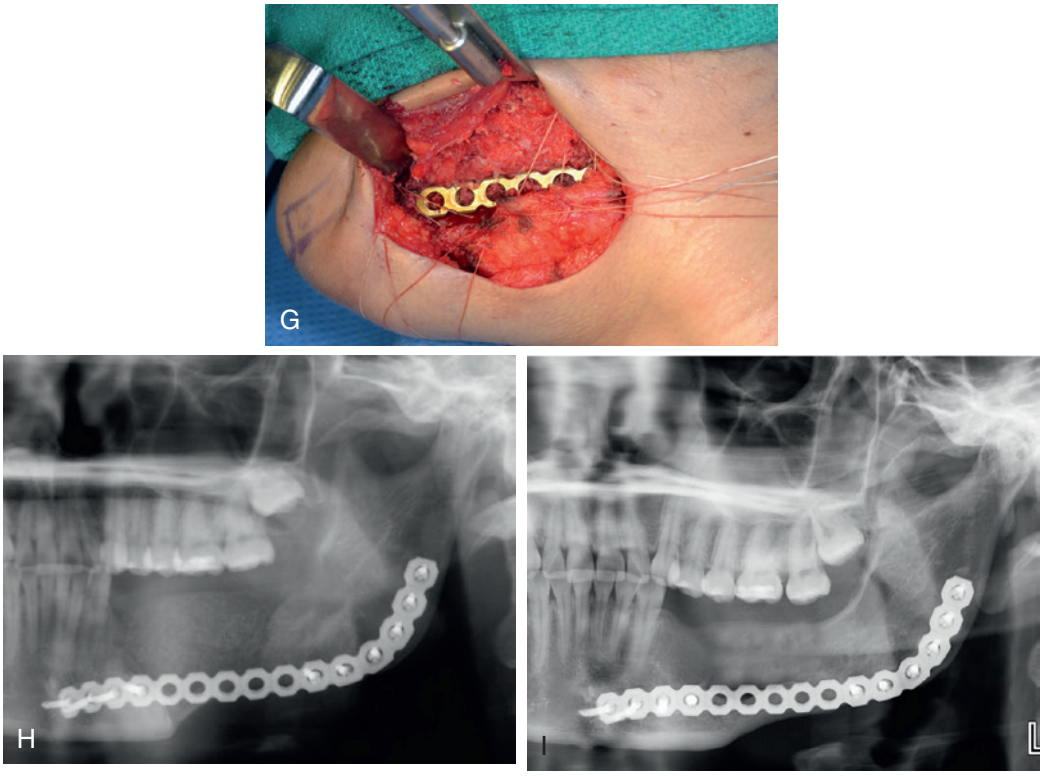
Soft Tissue Defect

Proper preparation of the soft tissue bed that is to receive the bone graft is just as important to the success of bone grafting as the bone graft material itself. The transplanted bone cells must survive initially by diffusion of nutrients from the surrounding soft tissues. Revascularization of the bone graft through the development of new blood vessels from the soft tissue bed must then occur. Thus an essential factor for the success of any bone-grafting procedure is the availability of an adequately vascularized soft tissue bed. Fortunately, this essential factor is usually obtainable in the lush vascular tissue of the head and neck region. However, occasionally the soft tissue bed is not as desirable as it could be, for example, after radiotherapy or excessive scarring from trauma or infection. Therefore a thorough assessment of the quantity and quality of surrounding soft tissue is necessary before undertaking bone graft procedures.

The reason for the osseous void often provides important information on the amount and quality of the remaining soft tissue. For example, if the patient lost a large portion of the mandible



• **Fig. 29.4** (A) Panoramic radiograph showing bone defect in the left mandible created when a benign tumor was removed. (B) Exposure of the defect through an incision in the left submandibular area. (C) Aspiration of bone marrow cells from the ilium through a trochar. This required a 5-mm incision in the skin. (D) Bone marrow aspiration concentrate after centrifugation to concentrate the bone cells. (E) Particulate allogeneic bone. (F) Adding pieces of collagen sponge soaked in bone morphogenetic protein to the combined allogeneic bone and bone marrow concentrate (red mass).



• **Fig. 29.4, cont'd** (G) The combined material (allogeneic bone chips, bone morphogenetic protein, bone marrow aspirate concentrate) packed into the defect. (H) Immediate postoperative panoramic radiograph. (I) Panoramic radiograph taken 2 years later. Note the bone fill.

from a composite resection for a malignancy, the chances are that the patient will have deficiencies in the quantity and quality of soft tissue. During the initial surgery, many vital structures were probably removed, and denervation of the platysma muscle results in atrophy of the muscular fibers. An intraoral examination helps the clinician determine how much oral mucosa was removed with the mandibular fragment.

Frequently, the tongue or the floor of the mouth appears to be sutured to the buccal mucosa, with no intervening alveolar ridge or buccal sulcus, because the gingiva is sacrificed with the osseous specimen.

If the patient received cancericidal doses of radiation to the area of the osseous defect, the clinician can assume that the patient's soft tissues have undergone extreme atrophy and scarring and will be nonpliable and fragile. In this instance, soft tissues will provide a poor bed for a bone graft because the environment is hypovascular, hypoxic, and hypocellular.[1] Similarly, if the patient's defect was caused by a severe infection, it is likely that an excess of scar tissue formation occurred, which will result in nonpliable, poorly vascularized tissue.

After a thorough evaluation, a decision must be made about the adequacy of soft tissues. If the quantity of tissue is deficient, soft tissue flaps from the neck containing muscle and skin can be used to enhance the amount of tissue available to close over the bone graft. If soft tissues are deficient in quality, one of two basic methods can be used to reconstruct a patient's defects. The first is to supply an autogenous bone graft with its own blood supply in the form of a free or pedicled composite graft. The second method is to improve the quality of the soft tissues already present by the use of hyperbaric oxygen (HBO). The HBO method improves tissue oxygenation by the administration of oxygen to the patient under higher-than-normal atmospheric pressures. Tissue oxygenation has been shown to improve to acceptable levels after 20 HBO treatments.[8]

After HBO treatment, bone-grafting procedures can be performed with success. Another course of HBO treatment is then recommended after the bone-grafting procedure.[8]

Associated Problems

The clinician must always remember that the cure should be less offensive to the patient than the disease process. In other words, if a reconstructive procedure will significantly risk the individual's life or is associated with a very high incidence of complications that may make life worse for the patient, it would probably be in the patient's best interests to avoid the procedure. As with any type of therapy, significant factors such as the patient's age, health, psychological state, and, most important perhaps, the patient's desires must be assessed. Thorough understanding by the patient of the risks and benefits of any treatment recommendation is imperative so that the patient can make an informed decision.

Goals and Principles of Mandibular Reconstruction

Marx and Sanders have identified several major goals for mandibular reconstruction that one should strive for and achieve before considering any grafting procedure a success.[1]

Restoration of Continuity

Because the mandible is a bone with two articulating ends acted on by muscles with opposing forces, restoration of continuity is the highest priority when reconstructing mandibular defects. Achieving this goal provides the patient with better functional movements and improved facial aesthetics by realigning any deviated mandibular segments.

Restoration of Alveolar Bone Height

The functional rehabilitation of the patient rests on the ability to masticate efficiently and comfortably. Prosthetic dental appliances are frequently necessary in patients who have lost a portion of their mandible. To facilitate prosthetic appliance usage, an adequate alveolar process must be provided during the reconstructive surgery. The ideal ridge form outlined in Chapter 13 for the edentulous patient applies equally to patients undergoing mandibular reconstructive surgery.

Restoration of Osseous Bulk

Any bone-grafting procedure must provide enough osseous tissue to withstand normal function. If too thin an osseous strut is provided, fracture of the grafted area may occur.

Surgical Principles of Maxillofacial Bone-Grafting Procedures

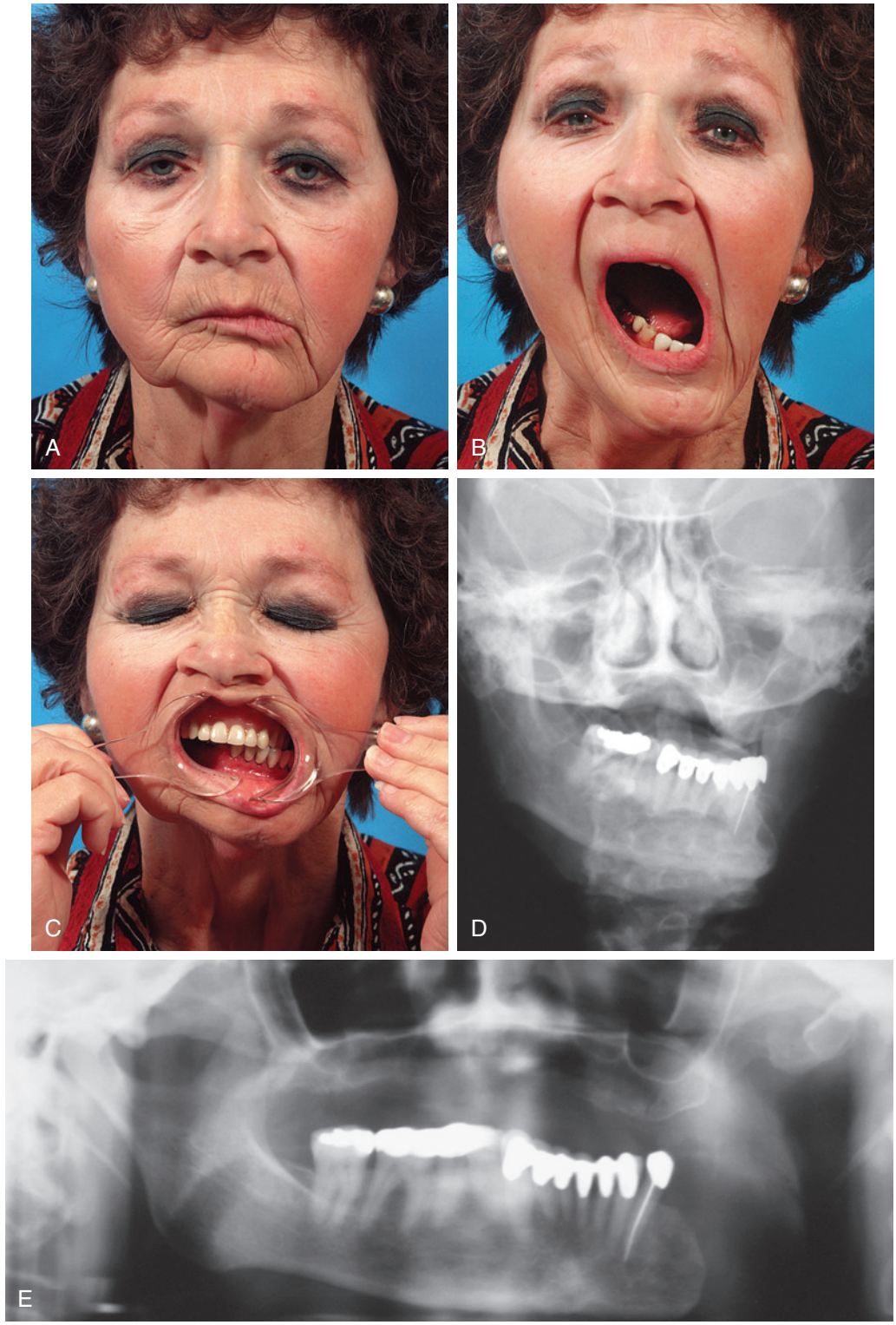
Several important principles should be followed during any grafting procedure. They must be strictly adhered to if a successful outcome is desired. The following are a few that pertain to reconstructing mandibular defects:

1. *Control of residual mandibular segments.* When a continuity defect is present, the muscles of mastication attached to the residual mandibular fragments will distract the fragments in different directions unless efforts are made to stabilize the remaining mandible in its normal position at the time of partial resection. Maintaining relationships of the remaining mandible fragments after resection of portions of the mandible is a key principle of mandibular reconstruction. This is important for occlusal and temporomandibular joint positioning. When the residual fragments are left to drift, significant facial distortions can occur from deviation of the residual mandibular fragments (Fig. 29.5). Metal bone plates inserted at the time of resection are useful for controlling the position of the mandibular fragments (Fig. 29.6; see also Fig. 29.1). These plates are of sufficient strength to obviate the need for intermaxillary fixation, permitting active use of the mandible in the immediate postoperative period. In older individuals or those with significant medical compromise, this may be the final form of reconstruction. Use of bone plates provides soft tissue support to maintain facial symmetry. When the mandibular symphysis has been removed, the tongue can be sutured to the plate, maintaining its forward position to prevent airway obstruction (see Fig. 29.1E). The bone plate can be left in place when the mandible is secondarily reconstructed with bone grafts, permitting mobility of the mandible during the healing phase of the bone graft (see Figs. 29.1 and 29.6).

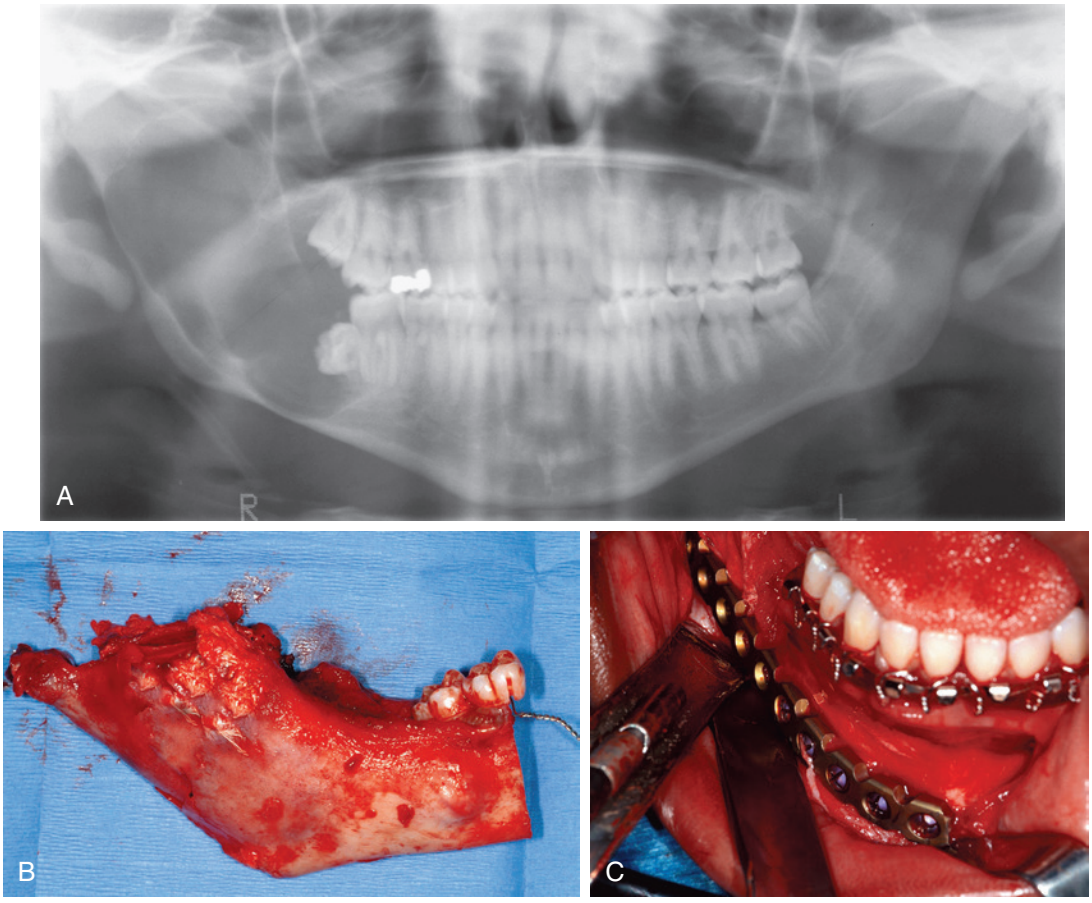
   When the positions of the residual mandibular fragments have not been maintained during the resection, realignment is more difficult during the reconstructive surgery. Over time, the muscles of mastication become atrophic, fibrotic, and nonpliable, which makes realignment of the fragments extremely difficult. During reconstructive surgery, it may be necessary to strip several muscles off the mandibular fragments to release the bone from their adverse pull. A coronoidectomy is usually performed to remove the superior pull of the temporalis muscle. Before inserting a bone graft, the clinician must be sure to reach the desired position of the remaining mandibular fragments because what is achieved at surgery is what the patient must live with in the future.

   If the mandibular condyle has been resected or is unusable, reconstruction of the condyle with a costochondral junction of a rib or alloplastic condyle is necessary to maintain the forward position of the reconstructed mandible (see Fig. 29.6).
2. *A good soft tissue bed for the bone graft.* All bone grafts must be covered on all sides by soft tissue to avoid contamination of the bone graft and to provide the vascularity necessary for revascularization of the graft. Areas of dense scar should be excised until healthy tissue is encountered. Incisions should be designed so that when the wound is closed, the incision will not be over the graft, which means that the initial incision may be very low in the neck. A multilayered soft tissue closure is performed to reduce any space that might allow collection of blood or serum and to provide a watertight closure.
3. *Immobilization of the graft.* Immobilization of bone is necessary for osseous healing to progress, which is why orthopedic surgeons apply a cast to a fractured extremity. In dealing with mandibular defects, the graft must be secured to remaining mandibular fragments, and these fragments must be rigidly immobilized to ensure that no movement exists between them. This immobilization is most often provided by the use of intermaxillary fixation, in which the mandible is secured to the maxilla. However, several other methods are possible, such as using a bone plate between the residual bone fragments. Immobilization for 8 to 12 weeks is usually necessary for adequate healing between the graft and the residual mandibular fragments.
4. *Aseptic environment.* Even when transplanting autogenous osseous tissue, the bone graft is basically avascular, which means that the graft has no way of fighting any amount of infection. Therefore a certain percentage of bone grafts become infected and must be removed. Several measures can be taken to improve the success of bone-grafting procedures. The first is to use an extraoral incision where possible. The skin is much easier to cleanse and disinfect than is the oral cavity. Bone grafts inserted through the mouth are exposed to the oral flora during the grafting procedure.

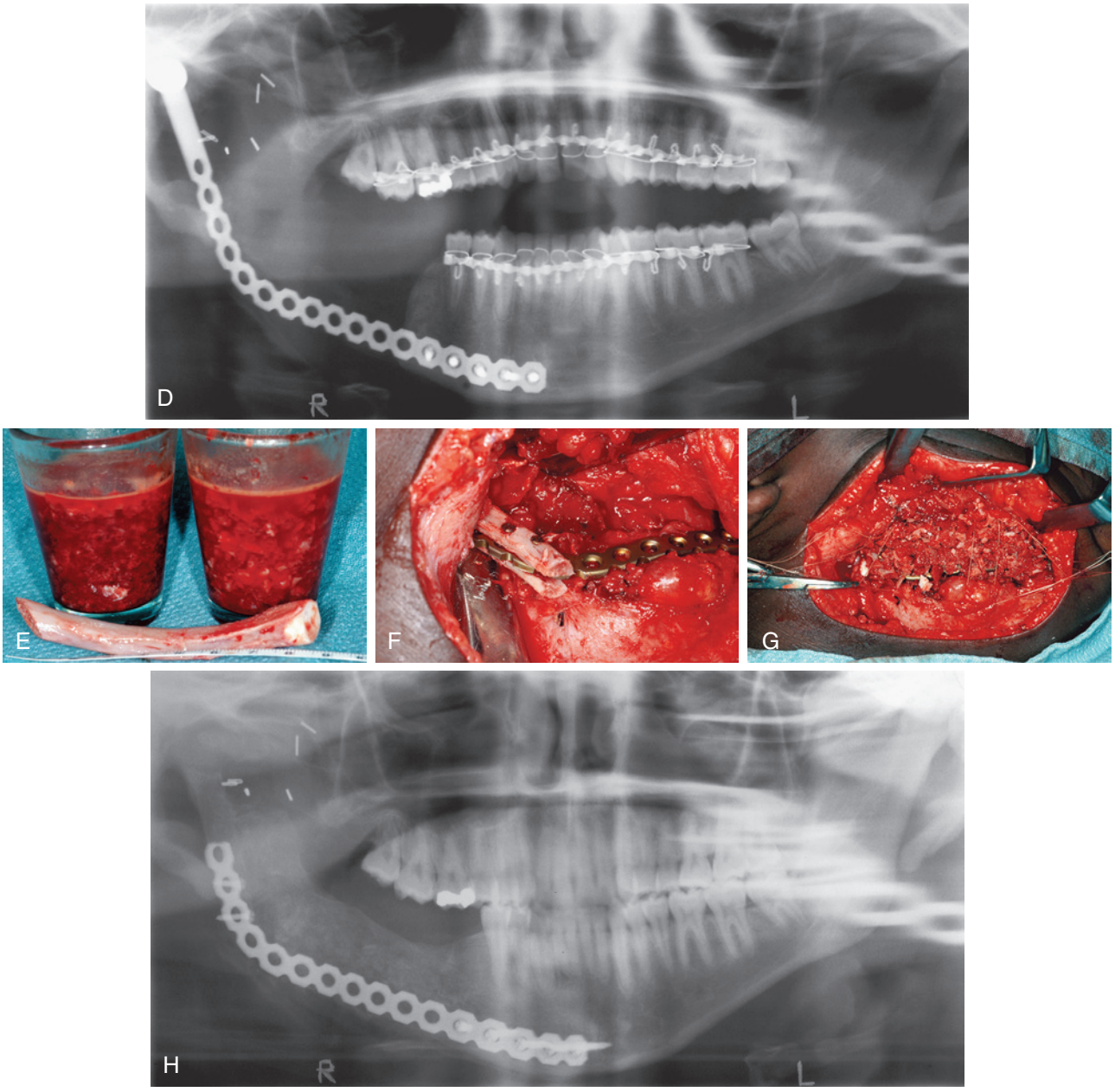
   Furthermore, the intraoral incision may dehisce and again expose the bone graft to the oral flora. Bone grafts placed through a skin incision are more successful than those inserted transorally. However, it is important that during the extraoral dissection the oral cavity is not inadvertently entered. Ideally, dissection to the level of the oral mucosa without perforation is preferred.
5. *Systemic antibiosis.* The prophylactic use of antibiotics may be indicated when transplanting osseous tissue. Prophylaxis may be beneficial in helping reduce the incidence of infection (see Chapter 16).



• **Fig. 29.5** (A) Patient whose left mandibular ramus and posterior body were removed 10 years previously because of malignant disease. The deviation of the chin to the left side is visualized. (B) Deviation to the left side when opening the mouth. (C) The mandibular deviation also causes a severe malocclusion. (D) Posteroanterior cephalogram showing deviation of the mandible to the left. (E) Panoramic radiograph showing residual mandible.



• **Fig. 29.6** Use of a reconstruction bone plate to temporarily maintain the position of the mandible before bony reconstruction. (A) Panoramic radiograph showing radiolucent lesion of the mandible that proved to be an ameloblastoma. (B) Resection specimen. (C) Because the condylar process had to be excised, a reconstruction bone plate with a condylar prosthesis attached to the end has been secured to the mandibular body and symphysis.

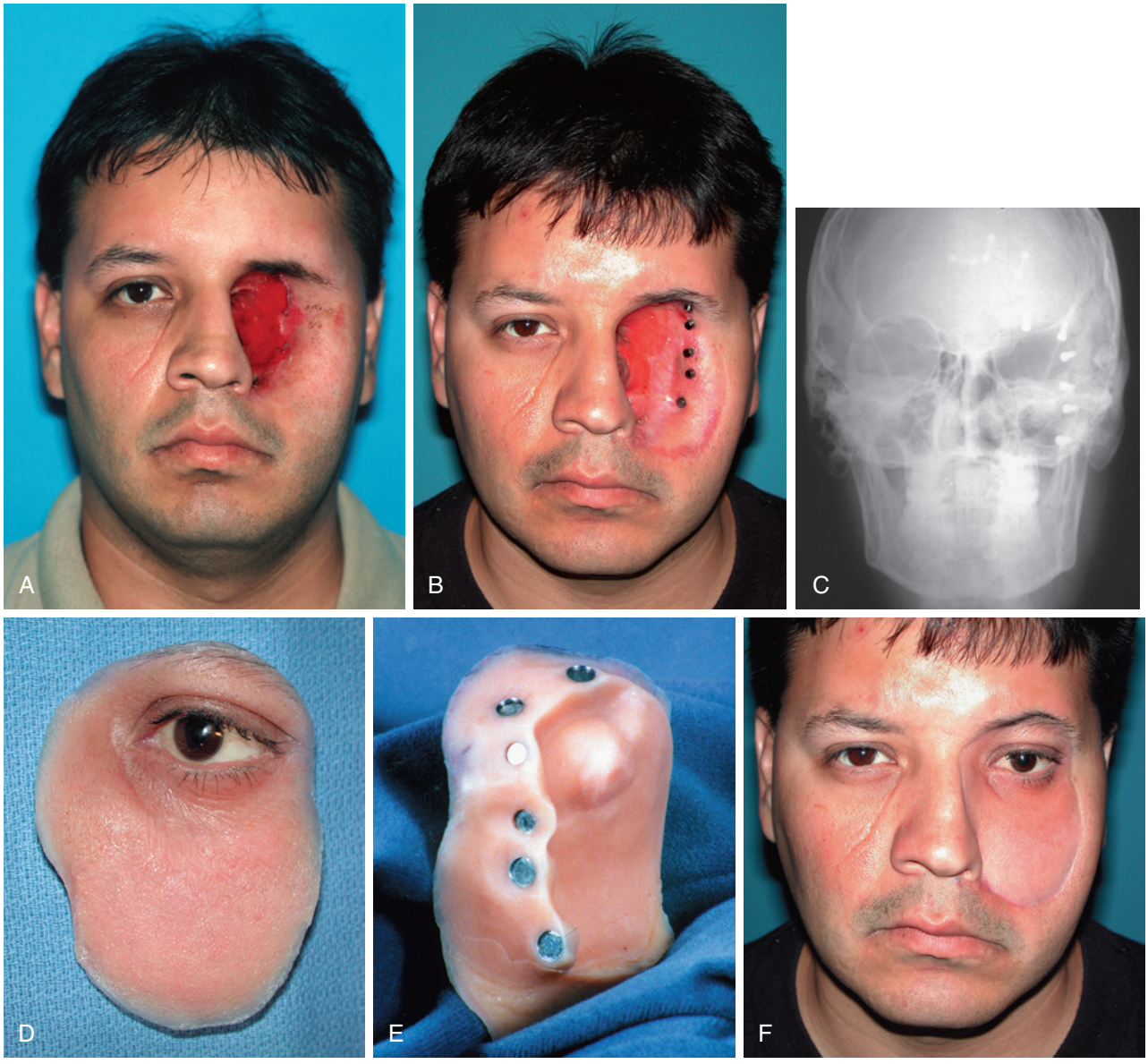


• **Fig. 29.6 cont'd** (D) Postoperative panoramic radiograph showing bone plate in place. After allowing 6 to 8 weeks for healing of the oral soft tissues, mandibular reconstruction was undertaken. (E) A rib with some of the costal cartilage attached to one end and particulate bone from the ilium were obtained. (F) The condylar prosthesis was removed from the end of the bone plate, and the body of the rib was grooved and placed into the glenoid fossa, surrounding the bone plate. (G) The mandibular ramus and posterior body were reconstructed by packing particulate bone into the defect. (H) Panoramic radiograph taken 6 months later shows good consolidation of the graft.

Because of the many muscles attaching to and providing mobility to the mandible, it is the facial bone that is the most difficult to reconstruct. Other facial bones are reconstructed on similar principles.

Prosthetic Reconstruction of the Midface

When the patient has lost a portion of the maxilla, the maxillary sinuses or nasal cavity may be continuous with the oral cavity, which presents great difficulties for the patient in speaking and eating. Defects of the maxilla can be managed by surgery or bone grafts. Defects that are not excessive may be closed with available soft tissues of the buccal mucosa and palate; bone grafts may also be used to provide the patient with a functional alveolar process. Very large defects or defects in patients who are poor surgical risks may require prosthetic obliteration in which a partial or complete denture extends into the maxillary sinus or the nasal cavities and effectively partitions the mouth from these structures (Fig. 29.7).



• **Fig. 29.7** Maxillofacial prosthetic reconstruction of patient who had the left eye and palate removed because of tumor. (A) Defect in the palate and loss of the eye. (B–C) Denture with obturator. (D) Prosthetic eye. (E) Prosthetic denture. (F) Patient with prosthetic eye and denture in place.

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PART VIII

Temporomandibular and Other Facial Pain Disorders

The dentist is commonly considered the health care provider with the most expertise in facial neuropathic and musculoskeletal problems, whether facial pain or altered nerve function, as well as disorders of the temporomandibular joint (TMJ) and surrounding musculature. Dentists receive extensive professional education in facial and TMJ anatomy, physiology, and pathology. Painful disorders of the maxillofacial region, whether neurologic or musculoskeletal, are common reasons for obtaining a dental opinion. Therefore it is critical for dentists to become knowledgeable about facial neuropathologic conditions and TMJ disorders.

Chapter 30 presents an overview of facial neuropathologic conditions. The neurophysiology of pain, differential diagnosis of facial pain disorders, and methods of managing various neurogenic facial pain problems are discussed. The evaluation and management of altered sensory nerve function are also considered.

TMJ physiology and pathology is a broad topic, and entire books exist on this topic. Chapter 31 is a concise, up-to-date discussion of the ever-changing field of TMJ disorders from the viewpoint of oral-maxillofacial surgeons. The chapter is designed to provide the reader with knowledge of the evaluation and management of patients with functional disorders of the TMJ, including internal derangements, ankylosis, and arthritides.

30

Facial Neuropathology

JAMES R. HUPP

CHAPTER OUTLINE

The dentist is frequently called upon to determine the etiology of pain in the oral-maxillofacial region. Although oral pain is most frequently of odontogenic origin, many facial pains arise from other sources. The diversity of structures in the head and neck region (e.g., eyes, ears, salivary glands, muscle, joints, sinus membranes, intracranial blood vessels) can make arriving at an accurate diagnosis challenging. Even typical toothache symptoms may occur in a healthy tooth because of referred pain or a damaged pain transmission system.

Basics of Pain Neurophysiology

Pain is a complex human psychophysiologic experience. This unpleasant experience is influenced by such factors as past pain experiences, cultural behaviors, and emotional and medical states. As the term implies, the pain experience has physiologic and psychological aspects. The physiologic aspects involve several processes: transduction, transmission, and modulation. The sum of these processes, when integrated with higher thought and emotional centers, yields the human experience of pain. *Transduction* refers to the activation of specialized nerves, namely, A-delta (Aδ) and C-fibers, that transmit information to the spinal cord or, in the case of the trigeminal nerve, to the trigeminal nucleus. Table 30.1 lists peripheral nerve fibers and their individual characteristics.

Chemical, thermal, and mechanical stimuli can activate the free nerve endings of nociceptors, the peripheral nerves indicated previously that transmit pain information. Once in the central nervous system (CNS), information regarding pain is transmitted to the thalamus and hence to cortical centers that process the sensory—discriminative and the emotional—affective aspects of the experience. Modulation systems are activated with pain transmission to varying degrees. The pain modulation system limits the rostral flow of pain information from the spinal cord and trigeminal nucleus to higher cortical centers. A schematic representation of these pain pathways is shown in Fig. 30.1. The chemical and receptor milieu in which transmission and modulation activity occurs is complex. The primary neurochemicals for transmission pathways involve glutamate and substance P, although dozens of neurochemicals have been implicated in pain transmission. The brainstem and spinal cord are the predominant structures involved in modulation. The related primary chemicals include the endogenous opioids, along with serotonin and norepinephrine. Alterations in receptor function are now thought to be critical to the generation of many chronic painful states.

Although the pain sensory system appears hardwired, the psychological influences on pain perception should not be underestimated. For the dentist, this influence is a daily part of clinical practice. All dentists are well aware of the extensive variability of the pain response that different patients display to similar procedures. For instance, for some patients, the sound of the dental drill evokes true pain perception despite the fact that the burr has not yet touched the tooth. Psychological influences are particularly important in determining perceived pain intensity and patient response to pain. When pain becomes chronic, generally defined as greater than 4 to 6 months in duration, attention to psychological influences can become particularly important when trying to manage the pain experience.

Classification of Orofacial Pains

Numerous classification systems exist for orofacial pain conditions. At the most basic level, it is appropriate to classify orofacial pains as primarily somatic, neuropathic, or psychological.

Somatic pain arises from musculoskeletal or visceral structures interpreted through an intact pain transmission and modulation system. Common orofacial examples of musculoskeletal pains are temporomandibular joint (TMJ) disorders or periodontal pain. Examples of visceral orofacial pains include salivary gland pain and pain caused by dental pulpitis, the tooth pulp behaving like

a visceral structure. Neuropathic pain arises from damage or alteration to the pain pathways, most commonly a peripheral nerve injury due to surgery or trauma. Other causes may involve CNS injury, as in thalamic stroke.

Orofacial pains of true psychological origin are so rare as not to be included in the differential diagnosis of orofacial pain for the general practitioner. Although psychological influences frequently modify the patient's perception of pain intensity and the patient's response to pain, an actual pain symptom generated by psychiatric disturbance (e.g., conversion disorder or psychotic delusion) is exceedingly rare. *Malingering*, a term used to identify behavior in which a patient consciously feigns illness or the extent of illness for personal gain, can and does occur, although the literature suggests that the incidence is low. However, a dental patient complaining of chronic pain should be presumed to have a real pain problem unless definitively proven otherwise.

The term *atypical facial pain* is still seen in the literature and is used as a diagnosis primarily by physicians and some dentists; therefore a medical diagnosis code (i.e., International Classification of Diseases, 10th revision, code G50.1) is associated with it. When reviewing the literature regarding atypical facial pain, a psychological cause is frequently implied. Because true psychogenic pain is rare, this term should be abandoned. For those undiagnosed facial pains, the appropriate term should be *facial pain of unknown cause* until a definitive diagnosis has been established. As a practical matter, these patients, unfortunately, continue to be labeled with the diagnosis of atypical facial pain for coding purposes, but the dentist should be aware that this is a "diagnosis" awaiting further clarification.

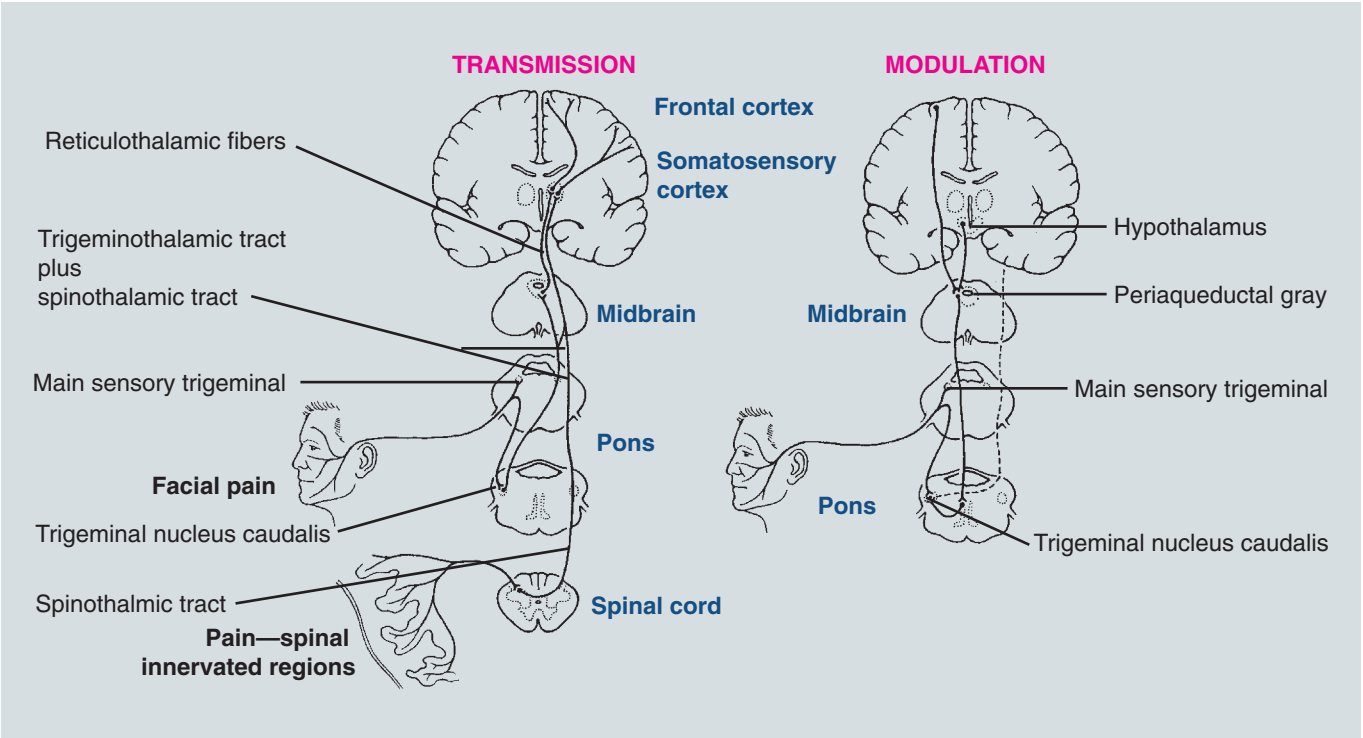
This chapter covers neuropathic facial pains and common headache disorders. TMJ disorders are discussed in Chapter 31. A glossary of pain terminology is provided in Box 30.1.

TABLE 30.1 Relationship Between Sensory Nerve Fiber Size (Diameter) and Conduction Velocity

Fiber Type	Diameter (μm)	Velocity (m/s)
Aα	13–22	70–120
Aβ	8–13	40–70
Aγ	4–8	15–40
Aδ	1–4	5–15
B	1–3	3–14
C	0.5–1.0	0.5–2.0

Neuropathic Facial Pains

Neuropathic pains arise from an injured pain transmission or modulation system. Surgical intervention or trauma is frequently the cause. For example, trauma to the infraorbital region may lead to numbness or pain in the distribution of the infraorbital nerve. In dental surgery, extraction of impacted mandibular third molars carries a measurable risk of nerve damage to the mandibular and lingual nerves. In the majority of these cases, damage leads to paresthesia, an abnormal sensation in the dermatome of the affected nerve. Typically this sensation is one of mild numbness or tingling. Loss of all sensation may occur when the nerve is transected. In a subset of cases, dysesthesia—an abnormal, unpleasant sensation—can result; it is often described as a burning or sharp electric shocklike sensation. When a patient complains of burning or sharp shocklike pain in the face or mouth, pain of neuropathic origin should be included in the differential diagnosis. One should appreciate that the oral cavity is the most common site of amputation, if one recognizes amputations to include the teeth and the dental pulp (i.e., endodontics). As in phantom limb pain after extremity



• **Fig. 30.1** Trigeminal and spinal pain transmission pathways *(left)* and trigeminal pain modulation system *(right)*. The dotted line indicates decreased pain transmission.

• BOX 30.1 Glossary of Pain Terms

Allodynia: Pain caused by a stimulus that does not normally provoke pain
Analgesia: Absence of pain in response to stimulation that would normally be painful
Anesthesia: Absence of all sensation
Deafferentation pain: Pain caused by loss of sensory input into the central nervous system
Dysesthesia: Unpleasant abnormal sensation, whether spontaneous or evoked (*Note:* Dysesthesia includes paresthesia, but not vice versa.)
Hyperalgesia: Increased sensitivity to noxious stimulation
Hyperesthesia: Increased sensitivity to all stimulation, excluding special senses (*Note:* When the sensation is painful, the terms *allodynia* and *hyperalgesia* may be appropriate.)
Hypoalgesia: Diminished sensitivity to noxious stimulation
Hypoesthesia: Diminished sensitivity to all stimulation, excluding the special senses (*Note:* When the sensation is pain, the terms *hypoalgesia* and *analgesia* may be appropriate.)
Neuralgia: Pain in the distribution of a nerve or nerves
Neuropathy: Disturbance of function or pathologic change in a nerve
Paresthesia: Abnormal sensation, whether spontaneous or evoked

From International Headache Society, 2003.

• BOX 30.2 Trigeminal Neuralgia: Clinical Characteristics

- Severe paroxysmal pain
- Unilateral location (96%); right > left
- Mild superficial stimulation provokes pain
- V_2 and V_3 dermatomes most commonly affected
- Frequently pain free between attacks
- No neurologic deficits
- No dentoalveolar cause found
- Local anesthesia of trigger zone temporarily arrests pain

From International Headache Society, 2003.

amputation, "phantom" sensations can also arise, albeit rarely, after pulpal trauma or extraction. Neuropathic pains may also give rise to the sensation of tooth pain, which is often a diagnostic dilemma for dentists. Referral of patients for management of these disorders to dentists focusing on orofacial pain diagnosis and management or to the patient's personal physician or a neurologist is customary.

Trigeminal Neuralgia

The prototypic neuropathic facial pain is trigeminal neuralgia (TN; Box 30.2)—literally nerve pain arising from the trigeminal nerve. Although this could refer to any neuropathic pain of trigeminal nerve origin, TN or tic douloureux (i.e., painful tic) has specific inclusion criteria. Occurring most frequently in patients older than 50 years (incidence 8:100,000; female-to-male ratio 1.6:1), TN usually occurs with sharp, electric shocklike pain in the face or mouth. The pain is intense, lasting for brief periods of seconds to 1 minute, followed by a refractory period during which the pain cannot be reinitiated. At times, a background aching or burning pain is present. Usually a trigger zone is present, where mechanical stimuli such as soft touch may provoke an attack. Firm pressure to the region is generally not as provocative. Common cutaneous trigger zones include the corner of the lips, cheek, ala of the nose, or lateral brow. Any intraoral site may also be a trigger zone for TN, including teeth, gingiva, or the tongue. Trigger zones in the V_2 and V_3 distributions are most common, after which they occur alone (and in decreasing order of incidence) in the V_3, V_2, and V_1 distributions. The pain of TN illustrates an important distinction of many neuropathic pains as opposed to somatic pains—the lack of a typical graded response to increasing stimulation. If light touch stimulation produces a pain response out of proportion to the stimulus, a neuropathic process should be considered. This also holds true for pain that has a burning or electric shocklike quality. Sometimes a background aching pain accompanies TN, making it difficult to distinguish from the pain of acute pulpitis or, possibly, periapical periodontitis. Importantly, local anesthetic block of the trigger zone arrests the pain of TN for the duration of anesthesia and sometimes longer, which can lead the dentist to mistakenly ascribe a "dental" cause to the pain complaint.

The cause of TN is not entirely clear, but the consensus is that pressure on the root entry zone of the trigeminal nerve by a vascular loop leads to focal demyelination. This demyelination, in turn, precipitates ectopic or hyperactive discharge of the nerve. The site of demyelination determines the trigeminal division involved and hence the clinical presentation. Other diseases such as multiple sclerosis, tumors, and Lyme disease can produce pain similar to that produced by TN. The treatment of TN is medical or surgical. Medical treatment is generally undertaken with anticonvulsants.

The classic medication for the condition is carbamazepine, but newer anticonvulsants (e.g., gabapentin and oxcarbazepine) and the antispastic baclofen are commonly used as well. Table 30.2 lists commonly used TN and neuropathic facial pain medications. Many of these medications have significant, even life-threatening, side effects; therefore only dentists focusing on orofacial pain diagnosis and management use them in dental practice. Surgical treatment includes microvascular decompression of the offending vascular loop (so-called *Janetta procedure*), Gamma Knife radiosurgery, percutaneous needle thermal rhizotomy, or balloon compression of the root entry zone. For the dentist, the critical issue is recognizing TN so that unneeded dental treatment or extractions are avoided. Unfortunately, when the trigger zone is located in an intraoral, dental, or periodontal site, unnecessary dental treatment is common.

Pretrigeminal Neuralgia

Although a rare condition, pretrigeminal neuralgia (pre-TN) may occur. The presenting condition is typically an aching dental pain in a region where clinical and radiographic examinations reveal no abnormality. Local anesthetic block of the tooth (or extraction site, if applicable) arrests pain for the duration of anesthetic's action. A number of patients with this condition have been demonstrated to go on to have typical TN symptoms (i.e., sharp electric shock pains in the area). Pre-TN responds to similar treatments as TN, beginning with anticonvulsant therapy. To avoid unnecessary dental treatment, the dentist must have a high index of suspicion for secondary diagnoses for those pains that are inconsistent with physical examination or do not respond in a predictable way after treatment. Clinical features of pre-TN are listed in Box 30.3.

Odontalgia Resulting From Deafferentation (Atypical Odontalgia)

Pain resulting from deafferentation refers to pain that occurs when damage to the afferent pain transmission system has occurred. Usually this condition is caused by trauma or surgery, including extraction and endodontic treatment. By definition, extraction

• BOX 30.3 Pretrigeminal Neuralgia: Clinical Characteristics

- Aching or burning pain
- Continuous or intermittent
- Unilateral location
- Local anesthesia of painful region temporarily arrests pain
- Neurologic examination normal
- No dentoalveolar cause found
- Frequently responsive to anticonvulsant therapy

From International Headache Society, 2003.

• BOX 30.4 Odontalgia Resulting From Deafferentation

- Burning or aching pain is continuous or almost continuous.
- Sharp paroxysms may occur.
- Allodynia, hyperesthesia, or hypoesthesia may be present.
- No dentoalveolar cause is found.
- History of surgical or other trauma exists.
- History of symptoms greater than 4–6 months exists.
- Local anesthetic block is equivocal.

From International Headache Society, 2003.

TABLE 30.2 Common Medications for Trigeminal Neuralgia and Neuropathic Facial Pains

Medications	Dosage (mg/day)
Anticonvulsants	
Carbamazepine (Tegretol)	400–1200
Gabapentin (Neurontin)	600–3200
Clonazepam (Klonopin)	2–8
Divalproex (Depakote)	500–2000
Oxcarbazepine (Trileptal)	300–2400
Lamotrigine (Lamictal)	50–500
Topiramate (Topamax)	50–400
Phenytoin (Dilantin)	300–600
Tricyclic Antidepressants	
Amitriptyline	10–300
Doxepin	10–300
Nortriptyline	10–150
Imipramine	10–300
Antispastic	
Baclofen (Lioresal)	15–80

and endodontics are deafferentating because they involve amputation of tissue that contains the nerve supply of a human structure—the tooth. Limb amputation is another example of a deafferentation procedure. As with phantom limb pain, a similar picture of oral deafferentation pain may occur, but only in a small subset of patients are the symptoms severe enough to warrant treatment. These pains may be maintained by various mechanisms—some readily appreciated and others not yet completely understood. Peripheral hyperactivity at the site of nerve damage is easily understandable. At the site of dental alveolar nerve damage, neuronal hyperactivity leading to persistent pain occurs. In this form, the pain is frequently arrested with local anesthetic block. CNS hyperactivity, however, also can be responsible for persistent pain experienced in the tooth site. In this model, peripheral neural damage leads to changes in the second-order nerve in the trigeminal nucleus that synapsed with the primary peripheral nociceptor. Changes occur centrally, in which ongoing pain transmission to higher cortical centers can occur despite minimal or even no peripheral input. Local anesthetic block does not arrest pain in this circumstance.

In addition, patients may exhibit both forms of compromise simultaneously (i.e., only a portion of pain may be arrested by local anesthetic block). Sympathetic nervous system activity has also been shown to augment some of these complex neuropathic processes. Clinical features of deafferentation pains are listed in Box 30.4. Interestingly, for many deafferentation pains, further peripheral surgical procedures frequently intensify symptoms and lead to a broader area of perceived pain. If pain resulting from deafferentation is suspected, further surgical procedures should be undertaken cautiously or not at all.

The key to recognizing all of these conditions and avoiding unnecessary and potentially harmful dental treatment frequently lies in obtaining an excellent description of the chief complaint, including quality of pain, duration, alleviating factors, and aggravating factors. The history of the complaint and how the symptoms have changed over time can also be valuable. A more complete discussion follows in the section, "Evaluation of Patient With Orofacial Pain" below.

Postherpetic Neuralgia

Postherpetic neuralgia (PHN), a potential sequela of *shingles* also known as *herpes zoster* (HZ), is the clinical manifestation of the reactivation of a lifelong latent infection with varicella zoster virus, usually contracted after an episode of chickenpox in early life. HZ occurs more commonly in later life and in immunocompromised patients. Each year in the United States, shingles strikes at least 1 million persons. Most cases occur in patients older than 60 years. By age 85 years, 25% of persons will have had a bout. Of those who do, 60% to 70% will have PHN. The varicella zoster virus tends to be reactivated only once in a person's lifetime, with the incidence of second attacks being less than 5%. PHN occurs after reactivation of the virus, which can lay dormant in the ganglia of a peripheral nerve. Most commonly this is a thoracic nerve, but approximately 10% to 15% of the time the trigeminal nerve is involved, with the V_1 dermatome affected in approximately 80% of trigeminal cases. When reactivated, the virus travels along the nerve and is expressed in the cutaneous dermatome of that nerve. For a thoracic nerve, for example, the patient has a unilateral patch of vesicular eruption closely outlining the classical dermatome for that nerve. In the ophthalmic division of the trigeminal nerve, the V_1 dermatome is outlined by rash. In the V_2 or V_3 distribution, intraoral and cutaneous expression is commonly seen. HZ can also affect other cranial nerves (CNs), including CN II and VIII, causing HZ ophthalmicus and oticus, respectively. The pain related to HZ commonly appears before any rash is visible. The acute phase is painful, but subsides, along with the rash, within 2 to 5 weeks. However, a subset of patients

develops a deafferentation pain that, as discussed previously, can have peripheral, central, or mixed features. The pain is typically burning, aching, or shocklike (consistent with a pain caused by a neuropathic condition). Treatment is undertaken with anticonvulsants or tricyclic or other antidepressants. Tramadol, a mild opioid with mild antidepressant effects, can be a useful adjunct. Local injections of painful sites, sympathetic block, or both are sometimes of value. Most importantly, preventive treatment of PHN with antivirals, analgesics, and frequently corticosteroids very early after rash presentation can significantly reduce the expression of PHN.

A related condition, *Ramsay Hunt syndrome*, is an HZ infection of the sensory and motor branches of the facial nerve (CN VII) and in some cases the auditory nerve (CN VIII). Symptoms include facial paralysis, vertigo, deafness, and herpetic eruption in the external auditory meatus. The tongue can also be involved via the chorda tympani.

Neuroma

After peripheral nerve transection, the proximal portion of the nerve generally forms sprouts in an effort to regain communication with the severed distal component. When sprouting occurs without distal segment communication, a stump of neuronal tissue, Schwann cells, and other neural elements can form. This stump, or neuroma, can become exquisitely sensitive to mechanical and chemical stimuli.

The pain is commonly burning or shocklike. Frequently a positive Tinel sign is present. In this test, tapping over the suspected neuroma produces sharp, shooting, electric shocklike pain. Damage to the mandibular or lingual nerve after third molar surgery is a source for neuroma formation that a dentist might see.

Some oral-maxillofacial surgeons provide microneurosurgical treatment of suspected neuromas, which is beneficial for some patients. When a patient develops a painful neuroma of the inferior alveolar or lingual nerve or a neuroma is discovered during management of a patient with a nerve injury, the surgeon typically resects the neuroma and then reattaches the distal portion of the nerve back to the proximal end. Although it is difficult to predict which patients will benefit from nerve repair, evidence shows that neurosurgical intervention should be accomplished as early as possible and certainly prior to 6 months after injury to improve the likelihood of success.

Burning Mouth Syndrome

In this condition, the patient perceives a burning or aching sensation in all or part of the oral cavity. The tongue is the most frequently involved site. Perceived dry mouth and altered taste are common. The cause is unknown, but a defect in pain modulation may be the most promising theory. Most patients are postmenopausal women, although hormone replacement therapy does not consistently improve symptoms. Approximately 50% of patients improve without treatment over a 2-year period, indicating the importance of placebo-controlled trials when scientifically testing any treatment modality. The predominant treatment approach is with anticonvulsants or antidepressants, although neither medication, even in combination, shows consistent results.

Other Cranial Neuralgias

As with TN, any of the CNs with a sensory component appear capable of a neuralgic presentation. The most common of the other CNs to present this way is the glossopharyngeal nerve (IX) producing glossopharyngeal neuralgia. The presenting symptom in glossopharyngeal neuralgia is typically sharp, electric shocklike pain on swallowing with a trigger zone in the oropharynx or the base of the tongue. Pain is usually experienced in the throat or tongue, but may be referred to the lower jaw. The facial nerve (CN VII) has a small somatic component on the anterior wall of the external auditory meatus in which shocklike pains are experienced (sometimes associated with symptoms of tinnitus, dysgeusia, and dysequilibrium). The vagus nerve (CN X) also has the potential for neuralgic activity manifesting as pain in the laryngeal region shooting deep to the mandibular ramus or even to the region of the TMJ. Most often, treatment of cranial neuralgias such as TN involves the use of anticonvulsants; however, in some cases intracranial surgery is necessary.

Chronic Headache

Headache has many causes and is one of the most common complaints encountered by the primary care physician. When headaches recur regularly, the majority are diagnosed as one of the primary headaches: migraine, tension-type headache, or cluster headache. Although most headaches are centered in the orbits and temples, many may present in the lower half of the face, teeth, or jaws.

Migraine

Migraine is a common headache, afflicting approximately 18% of woman and 8% of men. The first migraine headache a person suffers typically occurs in the teenage years or in young adulthood, but may begin in very young children as well. Before puberty, migraine occurs equally in both sexes. After puberty, the ratio changes, and women are at least twice as likely as men to have migraines. Migraine headaches are unilateral in approximately 40% of cases. An aura may develop several minutes to 1 hour before headache onset in approximately 40% of patients. The aura is a neurologic disturbance, frequently expressed as flashing or shimmering lights or a partial loss of vision.

Complicated auras may produce transient hemiparesis, aphasia, or blindness. About 80% of those suffering from migraine headaches have nausea and photophobia (intolerance to light) during attacks. Migraines typically last 4 to 72 hours. The International Headache Society criteria for migraine are listed in Boxes 30.5 and 30.6. Headache triggers include menstruation, stress, certain vasoactive foods or drugs, and certain musculoskeletal disorders that produce pain in the trigeminal system (e.g., TMJ disorders). The mechanism for migraine headache, although not completely understood, appears to involve neurogenic inflammation of intracranial blood vessels resulting from neurotransmitter imbalance in certain brainstem centers. Migraine is a referred pain process, and the intracranial vessel involved determines the site of perceived pain (e.g., the orbit, temple, jaw, or vertex of the head). Preventive treatment is directed at normalizing neurotransmitter imbalance with antidepressants, anticonvulsants, β-blockers, cyproheptadine, botulinum toxin, and other drugs. Biofeedback and other therapies are also helpful. Treatment of acute attacks is with the "triptans" (e.g., sumatriptan [Imitrex], zolmitriptan [Zomig], rizatriptan [Maxalt], naratriptan [Amerge], and almotriptan [Axert], naratriptan [Amerge], frovatriptan [Frova], eletriptan [Relpax]), ergots, nonsteroidal antiinflammatory drugs, opioid analgesics, antiemetics, and other agents.

• BOX 30.5 International Headache Society Criteria for Migraine Headache Without Aura

A. At least five attacks fulfilling criteria B through D
B. Headache attacks lasting 4–72 h (untreated or unsuccessfully treated)
C. Headache has two or more of the following characteristics:
   1. Unilateral location
   2. Pulsating quality
   3. Moderate or severe pain intensity
   4. Aggravation by or causing avoidance of routine physical activity (e.g., walking, climbing stairs)
D. During headache ≥1 of the following:
   1. nausea and/or vomiting
   2. photophobia and phonophobia
E. Not attributed to another disorder

• BOX 30.6 International Headache Society Criteria for Migraine Headache With Aura

A. At least two attacks fulfilling criteria B through D
B. Aura consisting of ≥1 of the following, but no motor weakness:
   1. Fully reversible visual symptoms including positive and/or negative features
   2. Fully reversible sensory symptoms including positive and/or negative features
   3. Fully reversible dysphasic speech disturbance
C. At least two of the following:
   1. Homonymous visual symptoms and/or unilateral sensory symptoms
   2. At least one aura symptom develops gradually over ≥5 min and/or different aura symptoms occur in succession over ≥5 min
   3. Each symptom lasts ≥5 and ≤60 min
D. Headache fulfilling criteria B through D for 1.1 Migraine without aura begins during the aura or follows aura within 60 min
E. Not attributed to another disorder

For the dentist, knowledge of migraine is important because TMJ disorders may precipitate a migraine attack in a migraine-prone patient. Likewise, cervical spine and cervical muscular disorders may precipitate migraine. It is also important for the dentist to recognize that cervical and masticatory muscle hyperactivity often occurs during a migraine headache. Migraine may thus be a perpetuating factor in some TMJ disorders or a reason for misdiagnosis. Although toothache and jaw pains are not a common expression of migraine, a number of cases have been reported in the literature and are seen with some frequency by pain specialists. When migraine is a cause of jaw or face pain, the key to the diagnosis is recognizing that nausea, phonophobia, and photophobia are not accompaniments of masticatory musculoskeletal disorders or jaw and tooth pain of dental origin.

Tension-Type Headache

The majority of patients who report to the physician with a chief complaint of headache are diagnosed with tension-type headache. The name can be misleading because "muscle tension" or "tension from stress" is not always present, alone or in combination. Tension-type headache is common in the general population, and most individuals have experienced tension-type headaches.

Chronic tension-type headache is more common in women than in men. The headache is generally bilateral. Pain is frequently bi-temporal or frontal-temporal in distribution. Patients commonly describe their pain as though their head is "in a vice" or a "squeezing hatband" is around their head. These headaches can occur with or without "pericranial muscle tenderness" (i.e., tenderness to palpation of the masticatory and occipital muscles). To be defined as chronic tension-type headache, symptoms must be present longer than 15 days per month. The International Headache Society criteria for tension-type headache are listed in Box 30.7. Treatment of a tension-type headache is commonly with tricyclic or other antidepressants. When tension-type headaches occur in those who also suffer from migraines, migraine treatments are usually beneficial.

Psychosocial factors are often a contributing factor influencing tension-type headache. In this situation, cognitive–behavioral and other psychological therapies such as regular aerobic exercise are frequently beneficial.

For the dentist, it is important to distinguish tension-type headache from masticatory myofascial pain. This can be confusing because both conditions have similar symptoms. It is significant that in myofascial pain, pressure to various head or neck muscles refers to the site of head pain, whereas in tension-type headaches, pressure identifies the site of pain. For either condition, identifying the site of pain does not always imply the source of pain. In addition, in tension-type headache, pain does not proportionally increase with increasing pressure to the headache site or refer pain to other areas.

• BOX 30.7 International Headache Society Criteria for Episodic Tension-Type Headache

A. At least 10 episodes occurring on <1 day/month (<12 day/year) and fulfilling criteria B through D
B. Headache lasting from 30 min to 7 days
C. Headache has two or more of the following characteristics:
   1. bilateral location
   2. pressing/tightening (nonpulsating) quality
   3. mild or moderate intensity
   4. not aggravated by routine physical activity
D. Both of the following:
   1. no nausea or vomiting (anorexia may occur)
   2. no more than one of photophobia or phonophobia
E. Not attributed to another disorder

Cluster Headache

Cluster headache is a clearly unilateral head pain typically centered around the eye and temporal regions. The pain is intense, frequently described as a stabbing sensation (i.e., as if an ice pick was being driven into the eye). Some component of parasympathetic overactivity is present (commonly lacrimation, conjunctival injection, ptosis, or rhinorrhea). Headaches tend to occur in cyclical patterns or clusters, last 15 to 180 minutes, and may occur once or multiple times per day, commonly with precise regularity (e.g., awakening the patient at the same time night after night). The headaches can occur in clusters such that they may be present for some months and then remit for several months or even years. Alcohol ingestion consistently triggers headache, but only during cluster episodes. Smoking tobacco is also associated with cluster headaches. As opposed to most other chronic headaches, men are much more likely to have cluster headaches compared with women, first developing the problem in their late 20s (Box 30.8). International Headache Society criteria are listed in Box 30.9. Treatment, as in migraine, is preventive or symptomatic. Preventive treatment is

• BOX 30.8 Common Cluster Headache Features

Sex: Mainly male
Frequency: Up to 8 per day
Quality: Throbbing or stabbing
Intensity: Severe

From International Headache Society, 2003.

• BOX 30.9 International Headache Society Criteria for Cluster Headache

A. At least five attacks fulfilling criteria B through D
B. Severe or very severe unilateral orbital, supraorbital and/or temporal pain lasting 15–180 min if untreated
C. Headache is accompanied by one or more of the following:
   1. Ipsilateral conjunctival injection and/or lacrimation
   2. Ipsilateral nasal congestion and/or rhinorrhea
   3. Ipsilateral eyelid edema
   4. Ipsilateral forehead and facial sweating
   5. Ipsilateral miosis and/or ptosis
   6. A sense of restlessness or agitation
D. Attacks have a frequency from 1 every other day to 8 per day
E. Not attributed to another disorder

accomplished with verapamil, lithium salts, anticonvulsants, corticosteroids, and certain ergot compounds. Symptomatic treatment is with triptans, ergots, and analgesics. Oxygen inhalation at 7 to 10 L/min may be an effective abortive treatment. Local anesthetics can also be used in localized areas of pain.

Dentists must be aware that cluster headache frequently produces pain in the posterior maxilla, mimicking severe dentoalveolar pain in the posterior maxillary teeth. The pain is frequently stabbing and intense, although background aching may occur. Unnecessary dental therapy is, unfortunately, common. Common features can distinguish a toothache resulting from cluster headache from a toothache produced by a dental problem:

- Rapid emergence and discontinuation of symptoms unlike typical toothache
- Toothache precipitated by alcohol ingestion
- Toothache accompanied by unilateral rhinorrhea or other parasympathetic symptoms
- Toothache that occurs with periodicity

Other Chronic Head Pains of Dental Interest

Temporal Arteritis (Giant Cell Arteritis)

Temporal arteritis, more properly termed *giant cell arteritis*, is literally an inflammation (i.e., vasculitis) of the cranial arterial tree that can affect any or all vessels of the aortic arch and its branches. The condition is most prevalent in those over 50 years of age. The inflammation results from a giant cell granulomatous reaction. Polymyalgia rheumatica, the most common nonarticular rheumatologic condition causing diffuse muscle inflammation, is frequently a comorbid condition. Dull aching or throbbing temporal or head pain is a common complaint affecting 70% of patients and is the presenting symptom in one-third of patients. Jaw claudication (i.e., increasing weakness and pain in the jaw or tongue with ongoing mastication) may lead the patient to visit the dentist for diagnosis. Any older patient reporting jaw or face pain not obviously of odontogenic origin and whose symptoms suggest temporal arteritis should be referred for an erythrocyte sedimentation rate or cross-reactive protein testing. Although a negative test does not rule out temporal arteritis, a significantly elevated erythrocyte sedimentation rate or cross-reactive protein testing may help confirm the diagnosis. A temporal artery biopsy may also be obtained, but again, a negative test does not conclusively rule out the condition. Treatment is with high-dose corticosteroids, frequently for many months, and early treatment is necessary to avoid blindness caused by extension of the disease process to the ophthalmic artery.

Indomethacin-Responsive Headaches

A number of head pains respond primarily or exclusively to the nonsteroidal antiinflammatory drug indomethacin. One of these headaches, chronic paroxysmal hemicrania is similar in presentation to cluster headache, although the attacks are short-lived (lasting several minutes) and occur many times a day. Unlike cluster headaches, women are more often affected compared with men. Again, a toothache may be the initial presentation. Exertional headaches, as in weight lifting or during sexual intercourse, may also produce intense, rapid-onset headache responsive to indomethacin. Hypnic headache, seen in older patients, wake the patient from sleep generally within 2 to 4 hours of sleep onset and last 15 minutes to 3 hours. These are frequently indomethacin responsive, but hypnic headache is not accompanied by symptoms of parasympathetic overactivity.

Evaluation of Patient With Orofacial Pain

Evaluation of the dental patient who has jaw or face pain of nonodontogenic origin is an important skill that must be mastered by dentists. Obtaining an accurate history is the most important component of information gathering. For chronic headache disorders and many neuropathic disorders, such as TN, pre-TN, and other cranial neuralgias, as well as burning mouth syndrome, generally no visible abnormality is found on physical examination; therefore the clinician must rely on the verbal history to arrive at an accurate diagnosis. Chronic headache disorders based on symptom description are presented in Table 30.3.

The pain history should include the chief complaint, including the current description of pain quality (e.g., aching, throbbing, burning, shocklike, paroxysmal, or some combination), intensity, when it occurs, how long it lasts, if it changes in character over time, precipitating factors, and alleviating factors. The history of the present illness should include date of onset, circumstances surrounding onset, how the pain evolved over time, diagnostic tests obtained, diagnoses rendered, what treatments were instituted in the past, and the response to those treatments. Finally, a comprehensive medical and dental history should be taken. Usually a short differential diagnosis can be made at this time. The physical examination attempts to narrow this list to obtain a working diagnosis.

The physical evaluation should include all aspects of the normal dental evaluation, including vital signs determination, intraoral examination with oral cancer screening, and head and neck examination with an evaluation of the temporal and carotid arteries, lymph nodes, skin, head, and neck, as well as myofascial and TMJ examination. In addition, a CN screening examination should be performed. It is understood that most dentists would not include all aspects of the formal neurologic examination, such as funduscopic examination and testing of ability to smell, in this screening. See Table 30.4 for cranial screening evaluation. This latter examination

TABLE 30.3 Differential Diagnoses of Common Headaches

	Temporal Arteritis	Migraine	Cluster	Tension
Onset	Acute or chronic	Acute	Acute	Chronic
Location	Localized	Unilateral (40%)	Unilateral	Global, unilateral
Associated symptoms	Weight loss, polymyalgia rheumatica, fever, decreased vision, jaw claudication	Nausea, vomiting, photophobia, phonophobia	Rhinorrhea, lacrimation of ipsilateral side	Multisomatic complaints
Pain character	Severe throbbing over area affected	Throbbing	Sharp stabbing	Aching
Duration	Prolonged	Prolonged	30 min to 2 h	Daily
Prior history	(–)	(+)	(+)	(+)
Diagnostic test	Erythrocyte sedimentation rate (+)	None—history	None—history	None—history
Physical examination	Tender temporal arteries, myalgias, fever	Nausea, vomiting, photophobia, phonophobia	Unilateral, rhinorrhea, lacrimation, partial Horner syndrome	

TABLE 30.4 Rapid Cranial Nerve Examination for the General Dentist

The examination begins with the patient seated in the dental chair. The clinician asks the patient if he or she has any severe problems with seeing, hearing, or dizziness, and observes the patient for signs of visual or auditory problems, including whether the eyes move consensually. The clinician also checks for eyelid ptosis and mouth symmetry when patient smiles.

Next, the patient tries to hold the eyelids tightly closed while the clinician tries to open them with the fingers. While the patient's eyes are closed, the clinician holds coffee or cloves to the patient's nose and asks the patient to identify the odor. The patient then opens the eyes wide while raising the eyebrows. The clinician shines a bright light into each eye and observes the reaction of each pupil. The patient looks directly left and right and then tries to look at each shoulder without moving the head.

The clinician then asks the patient to show the teeth, then pucker, and then evert the lower lip. Next, the patient clenches the jaw closed while the clinician palpates each masseter muscle. The patient then opens the mouth and sticks the tongue straight out. While the tongue is out, the clinician uses a cotton-tipped applicator to stroke each side of the uvula briefly. With the clinician's hands on the lateral aspects of the patient's chin, the patient then tries to push laterally against the hands. The clinician then rubs the fingers in front of each of the patient's ears and asks what the patient hears.

Finally, areas of hypoesthesia or hyperesthesia are identified and recorded. Areas of the pain complaint receive special attention if nerve injury is suspected. Trigger areas for trigeminal neuralgia are investigated if symptoms warrant.

Cranial Nerve (CN)	Abnormal Test Results
I—Olfactory	Failure to identify odor may indicate nasal obstruction or CN I problem
II—Optic	Failure of pupil to constrict or presence of nonconsensual gaze may indicate CN II problem
III—Oculomotor	Failure of pupil to constrict or presence of ptosis may indicate CN III problem
IV—Trochlear	Inability of eye to look to ipsilateral shoulder may indicate CN IV problem
V—Trigeminal	Inability to feel light touch may indicate sensory CN V problem. Weakness of masseter may indicate motor CN V problem. Areas of hypoesthesia or hyperesthesia should be identified and recorded. Areas of pain complaint should receive special attention if nerve injury is suspected. Trigger areas for trigeminal neuralgia should also be investigated if symptoms warrant
VI—Abducent	Inability of eye to look to ipsilateral side may indicate CN VI problem
VII—Facial	Inability to raise eyebrows, hold eyelids closed, symmetrically smile, pucker, or evert lower lip may indicate CN VII problem
VIII—Acoustic	Poor hearing or symptoms of vertigo may indicate CN VIII problem
IX—Glossopharyngeal	Failure of uvula to elevate on stroked side may indicate CN IX problem
X—Vagus	Failure of uvula to elevate on stroked side may indicate CN X problem
XI—Accessory	Weakness in turning head against resistance may indicate CN XI problem
XII—Hypoglossal	Deviation of tongue to one side may indicate CN XII problem on that side

is frequently an attempt to detect areas of hyperesthesia or hyperalgesia, allodynia, a trigger zone for TN, or an area of decreased sensation. In addition, it is important to define whether the pain follows normal neuroanatomic boundaries and, if so, to define these areas. Diagnostic anesthetic testing, usually with a vasoconstrictor-free solution, is appropriate to help define whether a suspected neuropathic pain condition has a significant peripheral component perpetuating pain.

When a peripheral component occurs, local anesthesia may arrest the pain for the duration of anesthesia. Most commonly, local anesthesia is applied to increasingly larger neuroanatomic regions. For instance, with a pain in the region of the mandibular canine, topical anesthesia in the anterior mandibular gingiva is applied. If pain is not arrested, the response to infiltration anesthesia is assessed. If no response is seen, a mental block (sparing the lingual nerve) is attempted, and finally, inferior alveolar and lingual nerve block anesthesia is undertaken if pain has not yet been alleviated. At each test, any alteration in pain response is noted.

Imaging is appropriate for many disorders to rule out an odontogenic, sinus, or bony pathologic condition. The orthopantograph is helpful when supported by selected dental periapical radiographs, as needed. For most neuropathic and headache disorders, intracranial imaging is important to rule out a CNS demyelinating process (e.g., multiple sclerosis in which TN may be the presenting symptom), vascular malformation, tumor, or other abnormality. Except for specially trained dentists, it is appropriate for the primary care physician or neurologist to order these studies. Other specialized studies (e.g., magnetic resonance arteriography, bone scan, and scintigraphy) may be indicated. With the information obtained from these studies, the dentist may elect to treat the patient or refer the patient to an oral-maxillofacial surgeon, general dentist focusing on orofacial pain diagnosis and management, or an appropriate physician. The role of the primary care dentist is mainly to establish a proper diagnosis and avoid unnecessary treatment, which may jeopardize the patient's health.

31

Management of Temporomandibular Disorders

JOHN C. NALE AND MYRON R. TUCKER

CHAPTER OUTLINE

Patients frequently consult a dentist because of pain or dysfunction in the temporomandibular region. The most common causes of temporomandibular disorders (TMDs) are muscular disorders, which are commonly referred to as *myofascial pain and dysfunction*. These muscular disorders are generally managed with a variety of reversible nonsurgical treatment methods.

Other causes of temporomandibular pain or dysfunction originate primarily within the temporomandibular joint (TMJ). These causes include internal derangement, osteoarthritis, rheumatoid arthritis, chronic recurrent dislocation, ankylosis, neoplasia, and infection. Although most of these disorders respond to nonsurgical therapy, some patients may eventually require surgical treatment. If a successful result is to be achieved, management of these patients requires a coordinated plan that includes the general dentist, the oral-maxillofacial surgeon, and other health care providers.

Evaluation

The evaluation of the patient with temporomandibular pain, dysfunction, or both is like that in any other diagnostic workup. This evaluation should include a thorough history, a physical examination of the masticatory system, and problem-focused TMJ radiography.

Interview

The patient's history may be the most important part of the evaluation because it furnishes clues for the diagnosis. The history begins with the chief complaint, which is a statement of the patient's reasons for seeking consultation or treatment. The history of the present illness should be comprehensive, including an accurate

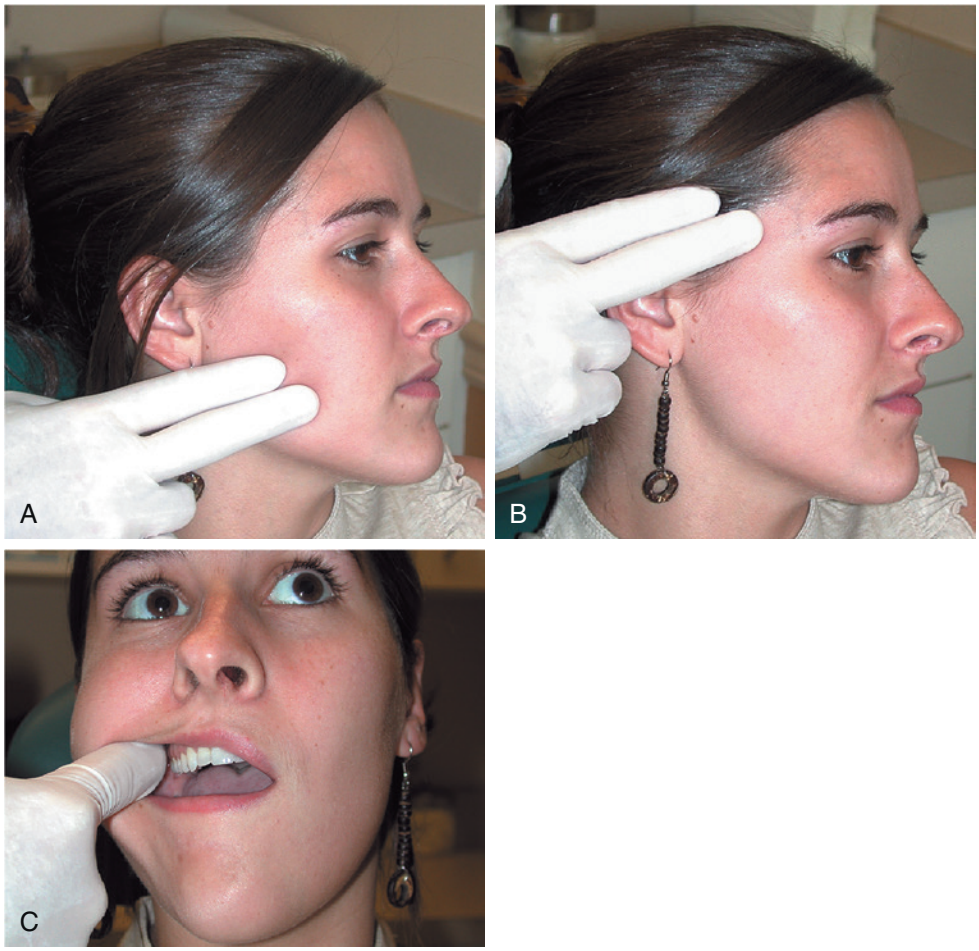
description of the patient's symptoms. The following attributes of symptoms should be explored during the interview: location, quality and severity, quantity, timing, setting in which symptoms occur, remitting or exacerbating factors, and associated manifestations.[1]

It is often helpful to have the patient point to the exact location where the symptom occurs, especially if the symptom is pain. Determining the origin of pain is more reliable if the patient points to one specific location (e.g., the joint capsule), rather than if the patient circles the entire left side of the face with a finger. Qualitative descriptors may also provide a clue as to the source of the symptom. For example, muscular pain is usually described as "dull" and "achy," whereas acute joint pain may be "sharp" or "shooting." The use of a visual analog pain scale, rating the pain level on a scale from 1 to 10, may also help obtain an understanding of the patient's perception of the severity of pain. The timing of the patient's perceived pain is also helpful in determining a cause. Pain that occurs primarily in the morning may indicate a systemic arthritis such as rheumatoid arthritis or myofascial pain resulting from nocturnal bruxism. If pain only occurs toward the end of the day, osteoarthritis may be explored as a potential cause. The setting in which a symptom occurs should also be noted. For example, a stressful situation might result in a patient initiating a parafunctional habit such as nail biting. Removing the patient from the stressful situation may be the only treatment indicated. Questioning the patient for remitting or exacerbating factors should also include any previous treatments and the response to those treatments. Lastly, TMDs are usually associated with other manifestations that may need to be addressed during treatment. Some of the more common associated symptoms include headaches, limited ability to open the mouth, and malocclusion. It is often helpful to have the patient fill out a general questionnaire with questions directed toward these issues to ensure that the appropriate information is gathered.

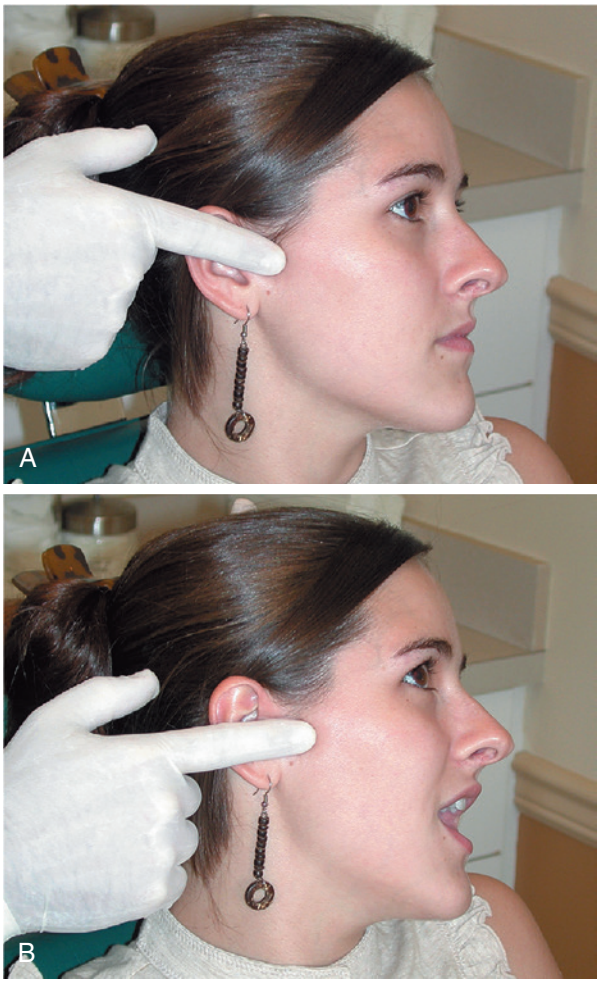
Examination

The physical examination consists of an evaluation of the entire masticatory system. The head and neck should be inspected for soft tissue asymmetry or evidence of muscular hypertrophy. The patient should be observed for signs of jaw clenching or other habits. The masticatory muscles should be examined systematically. The muscles should be palpated for the presence of tenderness, fasciculations, spasm, or trigger points (Fig. 31.1).

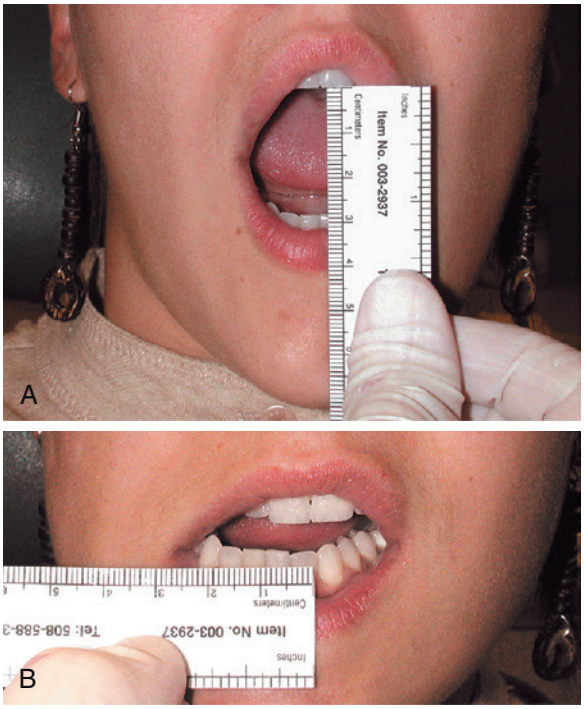
The TMJs are examined for tenderness and noise (Fig. 31.2). The location of the joint tenderness (e.g., lateral or posterior) should be noted. If the joint is more painful during different areas of the opening cycle or with different types of functions, this should be recorded. The most common forms of joint noise are



• **Fig. 31.1** Systematic evaluation of the muscles of mastication. (A) Palpation of the masseter muscle. (B) Palpation of the temporalis muscle. (C) Palpation of the temporalis tendon attachment on the coronoid process and ascending ramus.



• **Fig. 31.2** Evaluation of temporomandibular joint for tenderness and noise. The joint is palpated laterally in (A) the closed position and (B) the open position.



• **Fig. 31.3** Measurement of the range of jaw motion. (A) Maximum voluntary vertical opening. (B) Evaluation of lateral excursive movement (should be approximately 10 mm). Protrusive movements should be similar to excursion.

clicking (a distinct sound) and crepitus (i.e., scraping or grating sounds). Many joint sounds can be easily heard without special instrumentation or can be felt during palpation of the joint; however, in some cases, auscultation with a stethoscope may allow less obvious joint sounds such as mild crepitus to be appreciated.

The mandibular range of motion should be determined. Normal range of movement of an adult's mandible is about 45 mm vertically (i.e., interincisally) and 10 mm protrusively and laterally (Fig. 31.3). The normal movement is straight and symmetric. In some cases, tenderness in the joint or muscle areas may prevent opening. The clinician should attempt to ascertain not only the painless voluntary opening but also the maximum opening that can be achieved with gentle digital pressure. In some cases, the patient may appear to have a mechanical obstruction in the joint causing limited opening but, with gentle pressure, may actually be able to achieve near-normal opening. This may suggest muscular rather than intracapsular problems.

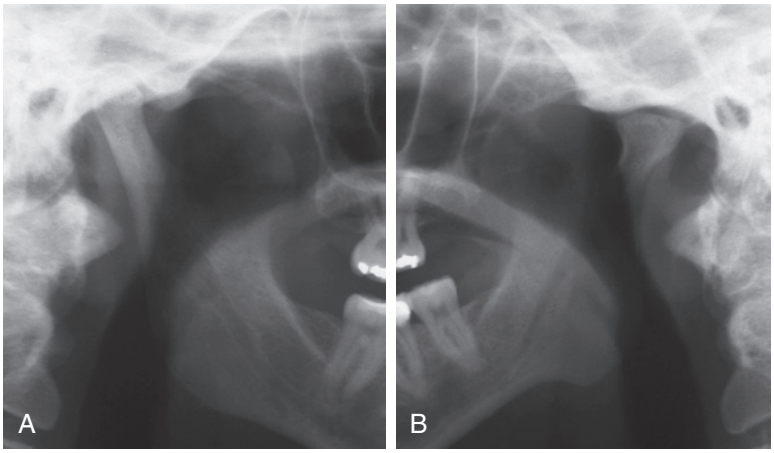
The dental evaluation is also important. Odontogenic sources of pain should be eliminated. Teeth should be examined for wear facets, soreness, and mobility, which may be evidence of bruxism. Although the significance of occlusal abnormalities is controversial, the occlusal relationship should be evaluated and documented. Missing teeth should be noted, and dental and skeletal classification should be determined. The clinician should note any centric relation (CR) and centric occlusion (CO) discrepancy or significant posturing by the patient. The examination findings can be summarized on a TMD evaluation form and included in the patient's chart. In many cases, a more detailed chart note may be necessary to document adequately all of the history and examination findings described previously.

Radiographic Evaluation

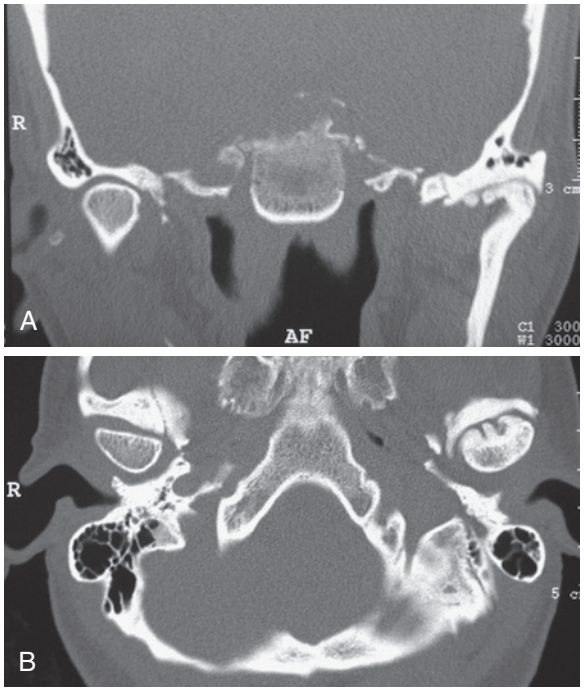
Radiographs of the TMJ are helpful in the diagnosis of intraarticular, osseous, and soft tissue pathologic conditions. The use of radiographs in the evaluation of the patient with TMD should be based on the patient's signs and symptoms instead of routinely ordering a standard set of radiographs. In many cases, the panoramic radiograph provides adequate information as a screening radiograph in evaluation of TMD. A variety of other radiographic techniques that are available may provide useful information in certain cases.

Panoramic Radiography

One of the best overall radiographs for screening evaluation of the TMJs is the panoramic radiograph. This technique allows visualization of both TMJs on the same film. Because a panoramic technique provides a tomographic-type view of the TMJ, this can frequently provide a clear assessment of the bony anatomy of the articulating surfaces of the mandibular condyle and glenoid fossa (Fig. 31.4), and other areas such as the coronoid process can also be visualized.[2] Many machines are equipped to provide special views of the mandible, focusing primarily on the area of the TMJs. These radiographs can often be completed in the open and closed positions.



• **Fig. 31.4** Panoramic imaging. (A) Normal anatomy of the right condyle. (B) Degenerative changes of the left condyle via remodeling.



• **Fig. 31.5** Computed tomography. (A) Coronal image illustrates normal architecture of the right *(R)* condyle with alteration of the left condyle resulting from a history of trauma. (B) Axial view depicts the altered condylar anatomy referenced against the contralateral joint.

Computed Tomography

Computed tomography (CT) provides a combination of tomographic views of the joint, combined with computer enhancement of hard and soft tissue images.[3] This technique allows evaluation of a variety of hard and soft tissue pathologic conditions in the joint. CT images provide the most accurate radiographic assessment of the bony components of the joint (Fig. 31.5). CT reconstruction capabilities allow images obtained in one plane of space to be reconstructed so that the images can be evaluated from a different view. Thus evaluation of the joint from a variety of perspectives can be made from a single radiation exposure.

Cone-Beam Computed Tomography

Cone-beam computed tomography (CBCT) scans have recently become a popular diagnostic tool among dentists and oral-maxillofacial surgeons, mostly because of their convenience, accuracy, and reduced cost. CBCT scanners are office-based scanners that are capable of providing tomographic views with three-dimensional reconstructions of the mandibular condyle and articular eminence (Fig. 31.6). When evaluating bony structures, it has the diagnostic accuracy of conventional CT scanners but requires much less radiation exposure to patients.[4,5] The major limitation to the CBCT scanner is that it does not provide diagnostic images of soft tissue structures.

Magnetic Resonance Imaging

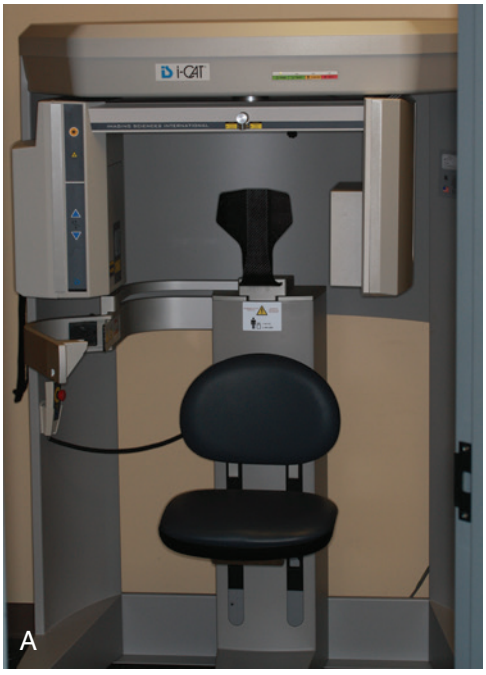
The most effective diagnostic imaging technique to evaluate TMJ soft tissues is magnetic resonance imaging (MRI; Fig. 31.7).[6] This technique allows excellent images of intraarticular soft tissue, making MRI a valuable technique for evaluating disk morphology and position. MRI images can be obtained showing dynamic joint function in a cinematic fashion, providing valuable information about the anatomic components of the joint during function. The fact that this technique does not use ionizing radiation is a significant advantage.

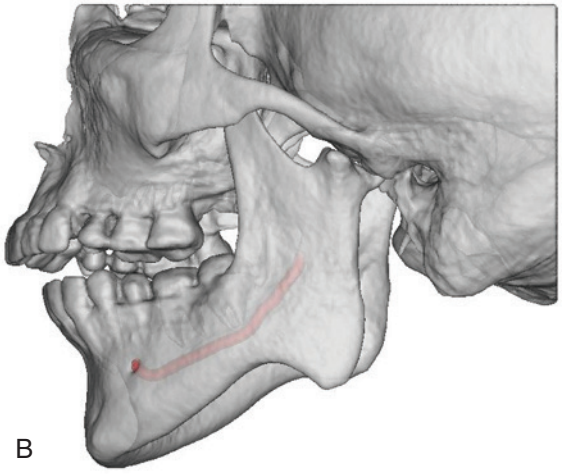
Nuclear Imaging

Nuclear medicine studies involve intravenous injection of technetium-99, a γ-emitting isotope that is concentrated in areas of active bone metabolism. Approximately 3 hours after injection of the isotope, images are obtained using a gamma camera. Single-photon emission CT images can then be used to determine active areas of bone metabolism (Fig. 31.8).[7] Although this technique is extremely sensitive, the information obtained may be difficult to interpret. Because bone changes such as degeneration may appear identical to repair or regeneration, this technique must be evaluated cautiously and in combination with clinical findings.

Psychological Evaluation

Many patients with temporomandibular pain and dysfunction of long-standing duration develop manifestations of chronic pain syndrome behavior. This complex may include gross exaggeration of symptoms and clinical depression.[8,9] The comorbidity of psychiatric illness and temporomandibular dysfunction can be as high





• **Fig. 31.6** Cone-beam computed tomography. (A) Cone-beam computed tomography scanner. (B) Three-dimensional image of a remodeled condyle as a result of a childhood fracture.

as 10% to 20% of patients seeking treatment.[10] A third of these patients are suffering from depression at the time on initial presentation, whereas more than two-thirds have had a severe depressive episode in their history.[11] Psychiatric disorders may elicit somatic components through parafunctional habits resulting in dystonia and myalgia, and individuals with chronic pain commonly have a higher incidence of concomitant anxiety disorders.[12-14] Behavioral changes associated with pain and dysfunction can be elicited in the history through questions regarding functional limitation that results from the patient's symptoms.[15] If the functional limitation appears to be excessive compared with the patient's clinical signs or the patient appears to be clinically depressed, further psychological evaluation may be warranted.[16]

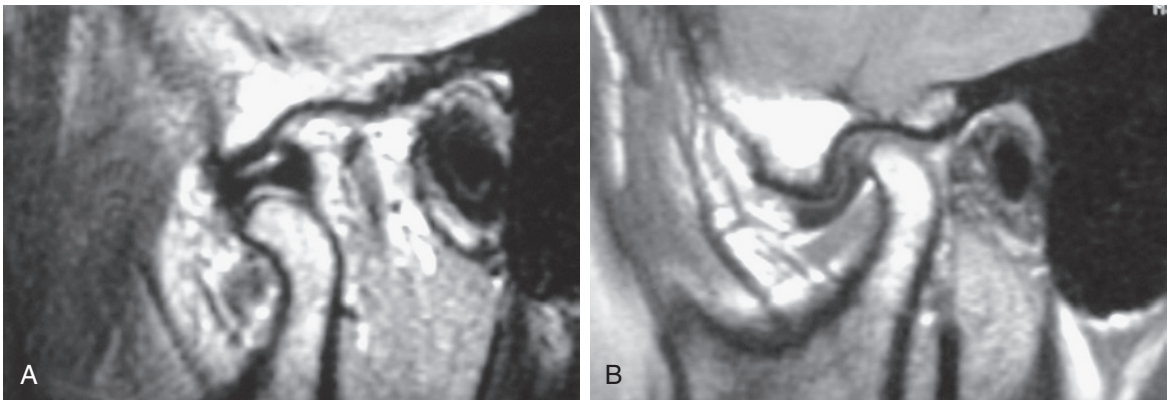
Classification of Temporomandibular Disorders

Myofascial Pain

Myofascial pain and dysfunction (MPD) is the most common cause of masticatory pain and limited function for which patients seek dental consultation and treatment. The source of the pain and dysfunction is muscular, with masticatory muscles developing tenderness and pain as a result of abnormal muscular function or hyperactivity. The muscular pain is frequently, but not always, associated with daytime clenching or nocturnal bruxism. The cause of MPD is multifactorial. One of the most commonly accepted causes of MPD is bruxism resulting from stress and anxiety, with occlusion being a modifying or aggravating factor. MPD may also occur because of internal joint problems such as disk displacement disorders or degenerative joint disease (DJD).

Patients with MPD generally complain of diffuse, poorly localized, preauricular pain that may also involve other muscles of mastication such as the temporalis and medial pterygoid muscles. In patients with nocturnal bruxism, the pain is frequently more severe in the morning. Patients generally describe decreased jaw opening with pain during functions such as chewing. Headaches, usually bitemporal in location, may also be associated with these symptoms. Because of the role of stress, the pain is often more severe during periods of tension and anxiety.

Examination of the patient reveals diffuse tenderness of the masticatory muscles. The TMJs are frequently nontender to



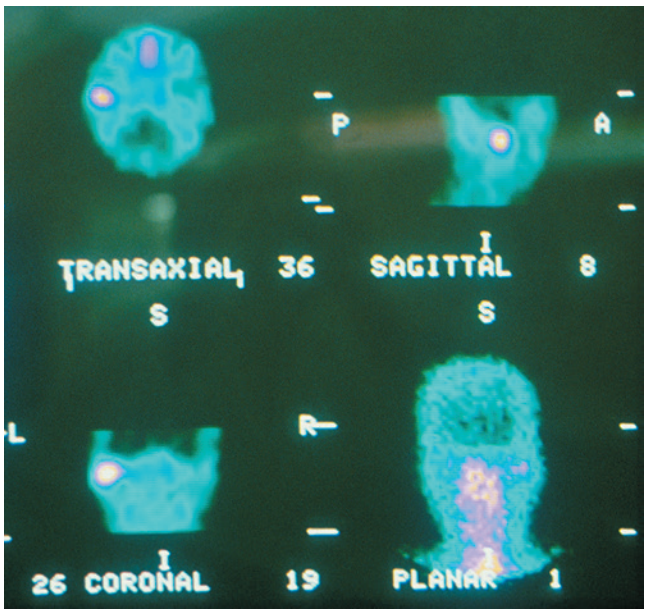
• **Fig. 31.7** Magnetic resonance image. (A) Normal positioning of the articular disk between the articular eminence and condyle during translation. (B) Anterior disk displacement without reduction, limiting range of motion.

palpation. In isolated MPD, joint noises are usually not present. However, as mentioned previously, MPD may be associated with a variety of other joint problems that may produce other TMJ signs and symptoms. The range of mandibular movement in patients with MPD may be decreased. In fact, limited range of motion is often more severe compared with an internal derangement. Also note that teeth frequently have wear facets. However, the absence of such facets does not eliminate bruxism as a cause of the problem.

Radiographs of the TMJs are usually normal. Some patients have evidence of degenerative changes such as altered surface contours, erosion, or osteophytes. These changes, however, may result from or be unassociated with the MPD problem.

Internal Derangements

In a normally functioning TMJ, the condyle functions in a hinge and a sliding fashion. During full opening, the condyle not only rotates on a hinge axis but also translates forward to a position near the most inferior portion of the articular eminence (Fig. 31.9). During function, the biconcave disk remains interpositioned between the condyle and the fossa, with the condyle remaining against the thin intermediate zone during all phases of opening and closing. Frequently, patients with TMJ pain and dysfunction have an abnormal relationship among the condyle, the disk, and the fossa. This abnormal relationship is commonly referred to as *internal derangement*. Clinical manifestations of internal derangements have been found to vary, but in a characteristic way, according to the degree of pathologic change. As a result, staging criteria were developed with respect to clinical, radiologic, and surgical findings, as seen in Box 31.1.[17]



• **Fig. 31.8** Single-photon emission computed tomography (bone scan). The area of increased activity is apparent in the right temporomandibular joint.

Anterior Disk Displacement With Reduction

In anterior disk displacement, the disk is positioned anterior and medial to the condyle in the closed position. During opening, the condyle moves over the posterior band of the disk and eventually returns to the normal condyle-and-disk relationship, resting on the thin intermediate zone. During closing, the condyle then slips posteriorly and rests on the retrodiscal tissue, with the disk returning to the anterior, medially displaced position (Fig. 31.10).

Patients with stage I internal derangement generally have no symptoms except minor joint noise. Joint noise (i.e., clicking) is commonly heard with opening, when the condyle moves from the area posterior to the disk into the thin concave area in the middle of the disk. In some cases, clicking can be heard or palpated during the closing cycle. Maximal opening can be normal or slightly limited, with the click occurring during the opening movement. Anatomically, the opening click corresponds to the disk reducing to a more normal position. The closing click (i.e., reciprocal click) corresponds to the disk failing to maintain its normal position between the condylar head and the articular eminence and slipping forward to the anteriorly displaced position. Crepitus may be present and is usually a result of articular movement across irregular surfaces. Examination of the patient with stage II internal derangement will demonstrate similar joint noises but will also reveal joint tenderness. Other symptoms may include muscle tenderness, temporal headaches, or transient joint locking.

The images obtained from plain TMJ radiography in patients with anterior disk displacement with reduction should be normal. MRI images in the closed mouth position usually demonstrate anterior displacement of the disk, whereas images in the open mouth position will show the intermediate zone of the disk reduced between the condyle and articular eminence.

Anterior Disk Displacement Without Reduction

In this type of internal derangement, stage III, the disk displacement cannot be reduced, and thus the condyle is unable to translate to its full anterior extent, which prevents maximal opening and causes deviation of the mandible to the affected side (Fig. 31.11).

In these patients, no clicking occurs, because they are unable to translate the condyle over the posterior aspect of the disk. This lack of translation may result in restricted opening, deviation to the affected side, and decreased lateral excursions to the contralateral side. Some evidence suggests that the limitation of motion may not be directly related to the actual displacement of the disk but

• **Fig. 31.9** Normal disk and condyle relationship. (A) The biconcave disk is interpositioned between the fossa and the condyle in the closed position. (B) When it translates forward, the thin intermediate zone stays in consistent relationship with the condyle. (C) Maximum open position.

BOX 31.1 Wilkes Staging Classification for Internal Derangement of the Temporomandibular Joint

1 Early Stage
a. *Clinical:* no significant mechanical symptoms, other than soft, reciprocal clicking; no pain or limitation of motion
b. *Radiologic:* slight forward displacement; good anatomic contour of the disk; normal CT scan
c. *Surgical:* normal anatomic form; slight anterior displacement; passive incoordination (clicking)

2 Early/Intermediate Stage
a. *Clinical:* first few episodes of pain, occasional joint tenderness and related temporal headaches, beginning major mechanical problems, increase in intensity of clicking
b. *Radiologic:* slight forward displacement, slight thickening of the posterior edge or beginning anatomic deformity of disk, and normal CT scan
c. *Surgical:* anterior displacement, early anatomic deformity (mild thickening of posterior edge of disk), and well-defined central articulating area

3 Intermediate Stage
a. *Clinical:* multiple episodes of pain, joint tenderness, temporal headaches, major mechanical symptoms—intermittent catching or locking and sustained locking, restriction of motion and pain with function
b. *Radiologic:* anterior displacement with significant deformity of the disk (moderate to marked thickening of posterior edge) and normal CT scan
c. *Surgical:* marked disk deformity with displacement, variable adhesions and no hard-tissue changes

4 Intermediate/Late Stage
a. *Clinical:* chronic pain with variable and episodic acute pain, headaches, variable restriction of motion, and undulating course
b. *Radiologic:* increase in severity over intermediate stage, abnormal CT scan, and early to moderate degenerative remodeling hard-tissue changes
c. *Surgical:* increase in severity over intermediate stage, hard-tissue degenerative remodeling changes of both bearing surfaces, osteophytes, multiple adhesions, and no perforation of disk or attachments

5 Late Stage
a. *Clinical:* characterized by crepitus, grinding symptoms, variable and episodic pain, chronic restriction of motion, and difficulty with function
b. *Radiologic:* anterior displacement, perforation with simultaneous filling of upper and lower joint space, filling defects, gross anatomic deformity of disk and hard tissue, abnormal CT scan as described, and degenerative arthritic changes
c. *Surgical:* gross degenerative changes of disk and hard tissues, perforation of posterior attachments, erosions of bearing surfaces, and multiple adhesions

CT, *Computed tomography.*

rather to the adherence of the disk to the fossa, causing a restriction of the sliding function of the joint.[18]

Evaluation of disk displacement without reduction using plain radiography or CT will produce similar findings as in anterior disk displacement with reduction. MRI generally demonstrates anteromedial disk displacement in the closed mouth position similar to Wilkes stage I and II internal derangements. However, in this disorder, images taken in the maximal open-mouth position continue to show anterior disk displacement.

Degenerative Joint Disease (Arthrosis, Osteoarthritis)

DJD includes a variety of anatomic findings, including irregular, perforated, or severely damaged disks in association with articular surface abnormalities such as articular surface flattening, erosions, or osteophyte formation (Fig. 31.12). The mechanisms of TMJ degenerative diseases are not clearly understood but are thought to be multifactorial. Current concepts of DJD incorporate three possible mechanisms of injury: (1) direct mechanical trauma, (2) hypoxia reperfusion injury, and (3) neurogenic inflammation.[19]

Mechanical trauma may result from significant and obvious trauma to the joint or much less obvious microtrauma such as excessive mechanical loading. The excessive stress produced in the joint can lead to molecular disruption and the generation of free radicals, with resulting oxidative stress and intracellular damage. Excess loading can also affect local cell populations and reduce the reparative capacity of the joint.

The hypoxia-reperfusion theory suggests that excessive intracapsular hydrostatic pressure within the TMJ may exceed the blood vessel perfusion pressure, resulting in hypoxia.

This type of increased intracapsular pressure has been clearly demonstrated in patients during clenching and bruxing.[20] When the pressure in the joint is decreased and perfusion is reestablished, free radicals are formed. These free radicals may interact with other substances in the joint (e.g., hemoglobin) to produce even more damage.

Neurogenic inflammation results when a variety of substances are released from the peripheral neurons. It is hypothesized that in cases of disk displacement, the compression or stretching of the nerve-rich retrodiscal tissue may result in release of proinflammatory neuropeptides.[19,21] The release of cytokines results in the release and activation of a variety of substances, including prostaglandins, leukotrienes, and matrix-degrading enzymes. These compounds not only have a role in the disease process but also may serve as biologic markers that may help diagnose and eventually treat pathologic conditions of the joint.[22,23] It must be emphasized that it is impossible to predict the progression of pathologic conditions of the joint.

The diagnosis of DJD or osteoarthritis is a broad term that encompasses both Wilkes stage IV and V internal derangements. Patients with DJD frequently experience pain associated with clicking or crepitus located directly over the TMJ. Typically an obvious limitation of opening is present, and symptoms usually increase with function. Radiographic findings are variable but generally exhibit decreased joint space, surface erosions, osteophytes, and flattening of the condylar head. These findings can be seen on panoramic radiographs and CT scans. Irregularities in the fossa and articular eminence may also be present. Perforation of the disk or its posterior attachments delineates the difference between stage IV and V internal derangement.

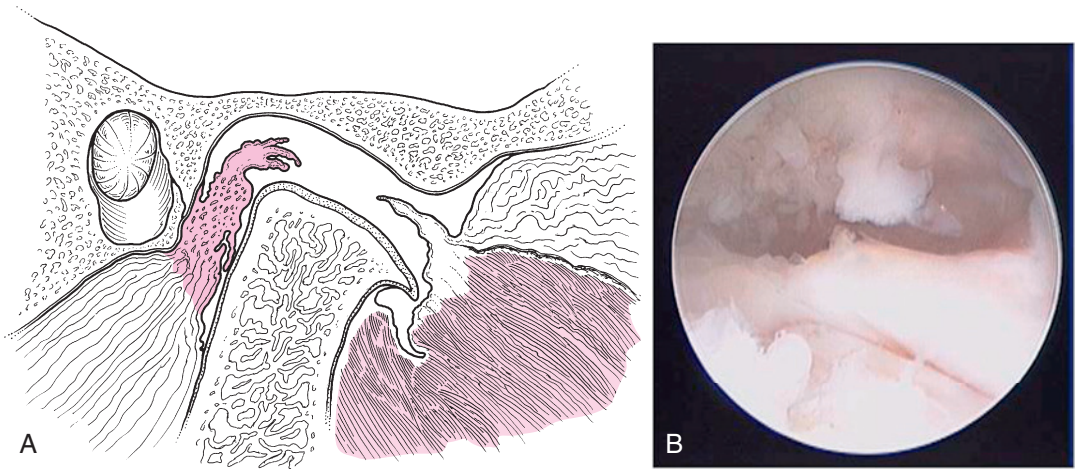
Systemic Arthritic Conditions

A variety of systemic arthritic conditions are known to affect the TMJ. The most common of these is rheumatoid arthritis. Other processes, such as systemic lupus erythematosus, can also affect the TMJ. In these cases, symptoms are rarely isolated to the TMJs, and several other signs and symptoms of arthritis are usually present in other areas of the body.

In the case of rheumatoid arthritis, an inflammatory process results in abnormal proliferation of synovial tissue in a so-called pannus formation (Fig. 31.13).

• **Fig. 31.10** Anterior disk displacement with reduction. (A) The biconcave disk is situated anterior to articulating surface of condyle. When the condyle translates forward, it eventually passes over the thickened posterior band of the disk, creating a clicking noise. (B) After the click occurs, the disk remains in appropriate relationship with the condyle through the remainder of the opening cycle. (C) Maximum opening position. When the mandible closes, the relationship between the condyle and the disk return to the position shown in A.

• **Fig. 31.11** Anterior disk displacement without reduction. (A) A disk that has been chronically anteriorly displaced has an amorphous shape rather than distinct biconcave structure. (B) When the condyle begins to translate forward, the disk remains anterior to the condyle. (C) In the maximal open position, the disk tissue continues to remain anterior to the condyle, with the posterior attachment tissue interposed between the condyle and the fossa.



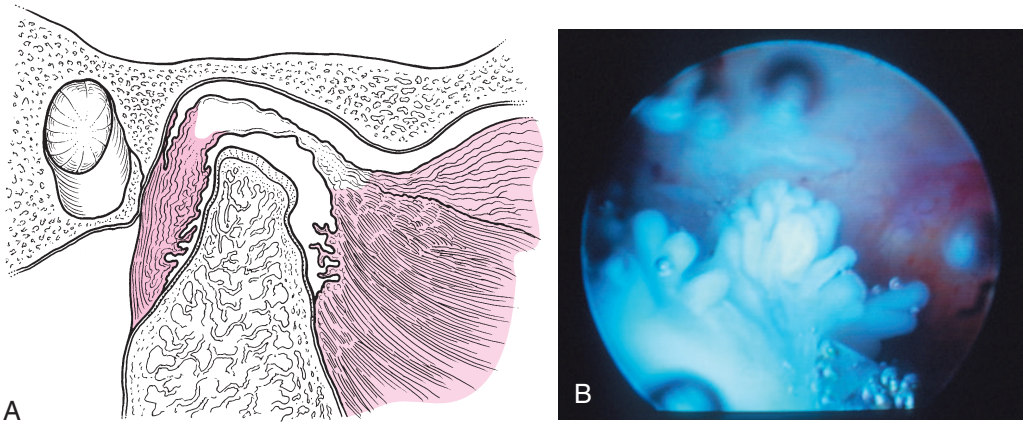
• **Fig. 31.12** (A) Degenerative joint disease demonstrates a large perforation of disk tissue and erosion and flattening of the articulating surfaces of the condyle and the fossa. (B) Arthroscopic visualization of disk perforation with exposure of the condyle in the superior joint space.

TMJ symptoms that result from rheumatoid arthritis may occur at an earlier age than those associated with DJD. As opposed to DJD, which is usually unilateral, rheumatoid arthritis (and other systemic conditions) usually affects the TMJs bilaterally.

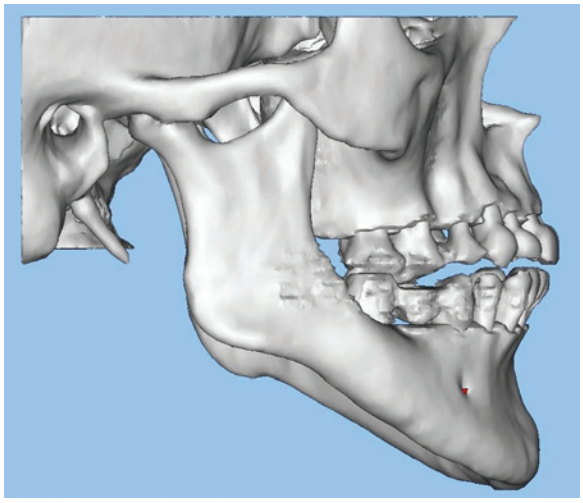
Radiographic findings of the TMJ initially show erosive changes in the anterior and posterior aspects of the condylar heads. These changes may progress to large eroded areas that leave the appearance of a small, pointed condyle in a large fossa. Eventually the entire condyle and condylar neck may be destroyed. Destruction of the condyles bilaterally may result in the loss of condylar-ramus height, resulting in premature contact of posterior teeth and an anterior open-bite malocclusion (Fig. 31.14). Laboratory tests such as rheumatoid factor and erythrocyte sedimentation rate may be helpful in confirming the diagnosis of rheumatoid arthritis.

Chronic Recurrent Dislocation

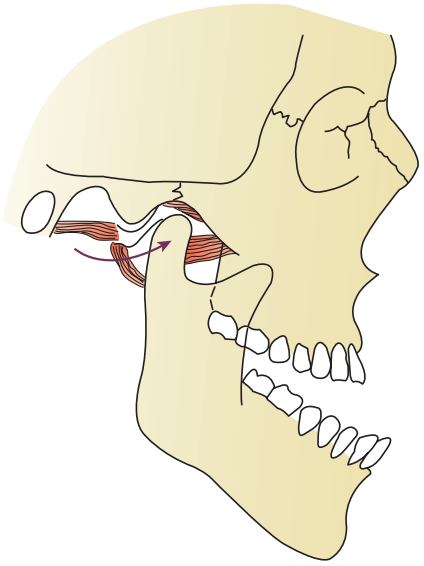
Dislocation of the TMJ occurs frequently and is caused by mandibular hypermobility. Subluxation is a displacement of the condyle, which is self-reducing and generally requires no medical management. A more serious condition occurs when the mandibular condyle translates anteriorly in front of the articular eminence and becomes locked in that position (Fig. 31.15). Dislocation may be



• **Fig. 31.13** (A) Changes seen in rheumatoid arthritis of the temporomandibular joint. These changes include proliferation of synovial tissue, creating resorption in the anterior and posterior areas of the condyle. Irregularities of disk tissue and the articulating surface of the condyle eventually occur. (B) Arthroscopic view of synovial hyperplasia.



• **Fig. 31.14** Three-dimensional reconstruction of a cone-beam computed tomography scan showing an anterior open bite as the result of loss of condylar-ramus height caused by degenerative joint disease.



• **Fig. 31.15** Hypermobility of the joint allowing dislocation of the condyle anterior to the articular eminence.

unilateral or bilateral, and may occur spontaneously after opening the mouth widely, such as when yawning, eating, or during a dental procedure. Dislocation of the mandibular condyle that persists for more than a few seconds generally becomes painful and is often associated with severe muscular spasms.

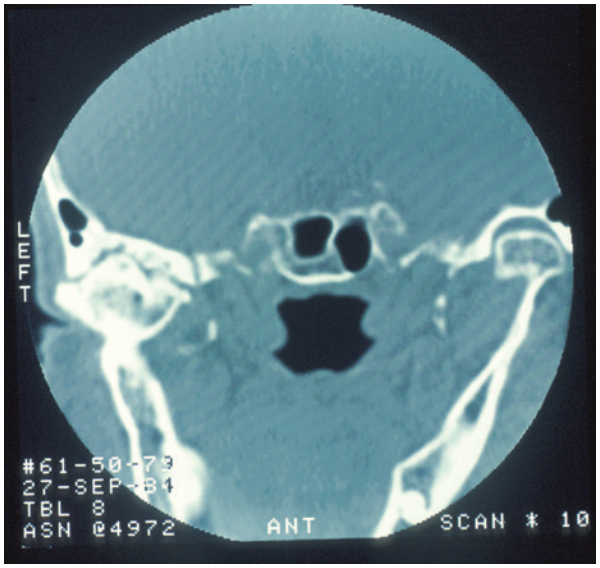
Dislocations should be reduced as soon as possible. This reduction is accomplished by applying downward pressure on posterior teeth and upward pressure on the chin, accompanied by posterior displacement of the mandible. Usually reduction is not difficult. However, muscular spasms may prevent simple reduction, particularly when the dislocation cannot be reduced immediately. In these cases, anesthesia of the auricular temporal nerve and the muscles of mastication may be necessary. Sedation to reduce patient anxiety and provide muscular relaxation may also be required. After reduction, the patient should be instructed to restrict mandibular opening for 2 to 4 weeks. Moist heat and nonsteroidal antiinflammatory drugs (NSAIDs) are also helpful in controlling pain and inflammation.

Ankylosis

Intracapsular Ankylosis

Intracapsular ankylosis, or fusion of the joint, leads to reduced mandibular opening that ranges from partial reduction in function to complete immobility of the jaw. Intracapsular ankylosis results from a fusion of the condyle, disk, and fossa complex as a result of the formation of fibrous tissue, bone fusion, or a combination of the two (Fig. 31.16). The most common cause of ankylosis involves macrotrauma, most frequently associated with condylar fractures. Other causes of ankylosis include previous surgical treatment that resulted in scarring and, in rare cases, infections.

Evaluation of the patient reveals severe restriction of maximal opening, deviation to the affected side, and decreased lateral excursions to the contralateral side. If the ankylosis is the result primarily of fibrous tissue, jaw mobility will be greater than if the ankylosis is a result of bone fusion.



• **Fig. 31.16** Bony ankylosis. Computed tomography scan illustrating partial bony fusion of condyle and glenoid fossa.

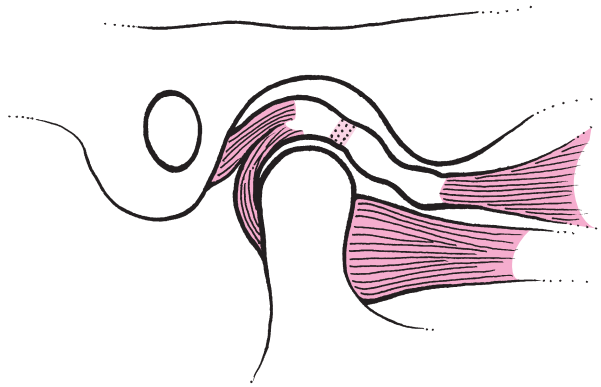
• **Fig. 31.17** Extracapsular ankylosis resulting from coronoid hyperplasia. Elongation of the coronoid process results in impingement against the posterior aspect of the maxilla during opening, limiting mandibular range of motion.

Radiographic evaluation reveals irregular articular surfaces of the condyle and fossa, with varying degrees of calcified connection between these articulating surfaces.

Extracapsular Ankylosis

Extracapsular ankylosis usually involves the coronoid process and the temporalis muscle. Frequent causes of extracapsular ankylosis are coronoid process enlargement, or hyperplasia, and trauma to the zygomatic arch area (Fig. 31.17). Infection around the temporalis muscle may also produce extracapsular ankylosis.

Patients initially have limitation of opening and deviation to the affected side. In these cases, complete restriction of opening is rare, and limited lateral and protrusive movements can usually be performed, indicating no intracapsular ankylosis. Panoramic radiography generally demonstrates the elongation of a coronoid process. A submental vertex radiograph or CBCT may be useful in demonstrating impingement caused by a fractured zygomatic arch or zygomaticomaxillary complex.



• **Fig. 31.18** An anteriorly displaced disk results in stress on the retrodiscal tissue. Subsequent fibrosis provides adaptation, producing a functional, although anatomically different, interpositional disk.

Neoplasia

Neoplasms in the TMJ are rare. Neoplasms can occasionally result in restriction of opening and joint pain. Tumors within the TMJ may result in an abnormal condyle and fossa relationship or an intracapsular ankylosis. A complete discussion of the neoplastic processes known to occur in the TMJ area is beyond the scope of this chapter.

Infections

Infections in the TMJ area are rare, even in the case of trauma or surgical intervention in this area. In many developing countries, where antibiotic therapy of middle ear infections may not be available, extension of infectious processes may occasionally involve the TMJ and result in intracapsular ankylosis.

Reversible Treatment

Although the cause of temporomandibular pain and dysfunction can arise from several different sources, initial treatment is frequently aimed at nonsurgical methods of reducing pain and discomfort, decreasing inflammation in muscles and joints, and improving jaw function. In some cases, as in ankylosis or severe joint degeneration, surgical treatment may be the preferred initial course of therapy. However, in most cases—including MPD, disk displacement disorders, and degenerative and systemic arthritic disorders—a nonsurgical, reversible treatment phase may provide significant reduction in pain and improvement in function. Most patients with MPD and internal derangements do well without any type of long-term or invasive treatment. In the case of anterior disk displacement without reduction (i.e., closed lock), most patients experience a gradual progression of increased opening and decreased discomfort without extensive treatment. This is apparently the result of physiologic and anatomic adaptation of tissue within the joint. It appears that in many patients the posterior attachment tissue undergoes fibrous adaptation and adequately serves as interpositioning tissue between the condyle and fossa.[24] This is often termed *pseudodisk adaptation* (Fig. 31.18). This pseudodisk formation, combined with other normal healing capabilities of joints, is most likely responsible for clinical improvement in many patients.

Patient Education

The first step in involving patients in their own treatment is to make them aware of the pathologic condition producing their pain and dysfunction and to describe the prognosis or possible progression of their pain and dysfunction. Many problems of masticatory pain and dysfunction stabilize or improve with conservative therapy despite patients' concerns that they may be on a continually deteriorating course. In the case of a patient with MPD, a precise, confident explanation should attempt to assure the patient that muscular pain usually improves with minimal treatment. The clinician should also explain that although symptoms may recur on occasion, they generally can be controlled with treatment (described later in this chapter).

In some cases, as in DJD, the patient should be made aware of the long-term spectrum of outcomes of this problem. Warning signs of further deterioration, including increased pain, limitation of motion, and increased joint noise, should be emphasized to the patient.

Patients who have an awareness of the factors associated with their pain and dysfunction can actively participate in their own improvement. Myofascial pain often results from parafunctional habits or muscular hyperactivity resulting from stress and anxiety. Patients who are aware of these factors are often able to control their activity, and thereby reduce discomfort and improve function. Biofeedback devices provide information to patients to help them control their muscular activity. For example, the output from surface electrodes over the masseter or temporalis muscle can be used to indicate clenching or grinding during daytime activity.[25] Electromyographic recordings can also be useful in evaluating nocturnal bruxism and associated pain and can be used to monitor the effectiveness of splint therapy and medication to control muscular hyperactivity. Other forms of stress control such as physical exercise reducing exposure to stressful situations and psychological counseling can also be explored. When the patient becomes aware of the relationship between personal actions and the symptoms of pain and dysfunction, behavior modification may follow.

Modification of diet combined with home exercise routines are also an important part of the patient's educational process. Patients who experience temporomandibular pain or dysfunction frequently find that it is most apparent when chewing hard food. Temporary alteration of the diet to a softer consistency may result in a significant reduction in symptoms. A gradual progression to a more normal diet over a period of 6 weeks may be sufficient to reduce joint or muscle symptoms. Aggravating factors, including chewing of gum, fingernails, or ice, should be reviewed, and cessation or limitation of these activities should be encouraged.

Medication

Pharmacologic therapy is an important aspect of nonsurgical management of TMD. Medications typically used in the treatment of TMDs include NSAIDs, occasionally stronger analgesics, muscle relaxants, and antidepressants.

NSAIDs not only reduce inflammation but also have an excellent analgesic action. Categories of NSAIDs include propionic acid derivatives (ibuprofen, naproxen), salicylates (aspirin, diflunisal), and acetic acid compounds (indomethacin, sulindac). These medications can be effective in reducing inflammation in muscles and joints and, in most cases, provide satisfactory pain relief. These drugs are not associated with severe addiction problems, and their use as an analgesic is strongly preferred over narcotic medications. Dosing of NSAIDs is most effective when they are administered on a time-regulated schedule rather than on a pain-dependent schedule. Patients should be instructed to take the medicine regularly, obtaining an adequate blood level that should then be maintained for a minimum of 7 to 14 days. Discontinuation or tapering of the medicine can then be attempted.

The cyclooxygenase-2 (COX-2) inhibitors such as celecoxib (Celebrex) have gained popularity in the treatment of inflammation and pain. Prostaglandins produced by COX-1 activity appear to be required for normal physiologic function, whereas those produced by COX-2 activation mediate pain and inflammation. The COX-2 inhibitors are intended to reduce pain and inflammation without affecting prostaglandin-dependent functions. Some COX-2 inhibitors have been associated with the potential for significant side effects, including cardiac complications, and they should be used with the appropriate caution and the patient closely monitored. Consultation with the patient's physician may be warranted.

Analgesic medicines for patients with TMJ disorders may range from acetaminophen to potent narcotics. One important principle of treatment for all pain and dysfunction in patients is to remember that the problem may be chronic and that medication could produce long-term addiction. Because of the sedative and depressive effects of narcotics and their potential for addiction, these medications should be restricted to short-term use for episodes of severe, acute pain, or in a postoperative setting. In such instances, medications such as acetaminophen with hydrocodone or oxycodone should be sufficient. This medication should not be used for longer than 10 days to 2 weeks, if possible.

Muscle relaxants may provide significant improvement in jaw function and relief of masticatory pain through control of dystonia. However, muscle relaxants have a significant potential for depression and sedation and can produce long-term addiction. In many patients with acute pain or exacerbation of muscular hyperactivity, muscle relaxants can be considered for short periods such as 10 days to 2 weeks. The lowest effective dose should be used. Diazepam (Valium), carisoprodol (Soma), cyclobenzaprine (Flexeril), and tizanidine (Zanaflex) are examples of commonly used muscle relaxants. Pharmacologic therapy often provides adequate relief of muscular symptoms in patients with TMD.

Antidepressants, most commonly tricyclic antidepressants used in low doses, appear to be useful in the management of patients with chronic pain.[26,27] Tricyclic antidepressants prevent the reuptake of amine neurotransmitters such as serotonin and norepinephrine, causing an inhibition of pain transmission. Recently anecdotal evidence has suggested that these antidepressants may be effective in decreasing nocturnal bruxism. It appears that nighttime bruxing may be, in part, a result of disruption of normal sleep patterns.[28,29] Amitriptyline (Elavil) used in small doses (10 to 25 mg at bedtime) may improve sleep patterns, decrease bruxism, and result in decreased joint and muscle pain.

Medications that must be administered by injection may occasionally be helpful in managing muscular and joint pain and inflammation. The use of botulinum toxin A has shown promise in decreasing masticatory muscle hyperactivity.[30,31] Botulinum toxin (Botox) is a neurotoxin produced by the bacterium *Clostridium botulinum*. This neurotoxin produces a paralytic effect on muscles by inhibiting the release of acetylcholine at the neuromuscular junction. In very low doses, botulinum toxin can be safely administered by injection directly into the affected muscle area, decreasing muscle contraction activity and the associated pain (Fig. 31.19). The effect of the botulinum toxin is temporary, often lasting several

months. In many cases, injection of botulinum toxin must be repeated to obtain long-term pain relief.

The injection of local anesthetic combined with steroids into the temporalis tendon and the joint has been shown to be an effective way to decrease pain and inflammation. Tendinitis in such areas as the insertion of the temporalis tendon along the ascending ramus and coronoid process often responds favorably to these injections. The local anesthetic provides temporary relief of pain, and the steroids exert their effect through the inhibition of proinflammatory cytokines.[32] However, one must be careful, as repeated intramuscular injections may result in fibrosis. Some debate is ongoing about the long-term effect of steroids in the joint and the possibility that further degeneration may be associated with steroid injection.[33] Further research in this area is required.

Physical Therapy

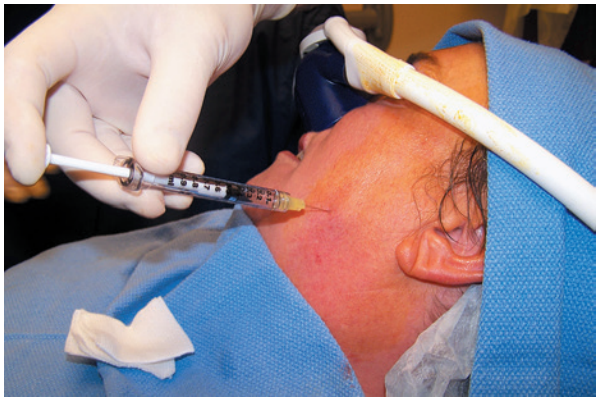
Physical therapy can be useful in the management of patients with temporomandibular pain and dysfunction. A variety of techniques have been used successfully as adjunctive therapy for treatment of temporomandibular dysfunction. The most common modalities used include range of motion exercises, relaxation training, ultrasound, spray and stretch, and pressure massage.[34,35]

Although the patient is generally encouraged to reduce the functional load placed on the joint and muscles, it is important to remember that maximizing range of motion is also an important aspect of treatment of all TMDs.[36] Limited mandibular range of motion may lead to problems in the TMJ and muscles of mastication. The lack of mobility may limit the lubrication of the joint via changes in the synovial membrane and contribute to degenerative changes of the articular surfaces. Limited muscular movement can result in fibrosis, further restriction of motion, and an increase in pain. Physical therapy is initially implemented through a home regimen. These exercises include gentle stretching exercises done within pain tolerance through passive opening or active exercise routines. Establishing a baseline is a valuable resource to gauge progress and can be measured via the number of fingers positioned between the incisal edges or dispensing a plastic ruler. Simple methods for passive therapy include stretching by exerting a scissor effect with the thumb and forefinger or interval increases in tongue blades placed between the upper and lower teeth (Fig. 31.20). The force is exerted until resistance or pain is encountered and is maintained for several seconds. Appliances are also available that provide easy and efficient methods for improving jaw mobility through passive exercise. Consultation with a physical therapist may be required to provide a regimen to assist in overcoming persistent immobilization.[37,38]

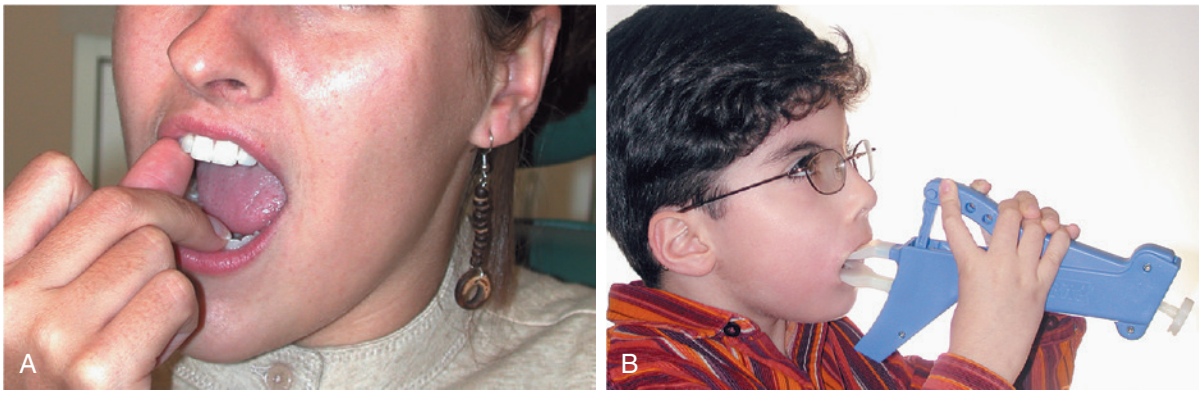
Relaxation training, although perhaps not physical therapy in the strictest sense, can be effective in reducing symptoms caused by muscular pain and hyperactivity. During the educational phase, patients are made aware of the contribution of stress and muscular hyperactivity to pain. Relaxation techniques can be used to reduce the effects of stress on muscle and joint pain. Electromyographic monitoring of the patient's muscular activity can be used as an effective teaching tool by providing instant feedback demonstrating relaxation therapy, reduction of muscular hyperactivity, and the resultant improvement in symptoms of pain.

Ultrasound is an effective way to produce tissue heating with ultrasonic waves, which alter blood flow and metabolic activity at a deeper level than that provided by simple surface moist-heat applications.[39] The effect of ultrasonic tissue heating is theoretically related to increase in tissue temperature, increase in circulation, increase in uptake of painful metabolic by-products, and disruption of collagen cross-linking, which may affect adhesion formation. All of these effects may result in a more comfortable manipulation of muscles and a wider range of motion. In addition, intraarticular inflammation may also be reduced with ultrasonic applications. Ultrasonic treatments are usually provided by a physical therapist in combination with other treatment modalities.

Spray and stretch is an effective method for improving range of motion. The theory behind spray and stretch is the concept that significant superficial skin stimulation can produce an overriding or distracting effect on pain input that originates in the muscles and



• **Fig. 31.19** Botulinum toxin infiltration into the muscles of mastication.



• **Fig. 31.20** Jaw exercising. (A) Passive stretch applied through scissoring of the thumb and forefinger. (B) Physical therapy with a Therabite appliance to increase range of jaw motion.

joints.[40] By spraying a vapocoolant material such as fluoromethane over the lateral surface of the face, the muscles of mastication can be passively or actively stretched with a reduced level of pain.

Friction massage involves the use of firm cutaneous pressure sufficient to produce a temporary degree of ischemia. This ischemia and the resultant hyperemia have been described as a method for inactivation of trigger points, which are areas responsible for pain referred to muscles in the head and neck area.[41] More frequently, this technique may be useful in disrupting small fibrous connective tissue adhesions that may develop within the muscles during healing after surgery and injury or as a result of prolonged muscular shortening from restricted motion.

Physical therapists and other practitioners sometimes use transcutaneous electrical nerve stimulation (TENS) to provide pain relief for patients with chronic pain when other techniques have been unable to eliminate or reduce pain symptoms. The exact mechanism of action of TENS is not completely understood. The technique was initially based on the concept that stimulation of superficial nerve fiber with TENS may be responsible for overriding pain input from structures such as masticatory muscles and the TMJs. Interestingly, many patients who use TENS units experience pain relief that is longer in duration than the time during which the unit is actually applied. This may be a result of the release of endogenous endorphin compounds that can provide extended periods of decreased pain.

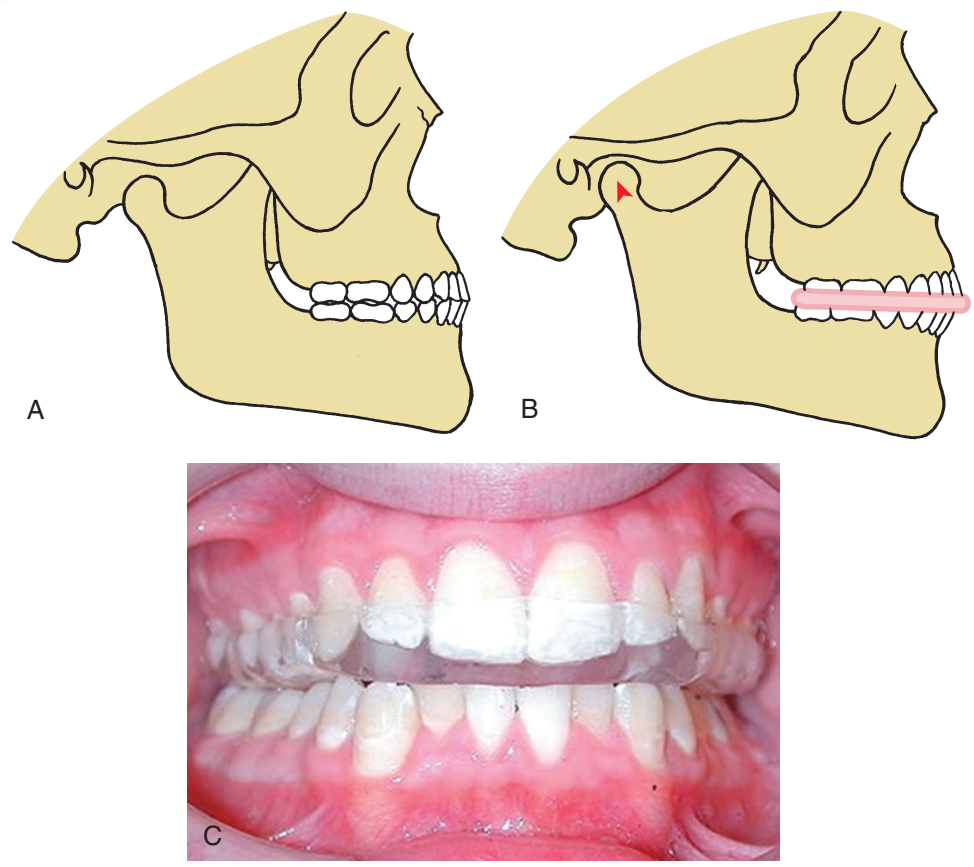
Each of the physical therapy modalities may be useful in the reduction of TMJ pain and increasing range of motion. The low cost of physical therapy compared with other medical treatment, the likelihood that some benefit will occur, and the minimal risk associated with these techniques are strong arguments for frequent use of physical therapy in the management of patients with TMD.

Splint Therapy

Occlusal splints are generally considered a part of the reversible or conservative treatment phase in the management of patients with TMD. Splint designs vary; however, most splints can be classified into three distinct groups: (1) autorepositioning splints, (2) anterior repositioning splints, and (3) muscular deprogrammers.

Autorepositioning Splints

The autorepositioning splints are also called *anterior guidance splints*, *superior repositioning splints*, or *muscle splints*. The splints are most frequently used to treat muscle problems or eliminate TMJ pain when no specific internal derangement or other obvious pathologic condition can be identified. However, these splints may be used in some cases, as in anterior disk displacement or DJD, in an attempt to unload or reduce the force placed directly on the TMJ area. These splints are designed to provide a flat surface with even contact in all areas of the occlusion. The splint provides full-arch contact without working or balancing interferences and without ramps or deep interdigitation that would force the mandible to function in one specific occlusal position (Fig. 31.21). This splint



• **Fig. 31.21** Autorepositioning splint. (A) Maximal interdigitation obtained with the condyle slightly down and forward. (B) Repositioning of the mandible by eliminating forced interdigitation of teeth results in posterior and superior repositioning of the condyle. (C) Clinical image of an occlusal splint.

allows the patient to seek a comfortable muscle and joint position without excessive influence of the occlusion. Nitzan has shown that properly designed splints can be effective in reducing intraarticular pressure.[20] An example of this type of splint would be in a patient with a class II malocclusion and significant overjet who continually postures forward to obtain incisor contact during mastication. Many of these patients complain of muscular symptoms and describe a feeling that they do not have a consistent, repeatable bite relationship. Wearing an autorepositioning splint allows full-arch dental contact with the condyles in a more posterior retruded position, which frequently results in reduction of muscle and joint symptoms.

Anterior Repositioning Splints

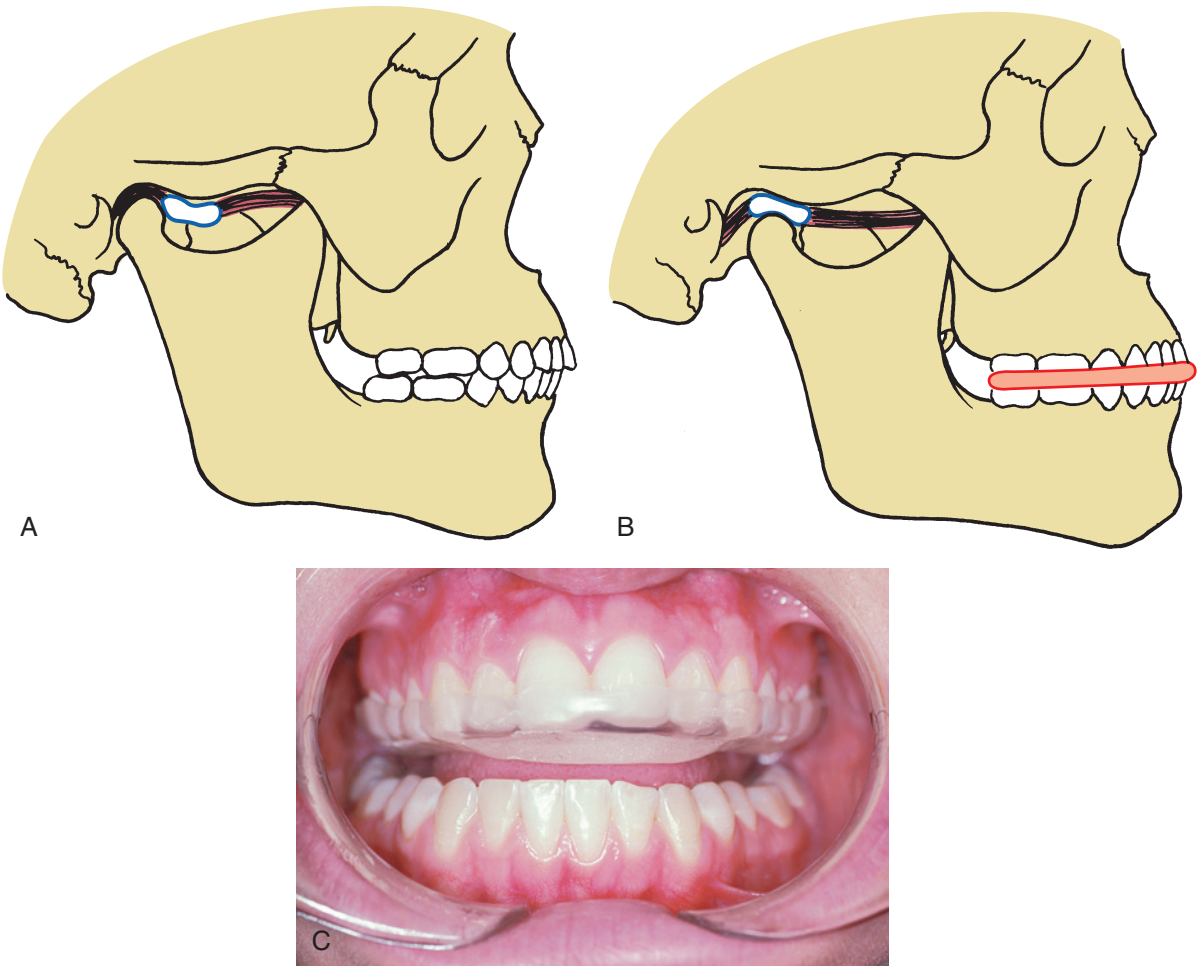
Anterior repositioning splints are constructed so that an anterior ramping effect forces the mandible to function in a protruded position (Fig. 31.22). This type of splint is most useful in providing temporary relief and, in rare cases, a long-term cure for anterior disk displacement with reduction. In these cases, the anterior position is determined by protrusion of the mandible necessary to produce the proper disk and condyle relationships (after the protruding or opening click has occurred).

The splint is usually worn 24 hours a day for several months. Theoretically, after the disk is repositioned for a long period, the posterior ligaments may shorten and maintain the disk in proper relationship to the condyle. Despite theoretical expectations, these splints are generally ineffective in producing permanent reduction of disk displacement. However, even when the splints are not curative, they often provide significant relief of discomfort in the acute stages of TMJ dysfunction.

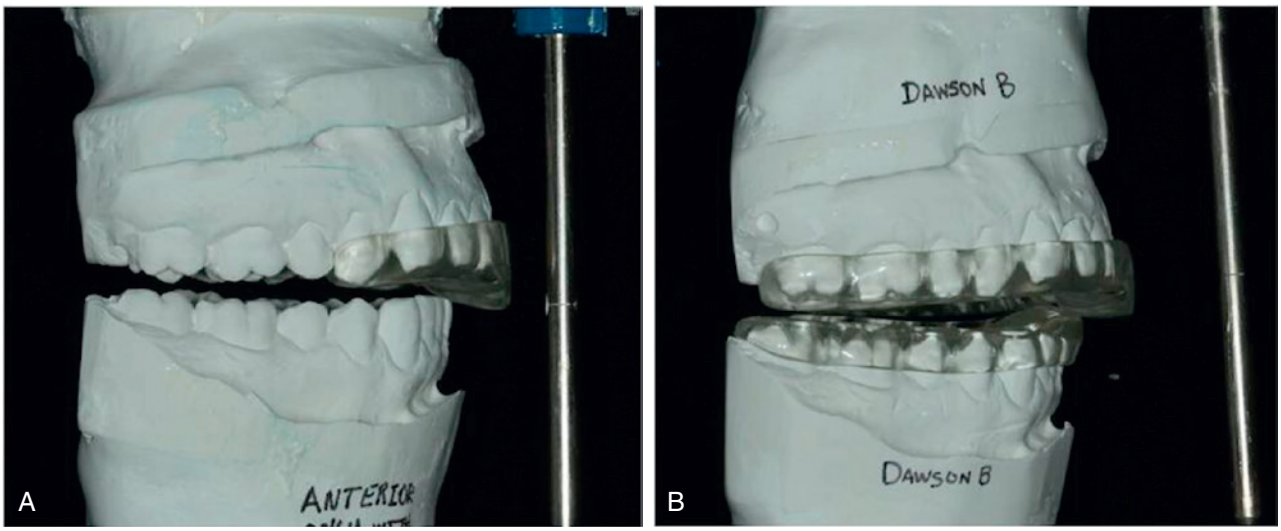
Muscular Deprogrammers

Splints that do not include posterior teeth are often referred to as muscular deprogrammers (Fig. 31.23A). They have been shown to lower muscle activity, especially in patients suspected of nighttime bruxism.[42,43] In theory, this may reduce myofacial pain and allow for improved results with passive stretching and other physical therapy modalities in patients with limited mouth opening related to the muscles of mastication.

The treating dentist should be aware that occluding against a muscular deprogrammer results in loading of the condyle. Therefore it should not be used in patients with intraarticular pain with occlusal loading. In addition, chronic use may result in supraeruption of the posterior teeth due to lack of occlusal contact, resulting



• **Fig. 31.22** Anterior repositioning splint. (A) An anteriorly displaced disk. (B) Disk interposition between the condyle and articular eminence, with an anterior repositioning splint in place. The anterior position of the mandible allows function with the condyle in appropriate relationship with the disk. (C) Clinical image of an anterior repositioning splint.



• **Fig. 31.23** Muscular deprogrammer. (A) Canine-to-canine anterior-only appliance. (B) Modified deprogrammer with occlusal coverage to prevent supraeruption of the posterior teeth.

in an anterior open-bite. As a result, one should only use a deprogrammer for 6 to 8 hours a day in order to minimize the risk of occlusal changes or add coverage of the posterior teeth that is left out of occlusion (Fig. 31.23B).

Interestingly, there are two additional occasions in which an anterior-only appliance may result in an anterior open bite. The first is when the patient has an undiagnosed CO/CR discrepancy. Use of the appliance may result in shutting off of the lateral pterygoid muscles, which could cause the condyles to sit in a more CR position. The key to managing this situation is to inform the patient ahead of time that this might occur and that the CO/CR discrepancy likely is contributing to their muscular pain. In this situation, the newly acquired open-bite should be treated with occlusal equilibration or orthodontics combined with orthognathic surgery.

The last situation in which an anterior open-bite may occur is when the deprogrammer is fabricated to only include the central incisors. The isolate force may cause intrusion of the anterior teeth. To avoid this problem, the splint should include the canines and incisors.

Permanent Occlusion Modification

After completion of a course of reversible treatment, many patients may be candidates for permanent modification of the occlusion. This permanent modification appears to be most appropriate when patients have had significant improvement in masticatory function and reduction in pain as a result of temporary alteration of occlusal position with splint therapy. Permanent occlusion modification may include occlusal equilibration, prosthetic restoration, orthodontics, and orthognathic surgery. Although the relationship between occlusion abnormalities and TMD is unclear, it does appear that permanent modification of the occlusion in indicated patients may provide long-term improvement in symptoms of pain and dysfunction.

Temporomandibular Joint Surgery

Despite the fact that many patients with internal pathologic conditions of the joint improve with reversible nonsurgical treatment, some patients eventually require surgical intervention to improve masticatory function and decrease pain. Several techniques are currently available for correction of a variety of TMJ derangements.

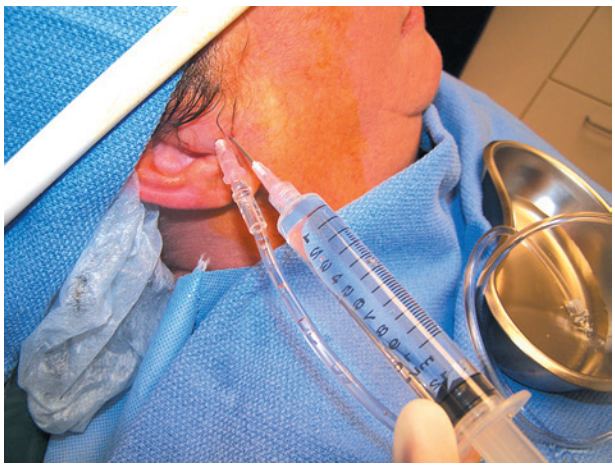
Arthrocentesis

Arthrocentesis is a minimally invasive technique that involves placing ports (needles or small cannulas) into the TMJ to lavage the joint and to break up fine adhesions. Most patients undergoing arthrocentesis do so with intravenous sedation and an auriculotemporal nerve block. Several techniques have been described for TMJ arthrocentesis.[17,41] The most common method involves initially placing one needle into the superior joint space (Fig. 31.24). A small amount of lactated Ringer solution is injected to distend the joint space and release fine adhesions that may be limiting disk mobility. With the joint insufflated, a second needle is placed into the superior joint space, allowing thorough lavage with large amounts of fluid (approximately 200 mL).

During arthrocentesis, the jaw can be gently manipulated. At the conclusion of the procedure, steroids, local anesthesia, or a combination of both can be injected into the joint space before the needles are withdrawn. Discomfort after the procedure is managed with mild analgesics or NSAIDs. Some type of exercise regimen or physical therapy is accomplished during the recovery period.

Many types of internal pathologic conditions of the joint appear to respond well to arthrocentesis. The most common use appears to be in patients with anterior disk displacement without reduction. Treatment appears to be effective, with results similar to or better than other types of arthroscopic and open surgical procedures. Nitzan demonstrated that arthrocentesis produced significant improvement in incisal opening and reduction of pain in patients with persistent and severe closed lock.[41]

The success seen with arthrocentesis has several potential explanations. When disk displacement occurs, negative pressure may develop within the joint, causing a "suction cup" effect between the disk and the fossa. Distending the joint obviously eliminates the negative pressure. In some cases of more chronic disk displacement, some adhesion may develop between the disk and the fossa. With arthrocentesis, the distention under pressure can release these adhesions. Capsular constriction may occur as a result of joint



• **Fig. 31.24** Arthrocentesis. Port placement into the superior joint space paralleling the external auditory meatus to allow lavage and lysis of fine adhesions.

hypomobility and can be stretched with pressure distention. Finally, an accumulation of some of the chemical mediators described previously may occur. The simple flushing action in the joint may eliminate or decrease biochemical factors contributing to inflammation and pain.

Arthroscopy

Arthroscopic surgery has become one of the most popular and effective methods of diagnosing and treating TMJ disorders.[44] The technique involves placement of a small cannula into the superior joint space, followed by insertion of an arthroscope to allow direct visualization of all aspects of the glenoid fossa, superior joint space, and superior aspect of the disk. Arthroscopic evaluation enables the surgeon to visualize the joint and therefore contributes to the diagnosis of the internal pathologic condition of the joint. Lysis of adhesions and lavage of the joint are also completed.

More sophisticated arthroscopic operative techniques have been developed, increasing the ability of the surgeon to correct a variety of intracapsular disorders. Current surgical techniques usually involve the placement of at least two cannulas into the superior joint space. One cannula is used for visualization of the procedure with the arthroscope, whereas instruments are placed through the other cannula to allow instrumentation in the joint (Fig. 31.25). Instrumentation used through the working cannula includes forceps, scissors, sutures, medication needles, cautery probes, and motorized instrumentation such as burrs and shavers. Laser fibers can also be used to eliminate adhesions and inflamed tissue and incise tissue within the joint. Disk manipulation, disk attachment release, posterior band cautery, and suture techniques have been developed in an attempt to reposition or stabilize displaced disks.[45] Although it appears that attempts to reposition displaced disks do not result in anatomic restoration of normal disk position, patients undergoing this type of treatment appear to have significant clinical improvement after arthroscopic surgery.[46]

Arthroscopic surgery has been advocated for treatment of a variety of TMJ disorders, including internal derangements, hypomobility as a result of fibrosis or adhesions, DJD, and hypermobility. The removal of disks with gross perforations can be accomplished with the arthroscope while preserving the surrounding synovial tissue for lubrication.[47] The efficacy of arthroscopic treatment appears to be similar to that of open joint procedures, with the advantage of less surgical morbidity and fewer and less severe complications.[45-48]

As with most TMJ surgical procedures, patients are placed on some type of physical therapy regimen and often continue splint therapy to help decrease loading on the joint during healing.[49]

Disk-Repositioning Surgery

Open joint procedures are generally reserved for individuals who have not responded favorably to other measures. Open surgical exploration of the TMJ traditionally proceeds after conservative techniques have been maximized. Disk plication and repositioning through a variety of open approaches has been a common surgical procedure performed to correct anterior disk displacement that has not responded to nonsurgical treatment and that most frequently results in persistent painful clicking joints or closed locking. Although these disorders are often managed surgically with arthrocentesis or arthroscopy, many surgeons still prefer this type of surgical correction. In this operation, the displaced disk is identified and repositioned into a more normal position by removing a wedge of tissue from the posterior attachment of the disk and suturing the disk back to the correct anatomic position (Fig. 31.26). In some cases, this procedure is combined with recontouring of the disk, articular eminence, and mandibular condyle. After surgery, patients generally begin a nonchew diet for several weeks, progressing to a relatively normal diet in 3 to 6 months. A progressive regimen of jaw exercises is also instituted in an attempt to obtain normal jaw motion within 6 to 8 weeks after surgery.

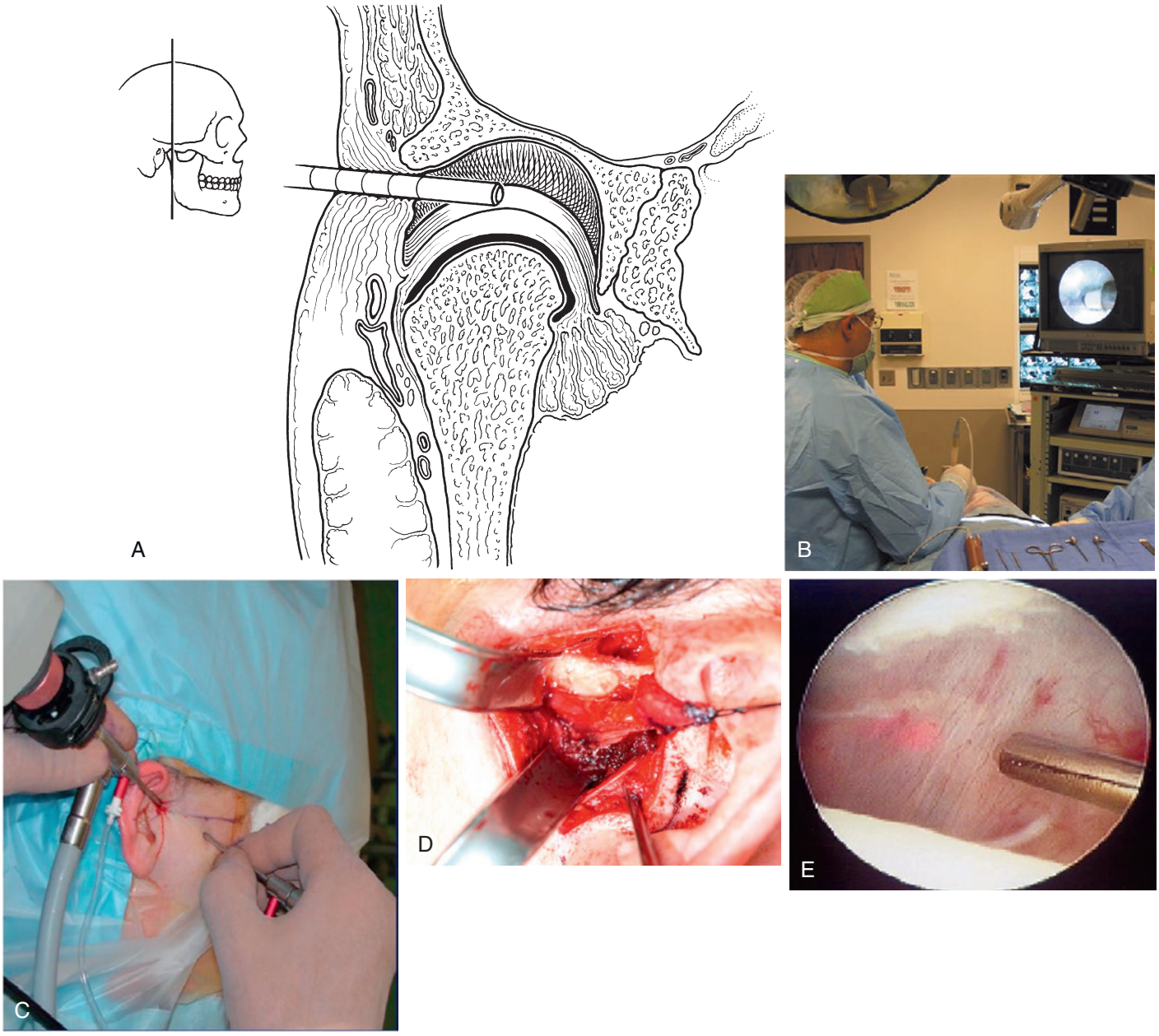
In general, the results of open arthroplasty have been favorable, with a majority of patients experiencing less pain and improved jaw function.[50] Unfortunately this surgery does not produce improvement in all patients, with 10% to 15% of patients describing no improvement or a worsening of the condition.

Disk Repair or Removal

In some cases, the disk is so severely damaged that the remnants of disk tissue must be removed. Diskectomy without replacement was one of the earliest surgical procedures described for treatment of severe TMJ internal derangements.[51] With current technology, the diskectomy procedure can be performed through arthroscopic techniques to minimize scar tissue formation and preserve lubrication provided by the synovium. Although this technique has been widely used, a wide variation seems to exist in clinical results, with some joints showing minimal anatomic changes and significant clinical improvement and some joints demonstrating severe degenerative changes with continued symptoms of pain and dysfunction.

In advanced internal pathologic conditions of the joint, the disk may be severely damaged and perforated but may have adequate remaining tissue so that a repair or patch procedure can be accomplished. Autogenous grafting techniques include the use of dermis, auricular cartilage, or temporalis fascia.[52,53] Dermis harvested from the abdomen or upper lateral thigh placed into the joint functions as an interpositional disk (Fig. 31.27). The dermal graft with associated adipose tissue provides lubrication and coverage of the articular surfaces.

Another alternative to the use of a free graft involves rotation of a temporalis muscle flap into the joint to provide interpositional tissue between the condyle and the fossa.[54] The posterior fibers of the temporalis are mobilized from the temporal bone with an



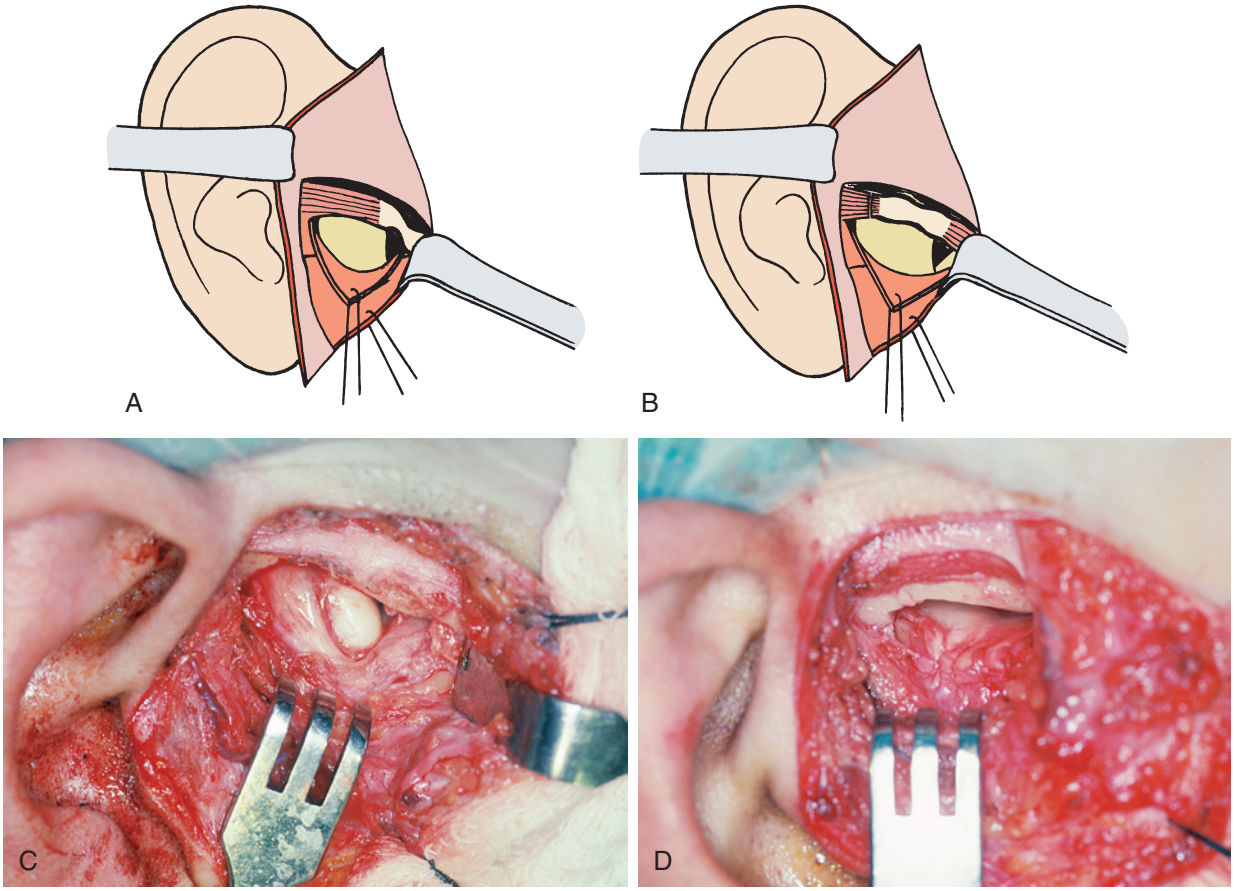
• **Fig. 31.25** Temporomandibular joint arthroscopy. (A) Arthroscope placement in the superior joint space. (B) Operating room orientation for arthroscopy. (C) Arthroscope orientation for visualization of the temporomandibular joint. (D) View of the superior joint space with the disk inferiorly and fibrous adhesions limiting disk mobility. (E) Instrumentation through a second port (radiofrequency, laser, motorized shaver) allows surgical manipulation within the joint space.

anterior pedicle originating from the coronoid process (Fig. 31.28). The maintenance of the anterior aspect of the temporalis muscle provides a blood supply to the flap, enhancing viability. The fascia, muscle, and the periosteum are ligated to prevent separation and are rotated under the zygomatic arch. The flap is positioned over the condyle and sutured to the residual retrodiscal tissue. The preservation of the overlying fascia may aid in continued lubrication of the obliterated joint.

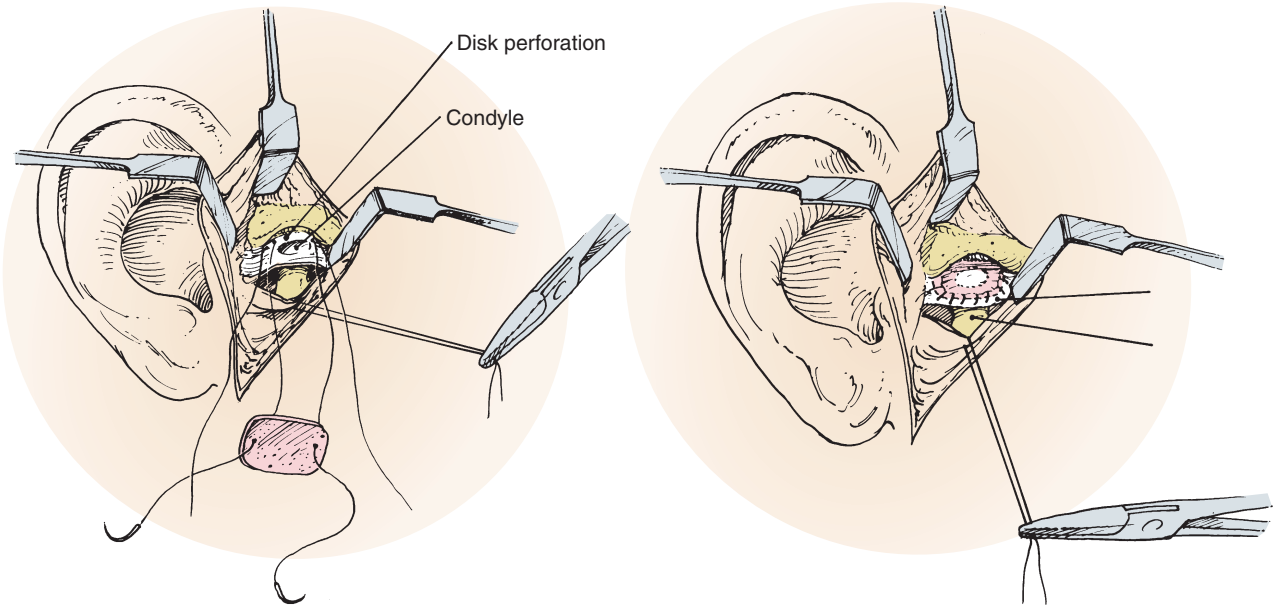
Modified Condylotomy

The modified condylotomy is an osteotomy completed in a manner identical to the vertical ramus osteotomy described in Chapter 26 (Fig. 31.29). When used for treatment of TMJ problems, the osteotomy is completed, but no wire or screw fixation is placed, and the patient is placed into intermaxillary fixation for a period ranging from 2 to 6 weeks. The theory behind this operation is that muscles attached to the proximal segment (i.e., segment attached to the condyle) will passively reposition the condyle, resulting in a more favorable relationship between the condyle, the disk, and the fossa.[55,56]

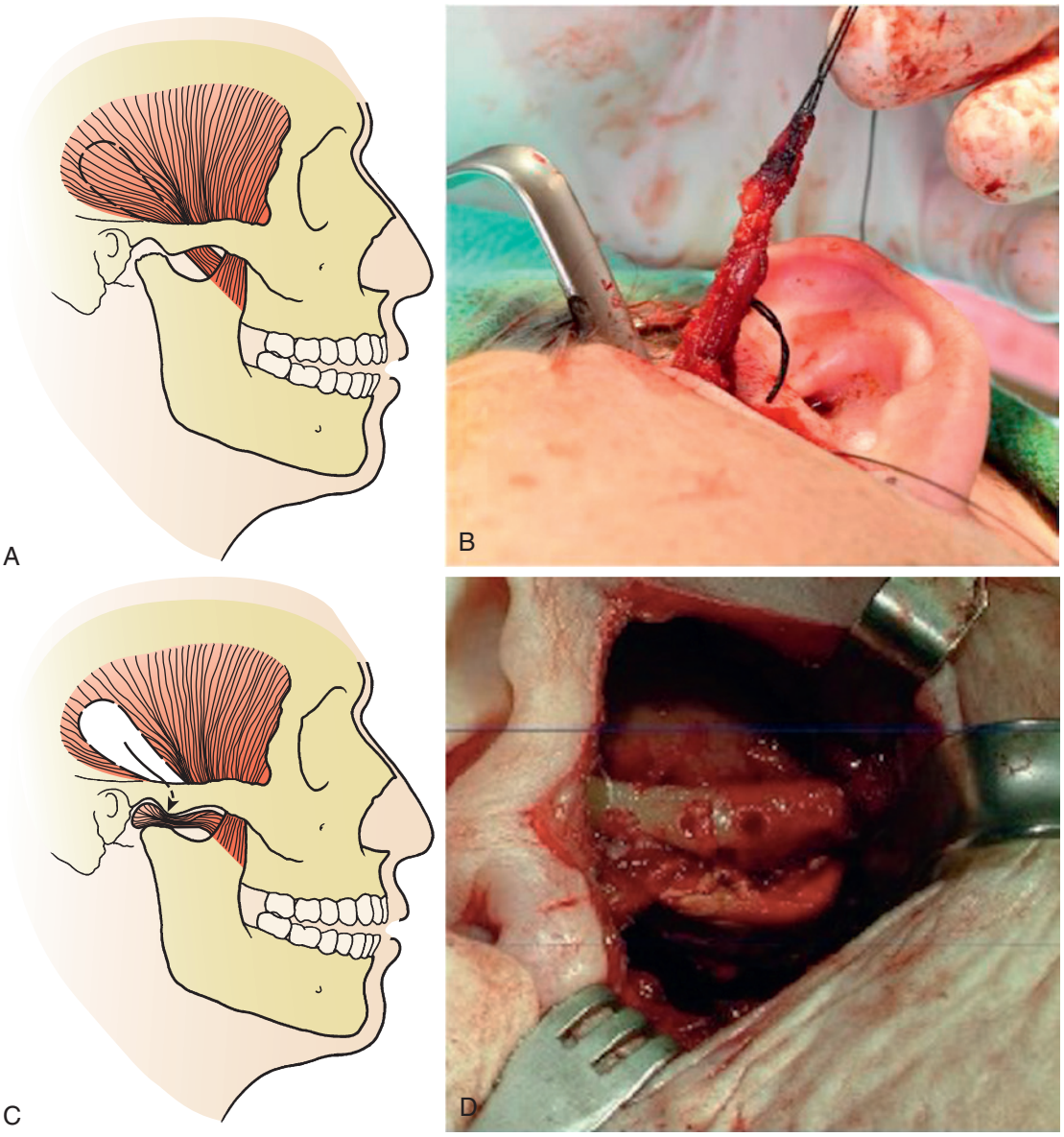
This technique has been advocated primarily for treatment of disk displacement with or without reduction. DJD and subluxation or dislocation have also been suggested as possible indications for use of this technique. Although this method of surgical treatment has been controversial, it appears to provide significant clinical



• **Fig. 31.26** Open temporomandibular joint surgery. (A) Preauricular incision through skin subcutaneous tissue and temporomandibular joint capsule, exposing an anteriorly displaced disk. (B) A wedge of tissue is removed from the posterior attachment area, and the disk is repositioned and sutured into its correct position. (C) Displaced disk anterior to mandibular condyle. (D) Disk repositioning and plication via open arthrotomy.



• **Fig. 31.27** Dermal graft used to patch a small perforation of the disk.



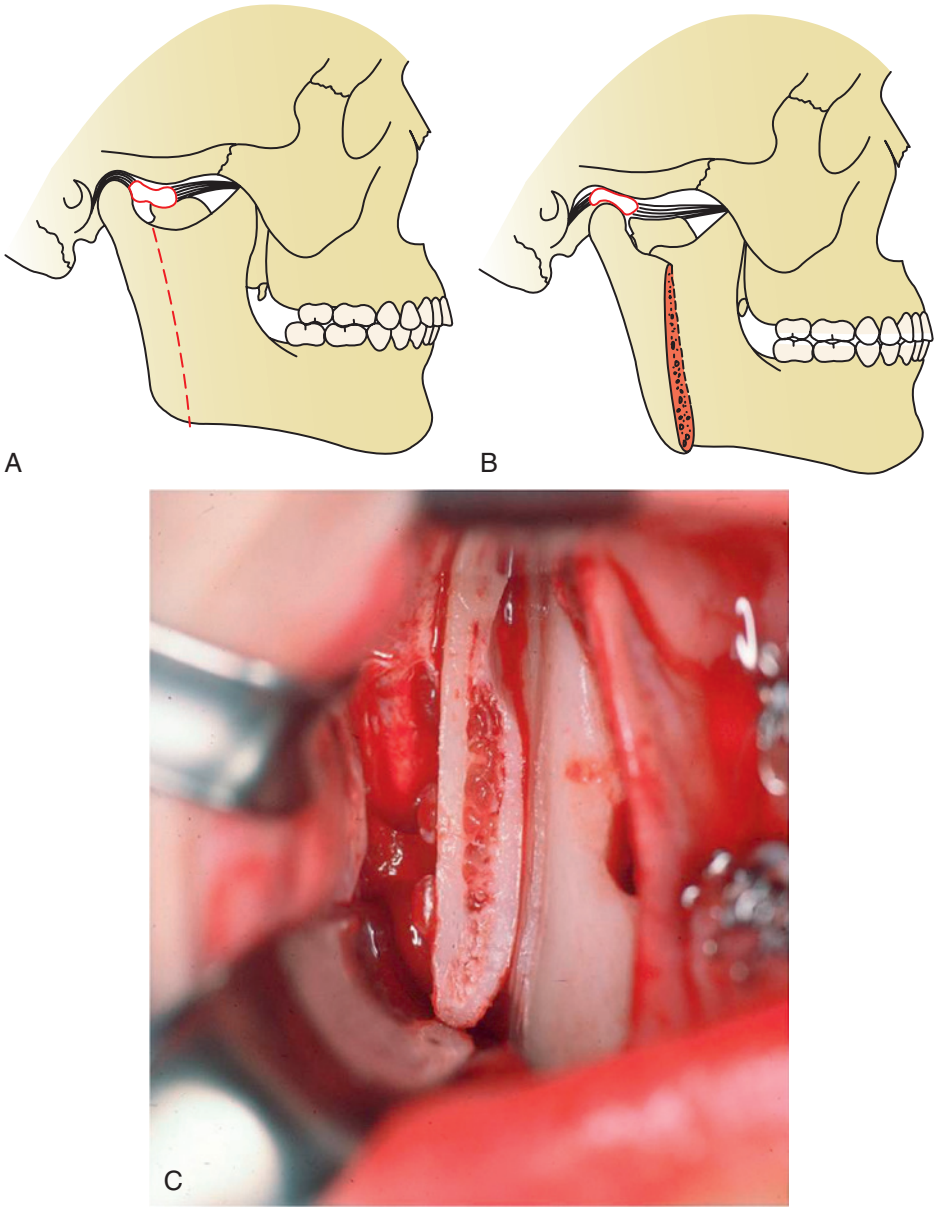
• **Fig. 31.28** (A) Temporalis muscle flap. (B) Elevation of the pedicled flap. (C) Rotation of the temporalis muscle flap recreating an articular surface for the condyle. Preservation of the overlying fascia allows lubrication of the joint space. (D) The temporalis muscle flap secured to the residual retrodiscal tissue.

improvement in a variety of TMJ disorders. This procedure is contraindicated in patients who are known bruxers, as they tend to reseat the condyle due to muscle hyperactivity. It is also relatively contraindicated in patients who are missing posterior teeth due to their tendency to develop anterior open-bites once intermaxillary fixation is released.

Total Joint Replacement

In some cases, a pathologic condition of the joint results in destruction of joint structures and in loss of vertical dimension of the condyle and posterior ramus, malocclusion, limited opening, and severe pain. In these cases, reconstruction or replacement of condylar and fossa components of the TMJ may be necessary. Surgical techniques may involve replacement of the condyle or fossa but most commonly include both elements.

Alloplastic joint prostheses are usually the only viable surgical option for patients with significant destruction of TMJ structures or those who have had poor results from previous surgical treatments that have resulted in severe pain, limited mouth opening or ankylosis, and malocclusion. In the past, several types of prosthetic joint replacement have been available.[57] Unfortunately, long-term results of prosthetic joint replacements placed prior to the mid-1990s have been disappointing because of a variety of engineering and biologic problems. However, current prosthetic joints have been shown to be a safe, effective, and reliable treatment modality for those with advanced disease.[58,59] Total joint replacement aims to restore function through improved range of motion and reduction in pain. Older joint prostheses met with limited success because of the excessive scar tissue associated with multiple previous open joint surgeries, mechanical failure, and foreign body reaction from wear debris. Newer-generation joint prostheses have improved

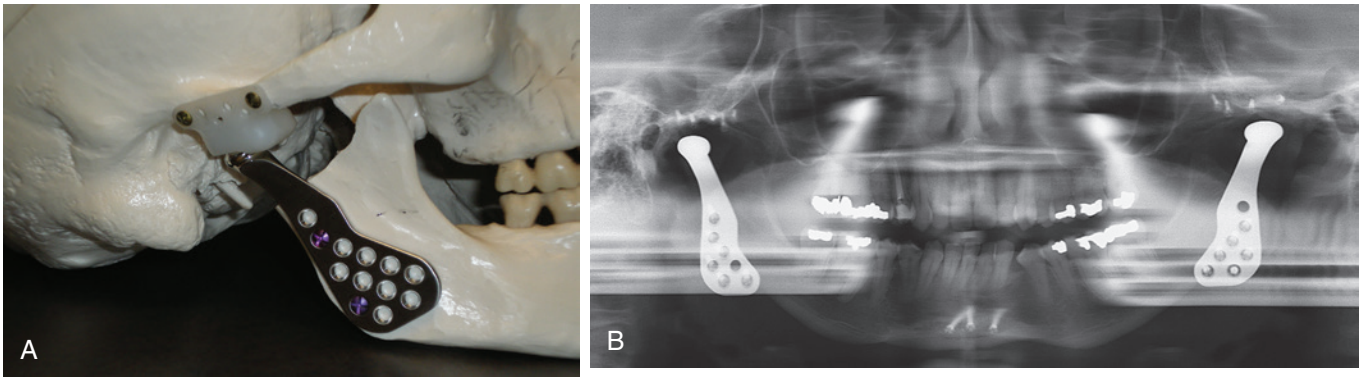


• **Fig. 31.29** (A) The modified condylotomy osteotomy is identical to the intraoral vertical ramus osteotomy. (B) The medial pterygoid muscle is stripped from the proximal segment, resulting in condylar sag to correct internal derangement. (C) Clinical image showing intraoperative position of the bony segment. No fixation is used after the osteotomy. The patient is placed in maxilla-mandibular fixation for 2 to 6 weeks while the segments heal.

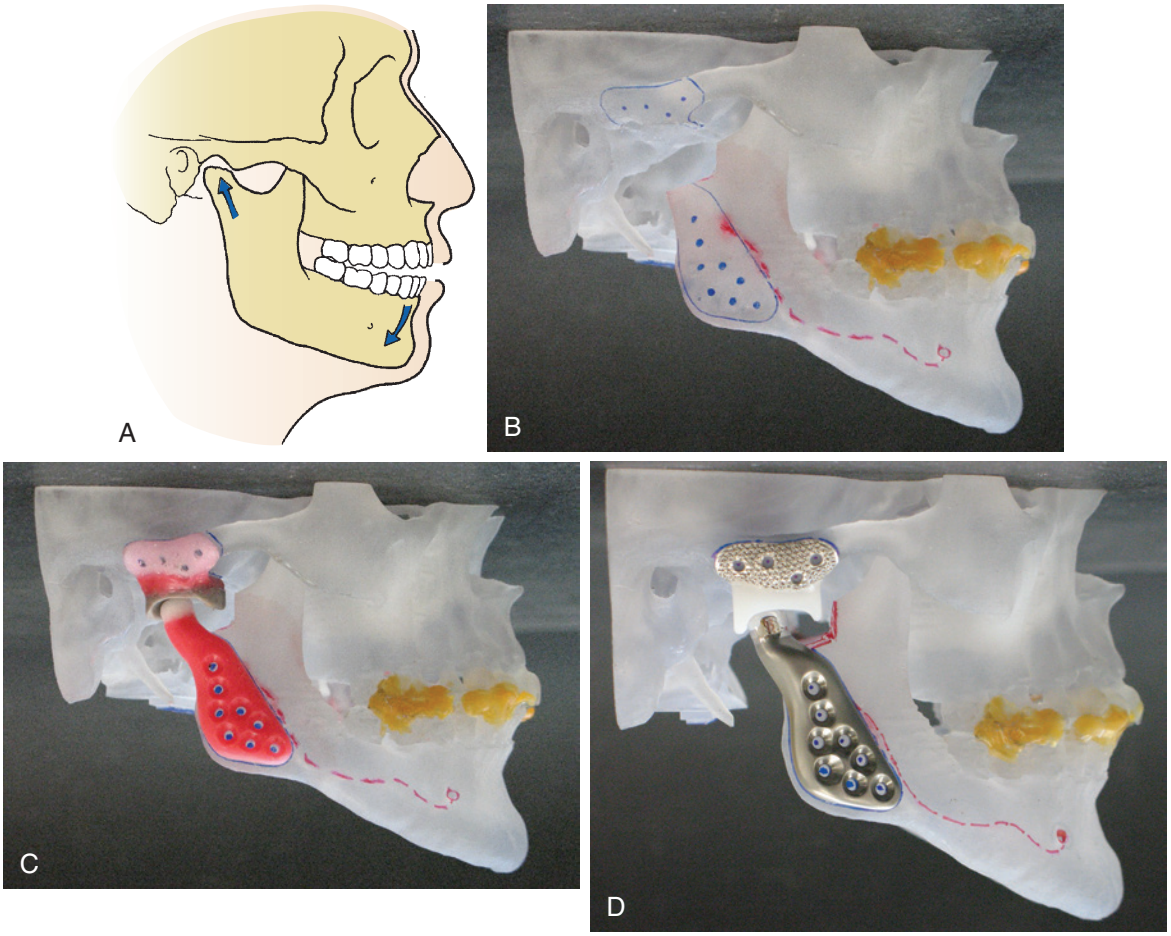
engineering, better biocompatibility, and materials with greater wear resistance. These recent advantages have provided significant improvement in the outcome after total joint replacement.[58,59]

Total joint replacement can be completed with standard preformed fossa and condyle parts (Fig. 31.30) or with custom fabrication of joint components. Prefabricated fossas are sized based on the available bone for fixation along the zygomatic arch, whereas the condylar component is sized based on the height of the native condyle-ramus unit. Custom joints are generated from a wax template created on a stereolithic model based on three-dimensional CT scan imaging of the articular fossa and mandibular anatomy (Fig. 31.31).

Access to the joint and ramus are achieved through a preauricular and retromandibular incision, respectively. A nerve simulator is used during the dissection to ensure preservation of the facial nerve to the muscles of facial expression. Soft tissue dissection is completed to expose the TMJ capsule, condyle, coronoid, and ramus. Removal of the diseased condyle is completed, followed by debridement of the articular fossa. At this point, if a prefabricated prosthesis is being placed, the articular eminence must be flattened to allow for adaptation of the fossa component (Fig. 31.32). Next, sizers are placed along the lateral aspect of the ramus to determine the correct size of the condylar component. Once the correct size is chosen, the lateral aspect of the ramus must be flattened to eliminate potential high spots underneath the prosthesis that might result in micromotion. Regardless of the prosthesis chosen, the joint fossa and condylar prosthesis are then placed after the occlusion has been established with maxillomandibular fixation and secured



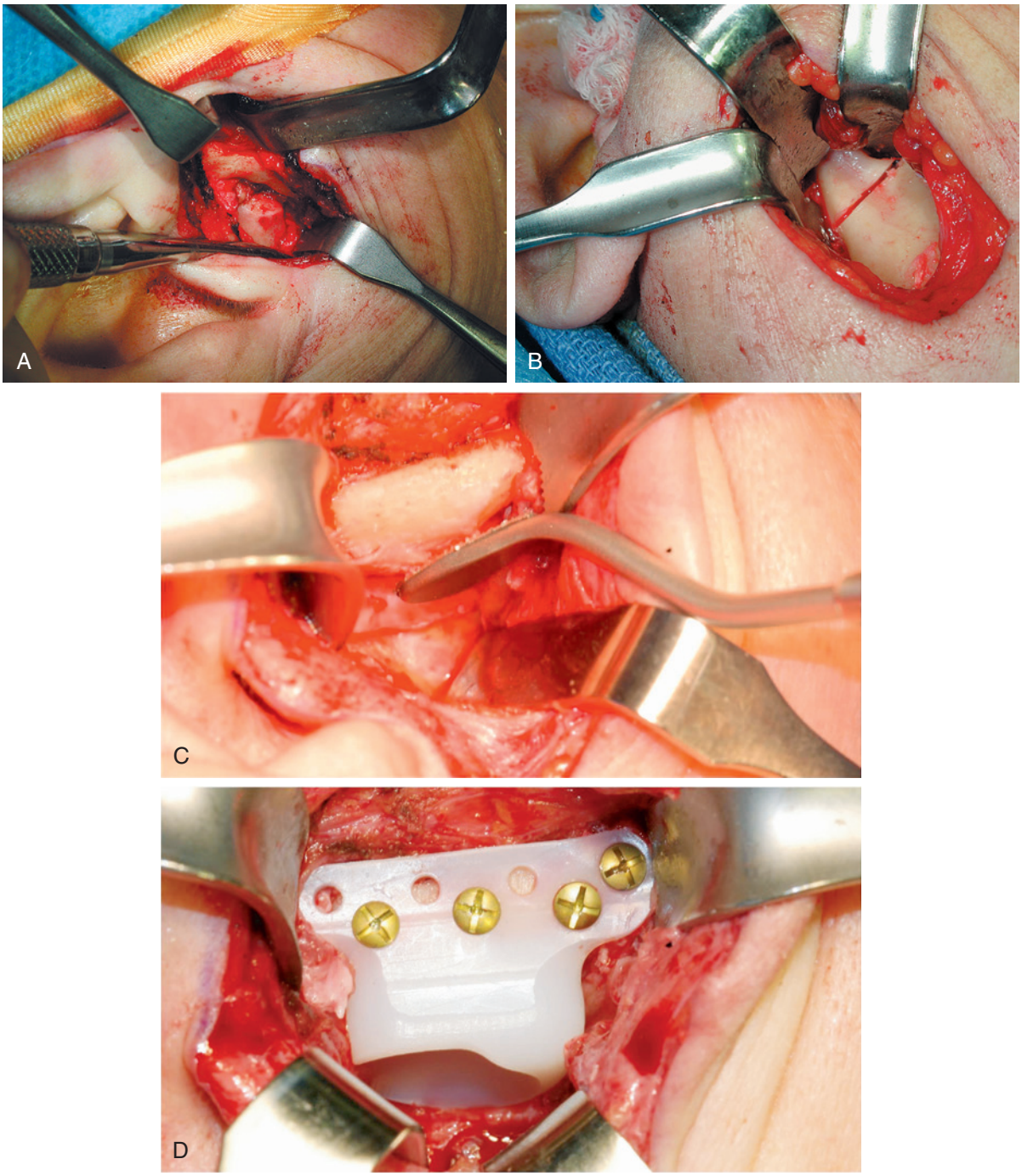
• **Fig. 31.30** (A) Skull model demonstrating a stock temporomandibular joint prosthesis. The patient's skull is modified to achieve a proper fit of the prosthesis. (B) Postoperative panoramic radiograph after joint replacement surgery.



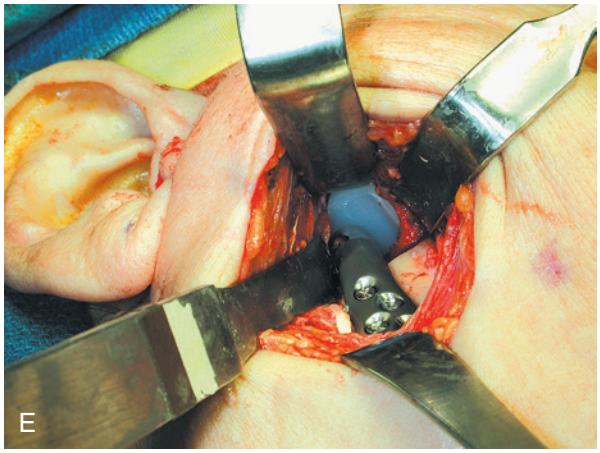
• **Fig. 31.31** (A) Severe degenerative joint disease resulting in open-bite malocclusion caused by resorption of the condyle. (B) Stereolithic model, with proposed condylectomy and closure of open bite from which the custom prosthesis will be fabricated. (C) Wax rendering of the prosthesis, which allows the surgeon to make modifications before final fabrication of the joint. (D) Final prosthesis.

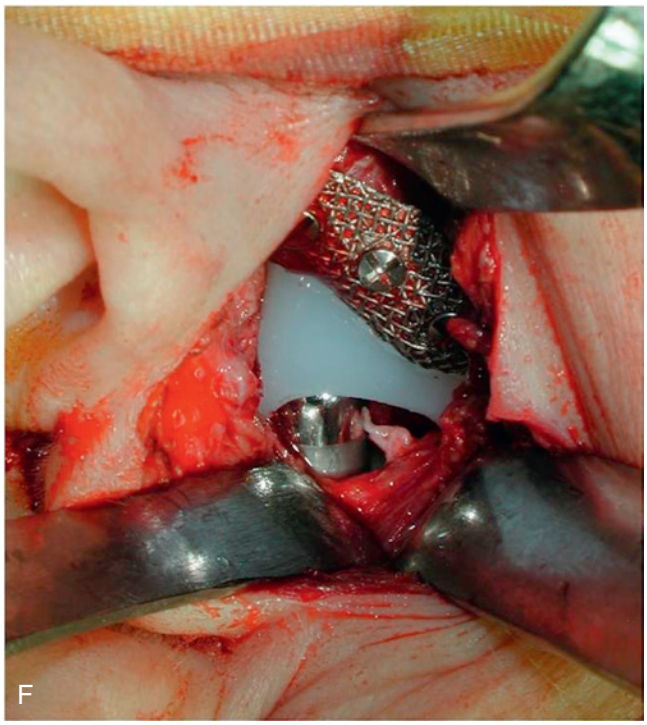
with bone screws. The established occlusion is verified while maintaining sterility of the surgical field. Manipulation of the mandible intraoperatively allows for evaluation of joint function in the absence of muscular influences.

Like other surgeries performed on the TMJ, postoperative physical therapy helps minimize intracapsular scarring and lengthen the muscles of mastication. The end result would be improvement of mouth opening. Since the attachments of the lateral pterygoid muscles to the condylar neck are removed, the recipient of the joint prosthesis will no longer have the ability to translate the condyle during opening. In addition, they will no longer be able to perform excursive nor protrusive movements of the mandible.



• **Fig. 31.32** (A) Exposure via a preauricular approach confirms the severe degeneration of the condyle. (B) Bone cut for condylectomy completed with sagittal saw while protecting important adjacent neurovascular structures. (C) Flattening of the articular eminence in preparation for a prefabricated fossa. (D) Fixation of the prefabricated fossa.





• **Fig. 31.32, cont'd** (E) Positioning of the condyle and fossa in total joint reconstruction. (F) Custom fossa and condyle in their final position.

Combined Orthognathic Surgery and Alloplastic Temporomandibular Joint Reconstruction

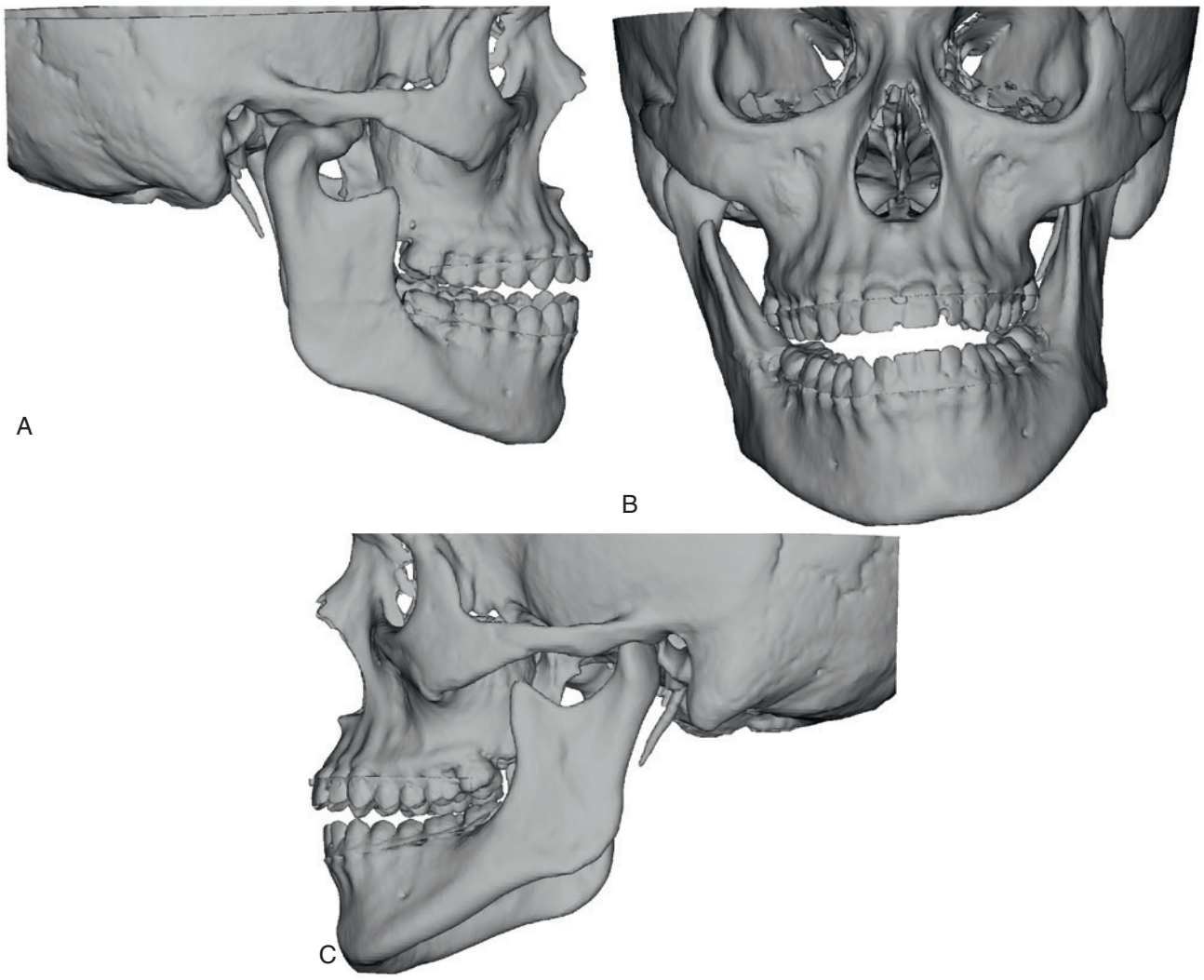
Occasionally a patient may present with both a skeletal-facial deformity and an end-stage TMJ pathologic condition (Fig. 31.33). In this scenario, orthognathic surgery combined with alloplastic TMJ reconstruction should be considered.[60] Commonly the dentofacial deformity occurs as a result of the TMJ disease—either DJD or abnormal condylar growth.

TMJ disorders commonly associated with skeletal-facial deformities include reactive arthritis, condylar hyperplasia or hypoplasia, idiopathic condylar resorption, congenital deformation, trauma, or other end-stage TMJ pathologic conditions. With the exception of condylar hyperplasia, these common TMJ disorders often result in a loss of condylar-ramus height. Patients with advanced disorders will have a steep mandibular plane angle, loss of chin projection, and possibly an anterior or posterior open bite. Their chief complaints may include joint or facial pain, difficulty chewing, and esthetics. For these patients, one might consider a combination of orthognathic surgery and alloplastic joint reconstruction. If the patient has a unilateral TMJ pathologic condition, one would consider a Le Fort I osteotomy combined with a total joint reconstruction on the pathologic side and a sagittal split osteotomy on the contralateral side. For a bilateral TMJ pathologic condition, one would consider a Le Fort I osteotomy combined with bilateral total joint reconstruction.

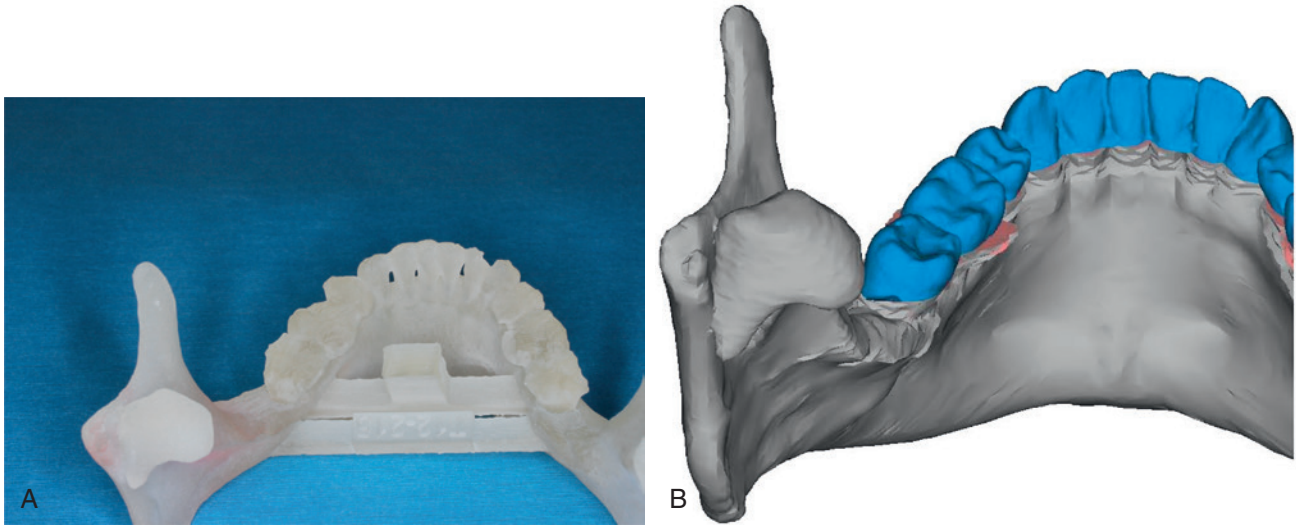
TMJ reconstruction plus mandibular advancement with custom alloplastic total joint prostheses in conjunction with a maxillary osteotomy, for counterclockwise rotation of the maxillo-mandibular complex, has been shown to be a stable procedure.[61] However, the surgery requires meticulous planning to restore form and function to the patient. The difficulty of the surgery arises from the fact that the joint prosthesis must be manufactured to correspond with the planned new position of the maxilla and mandible. Any inaccuracy may result in a persistent malocclusion and compromised facial esthetics.

Within the last decade, there has been a paradigm shift in surgical planning to help combat associated inaccuracies. Surgeons are no longer using analog models to predict jaw position and occlusion. There were too many steps in which inaccuracies could occur. Errors in data acquisition could occur in impressions, bite registration, face-bow transfer, and model surgery. Another step that may have also introduced errors during planning was when the intermediate occlusion was established on a stereolithographic model. It is very common for these models to have gross inaccuracies in tooth anatomy (Fig. 31.34). There are two reasons for this. The first is that patients typically have their images taken in the CT scanner with their mouths closed. Having their upper and lower teeth touch during the imaging process ultimately distorts the image quality of the occlusal surfaces of the teeth. The other reason is that metallic restorations cause scattering of the image. This scattering is then transferred to the stereolithographic model. The surgeon is then left to establish mandibular position based off of hand articulation of poor occlusion.

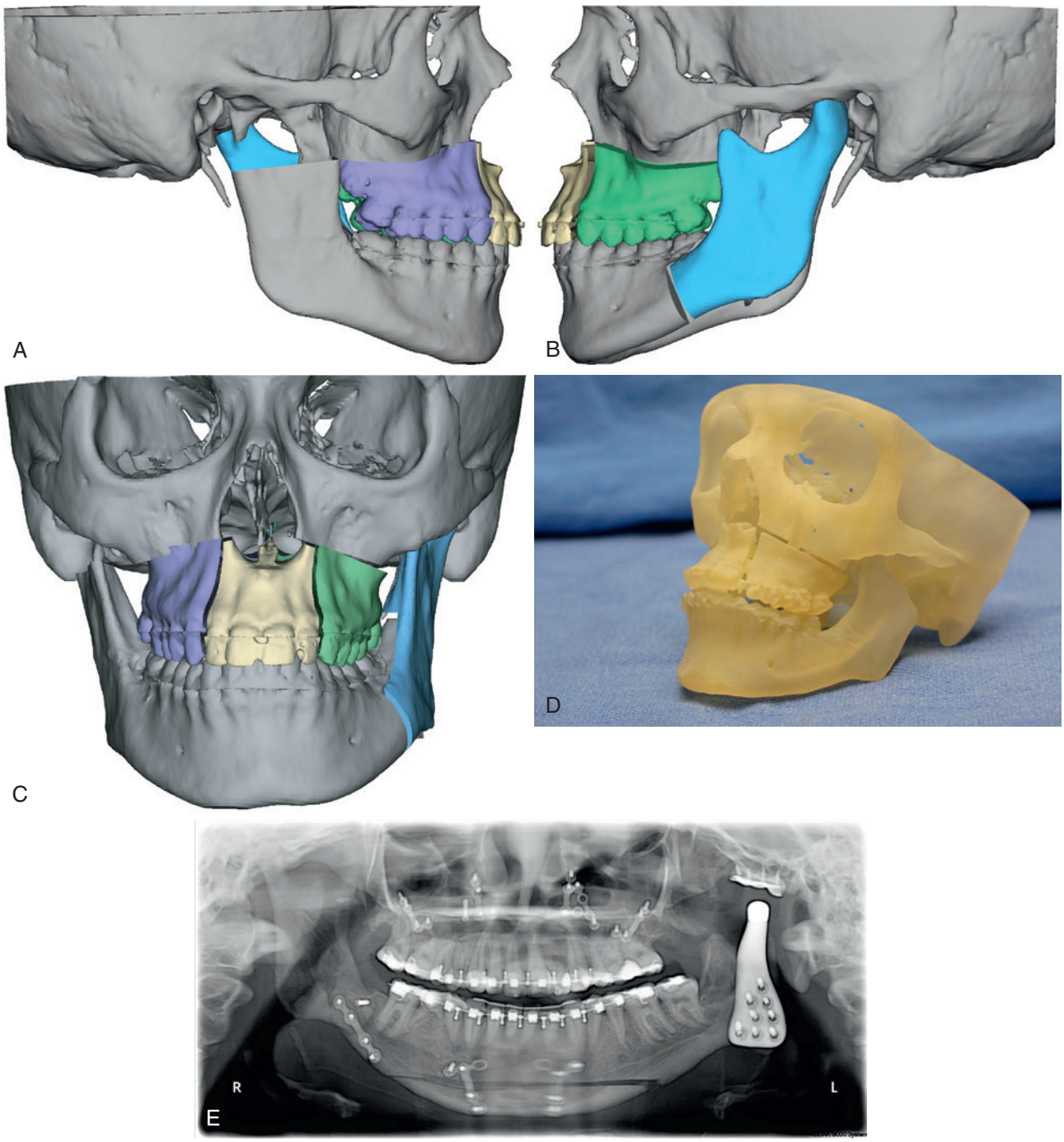
Digital planning, or virtual surgical planning, has become the new standard of care with regard to surgical planning. First described by Gateno and colleagues,[62] and made popular by orthognathic surgeons, patient data from a CT scan and an intraoral scan are merged and manipulated digitally to more accurately create the new jaw position and occlusion, thus minimizing the risk of a postoperative malocclusion or poor facial esthetics. Once the data has been merged and manipulated to create a new virtual occlusion and jaw position, a one-piece stereolithographic model can be manufactured (Fig. 31.35). From this point on, the custom TMJ prosthesis is manufactured exactly the same as traditional joint reconstruction, which has been previously described. The



• **Fig. 31.33** Three-dimensional imaging of a patient with facial canting and an open bite secondary to a right temporomandibular joint osteochondroma.



• **Fig. 31.34** (A) Occlusal view of a stereolithographic model. The occlusal surfaces of the teeth have very distorted anatomy on the model. (B) Digital image of the same patient. The digital images of the patient's occlusion have been merged with the computed tomography scan data to create improved accuracy.



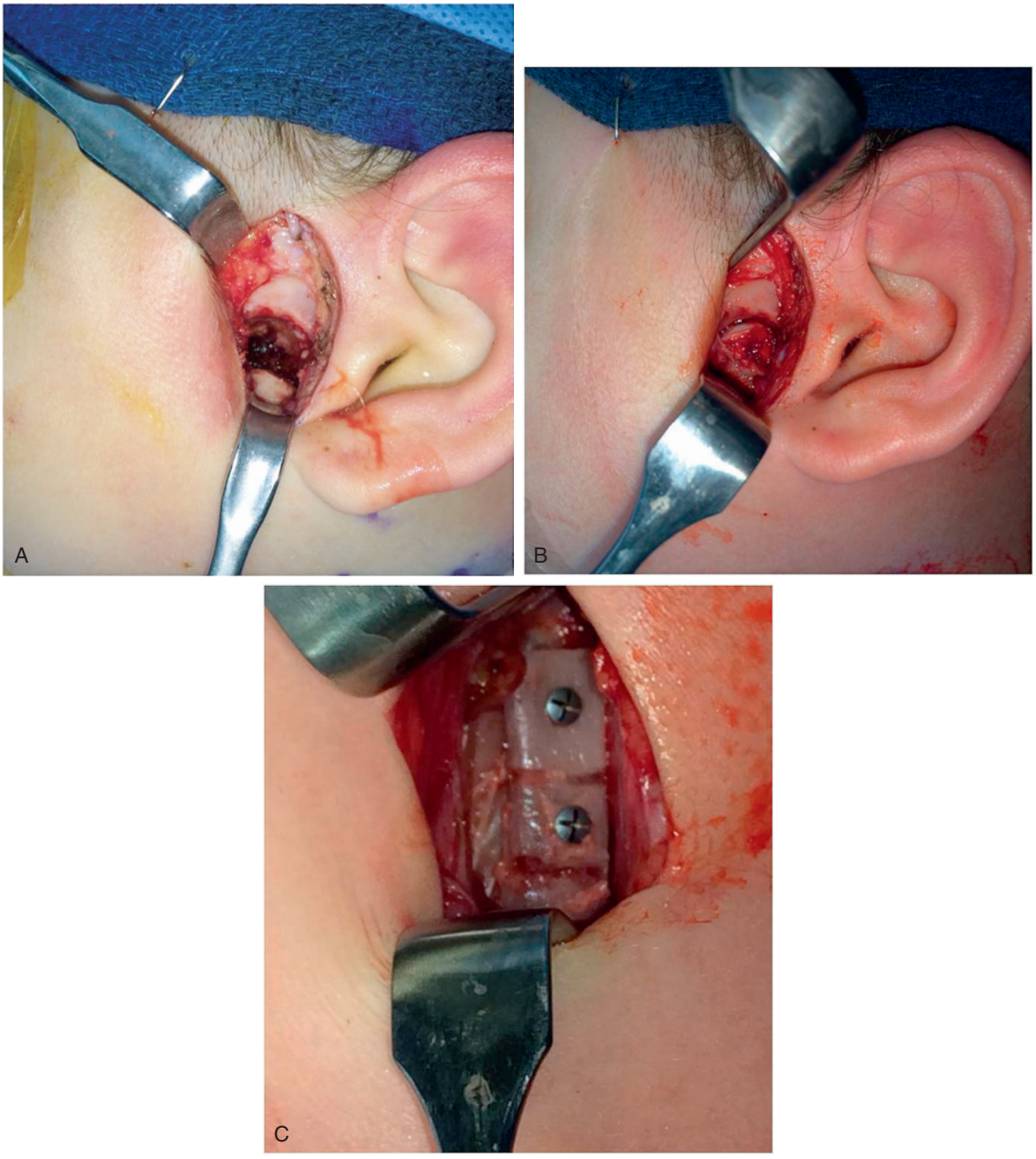
• **Fig. 31.35** Simulated surgery conducted through virtual planning software allows the surgeon to minimize errors associated with traditional analog techniques. (A) View of the right side with the pathologic condyle removed with a subcondylar osteotomy. (B) Left-side view showing sagittal split osteotomy. (C) Frontal view showing accurate correction of the facial asymmetry. (D) One-piece stereolithographic model made after virtual surgical planning for the fabrication of an alloplastic custom temporomandibular joint prosthesis. (E) Postoperative Panorex of a patient who underwent a combined temporomandibular joint reconstruction and orthognathic procedure.

intraoperative steps to the surgery are also similar to traditional joint reconstruction and orthognathic surgery; however, care must be taken to prevent contamination of the prostheses with oral bacteria.

As with most TMJ surgeries, postoperative physical therapy is recommended. However, passive range of motion stretches should be avoided if a LeFort osteotomy is performed in conjunction with the joint reconstruction. Passive stretching against an unstable maxilla may result in a nonunion or fibrous union of the maxillary osteotomy. If the patient has severe limited mouth opening prior to the joint reconstruction, the surgeon may elect to stage the procedures so that the patient can perform the passive stretches against a stable maxilla.

Temporomandibular Joint Reconstruction in the Growing Patient

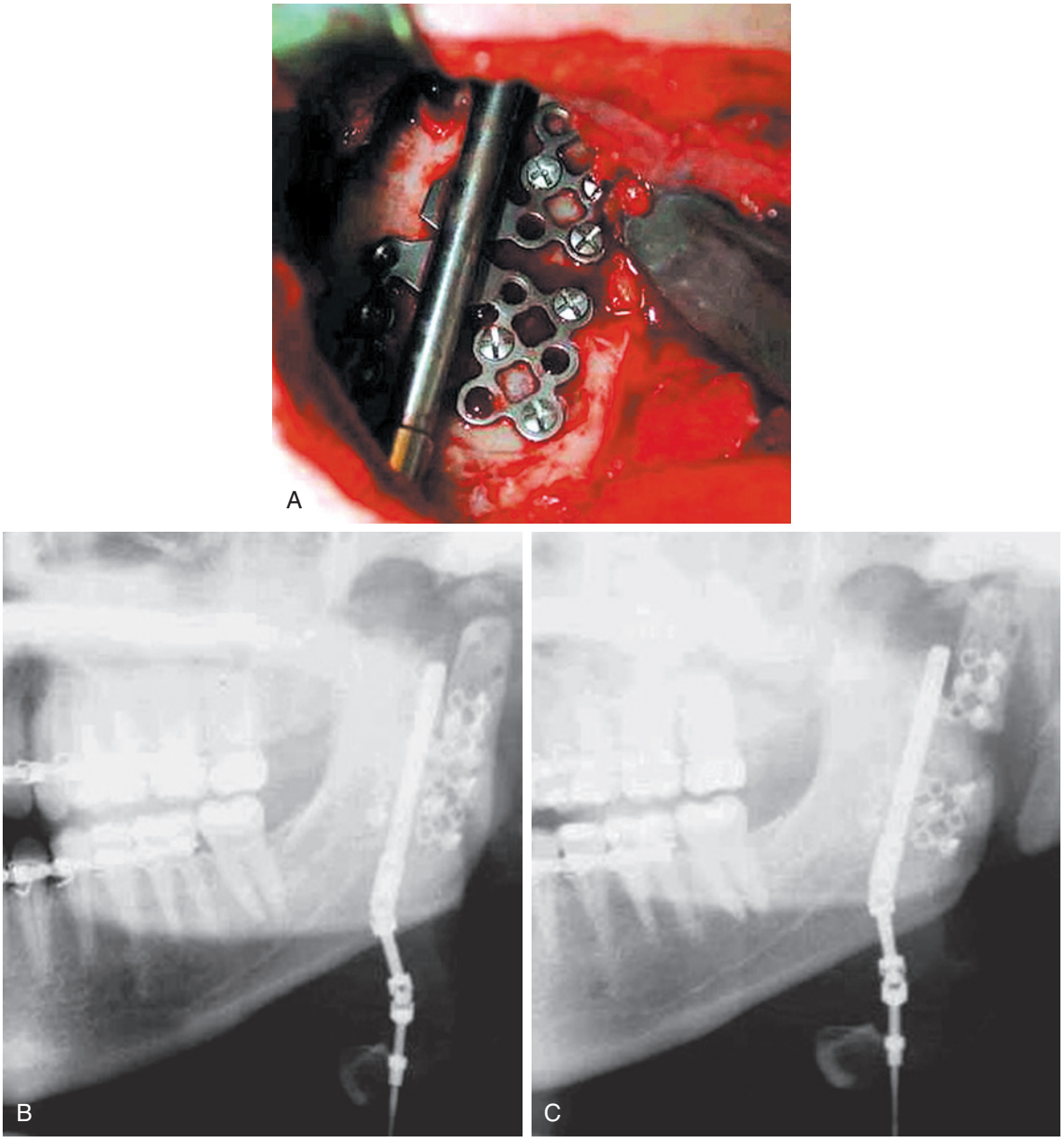
The loss of vertical ramus height is a consequence of a condylar pathologic condition and may result in asymmetry and malocclusion, as well as dysfunction and pain. Severe alteration of condylar anatomy may result from a variety of conditions such as hemifacial microsomia, growth disturbances, trauma, or a pathologic condition. Until recently, skeletally immature patients were treated primarily with grafting autogenous tissue using a costochondral bone graft.[63,64] Fig. 31.36 shows the use of a costochondral graft for replacement of a severely degenerated pediatric condyle. In this situation, the graft replaces only the condylar portion of the joint and does not address significant abnormalities of the fossa. Problems with



• **Fig. 31.36** (A) A gap arthroplasty of at least 1 cm has been created in a pediatric patient with temporomandibular joint ankylosis. (B) The cartilaginous cap of the costochondral bone graft has been contoured to serve as a neocondyle. (C) Screw fixation is used to stabilize the costochondral bone graft to the native mandible.

costochondral grafting include recurrent ankylosis, degenerative changes of the graft, and (in some cases) excess and asymmetric growth of the graft. The need for donor site surgery and unpredictable results, including asymmetric growth and ankylosis, yielded less than ideal results in many patients.

Distraction osteogenesis has been used successfully to reconstruct the mandibular condyle.[65] This procedure involves exposing the mandibular ramus, usually through an extraoral approach. The distractor is temporarily stabilized on the lateral surface of the mandible, an osteotomy of the posterior ramus is completed, and the distraction appliance is attached to the osteotomized (condyle) segment and to the stable portion of the ramus (Fig. 31.37). Following an initial latency period of 5 to 7 days, the distraction appliance is activated, producing approximately 1 mm of bone movement per day. This process creates regenerate bone formation in response to distraction of the condylar segment. Range of motion is maintained during distraction, and control of the occlusion and molding of the regenerate can be completed with elastic traction guidance. The consolidation period is typically calculated as three times the period of distraction. During this time, the structural integrity over the regenerate is maintained with the distraction appliance. A second intervention is required to remove the distractor, and a stabilizing bone plate can be placed over the regenerate gap. Surgical access to remove the distractor is through the existing incision. Reestablishment of the vertical ramus height and increased mandibular continuity allows for



• **Fig. 31.37** Distraction osteogenesis. (A) Distractor placement on the mandibular ramus with orientation and vector toward glenoid fossa. (B) Panoramic radiograph before distraction of the ramus to recreate the mandibular condyle. (C) Pseudocondyle formation following distraction.

reestablishment of symmetry and occlusion. Finalizing the occlusion often requires orthodontic detailing or equilibration to aid in providing a stable, balanced interdigitation.

Distraction osteogenesis is not without its own set of challenges to overcome. Results can be unpredictable due to difficulty with vector control. In addition, the patient often requires a second surgery to remove the distractor. Lastly, the patient must be old enough to allow the surgeon or parents to activate the device multiple times a day. Recently it has been suggested that surgeons should consider alloplastic TMJ reconstruction in the growing patient to avoid the complications associated with costochondral grafts and distraction osteogenesis.[66] The rationale is that even though the alloplastic prosthesis does not grow with the child, the patients would be better off with planned revision surgeries compared with incurring continued failures with autogenous grafts that will also require future surgical interventions.

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Appendix 1

Operative Note (Office Record) Component Parts

1. Date
2. Patient identification
3. Diagnosis
4. Review of medical history, medications, and vital signs
5. Oral examination
6. Anesthesia (dose and block technique used)
7. Procedure, including statement of progress of procedure and complications
8. Discharge instructions
9. Medications prescribed (drug and amount or copy of prescription)
10. Return appointment (scheduling)
11. Signature (legible or printed underneath, or electronic signature)

DATE: July 1, 2020

ID and DX: This 52 y.o. m requires extraction of mandibular left second premolar and first molar. Both teeth are nonrestorable because of extensive caries.

MEDICAL HISTORY: Patient has chronic hypertension for which a thiazide diuretic has been prescibed. Remainder of history is unremarkable. Pulse 84; BP 130/85.

ORAL EXAMINATION: Soft tissue of cheeks, lips, tongue, floor of mouth, and palate are WNL. No palpable nodes or masses. Carious, nonrestorable teeth #19 and 20.

ANESTHESIA: Lidocaine 36 mg with 0.018 mg epinephrine via mandibular and long buccal blocks.

PROCEDURE: Routine forceps extraction of teeth #19 and 20. Distal root of first molar fractured—retrieved with Cryer elevator. No flap required. Patient tolerated procedure without difficulty.

DISCHARGE: Copy of routine postoperative instructions given and reviewed.

MEDICATIONS: Tylenol #3—24 caps. 1 or 2 caps q4h prn pain.

RETURN: Patient asked to return in 1 week for postoperative checkup.

SIGNATURE: John Jay Jones

• **Fig. A1.1** Example of an oral surgery note.

Appendix 2

Drug Enforcement Administration Schedule of Drugs and Examples

Schedule I: Controlled Substances

Substances in this schedule have a high potential for abuse and have no currently accepted medical use in treatment in the United States. Accepted safety for use of the drug or other substance under medical supervision is lacking.

Some examples of substances listed in schedule I are heroin, lysergic acid diethylamide, marijuana (cannabis), peyote, methaqualone, and 3,4-methylenedioxymethamphetamine ("ecstasy").

Schedule II: Controlled Substances

Substances in this schedule have a high potential for abuse, which may lead to severe psychological or physical dependence.

Examples of single-entity schedule II narcotics include morphine and opium. Other schedule II narcotic substances and their common name brand products include hydrocodone combinations (Vicodin), hydromorphone (Dilaudid), methadone (Dolophine), meperidine (Demerol), oxycodone (OxyContin), and fentanyl (Sublimaze or Duragesic).

Schedule III: Controlled Substances

Substances in this schedule have a potential for abuse, but less than substances in schedules I or II, and abuse may lead to moderate or low physical dependence or high psychological dependence.

Examples of schedule III narcotics include products containing not more than 90 mg of codeine per dosage unit (Tylenol with codeine). Also included are buprenorphine products (Suboxone and Subutex), which are used to treat opioid addiction.

Schedule IV: Controlled Substances

Substances in this schedule have a low potential for abuse compared with substances in schedule III.

An example of a schedule IV narcotic is propoxyphene (Darvon and Darvocet-N 100).

Other schedule IV substances include alprazolam (Xanax), clonazepam (Klonopin), clorazepate (Tranxene), diazepam (Valium), lorazepam (Ativan), midazolam (Versed), temazepam (Restoril), and triazolam (Halcion).

Schedule V: Controlled Substances

Substances in this schedule have a low potential for abuse compared with substances listed in schedule IV and consist primarily of preparations containing limited quantities of certain narcotics. These are generally used for antitussive, antidiarrheal, and analgesic purposes.

Examples include cough preparations containing not more than 200 mg of codeine per 100 mL or per 100 g (Robitussin AC and Phenergan with Codeine).

Note: Nonsteroidal antiinflammatory drugs are not scheduled drugs.

Appendix 3

Examples of Useful Prescriptions

Don Carlos Buell, DMD
1825 Battlefield Road
Perryville, KY 40468
(859) 555-8631

Name Braxton Bragg Date 10/8/20

Address 207 Polk St., Perryville, KY

Amoxicillin 500mg
Disp: 4 caps
Sig: 4 caps at 8:00 am

Refill ⓪ ~~1 2 3~~ Don Carlos Buell DMD

DEA No _____

Figure A4.1 Prescription for oral bacterial endocarditis prophylaxis with amoxicillin.

Don Carlos Buell, DMD
1825 Battlefield Road
Perryville, KY 40468
(859) 555-8631

Name Braxton Bragg Date 10/8/20

Address 207 Polk St., Perryville, KY

Penicillin V 500mg
Disp: 28 tabs
Sig: 1 tab qid until gone

Refill ⓪ ~~1 2 3~~ Don Carlos Buell DMD

DEA No _____

Figure A4.2 Prescription for oral penicillin therapy of odontogenic infection.

Don Carlos Buell, DMD
1825 Battlefield Road
Perryville, KY 40468
(859) 555-8631

Name Braxton Bragg Date 10/8/20

Address 207 Polk St., Perryville, KY

Aspirin 325 mg c̄ 5 mg Oxycodone
Disp: 12 (twelve) tabs
Sig: One tab q 4 h prn pain. Take with food.

Refill ⓪ ~~1 2 3~~ Don Carlos Buell DMD

DEA No CBxxxxxxxx

Figure A4.3 Prescription for aspirin with oxycodone. This prescription must have a Drug Enforcement Administration number and cannot be telephoned in to the pharmacy.

Don Carlos Buell, DMD
1825 Battlefield Road
Perryville, KY 40468
(859) 555-8631

Name Braxton Bragg Date 10/8/20

Address 207 Polk St., Perryville, KY

Tylenol # 3
Disp: 18 (eighteen) caps
Sig: One cap q 4 h prn pain. Take with food.

Refill ~~0~~ ① ~~2 3~~ Don Carlos Buell DMD

DEA No CBxxxxxxxx

Figure A4.4 Typical brand name prescription. This compound has 300 mg of acetaminophen and 30 mg of codeine.

Appendix 4

Consent for Extractions and Anesthesia

1. I, _____, give my permission for Dr. _____ and any assistants deemed necessary, to perform the procedure(s) discussed below in #2.

2. The reason(s) for the surgery and anesthesia have been explained to me and I understand the procedure(s) to consist of:

   Lay terminology _____

   Medical terminology _____

   Sensible alternative procedures including not doing surgery at all have been discussed with me.

3. I have been advised of potential complications of this procedure that are able to be reasonably anticipated, which are:

   _____

   _____

4. I understand that anesthesia will be necessary for my surgery and give permission for the use of medications the doctors feels are necessary except those to which I am allergic that are listed below:

   _____

5. I understand that no guarantees can be given of the results of surgery on the human body but that the doctor and office staff will do their best to achieve excellent results.

6. All my questions concerning this procedure have been answered to my satisfaction.

Patients signature indicating agreement with statements 1 through 6:

_____ Date _____

Witness of the consent signature:

_____ Date _____

• **Fig. A4.1** Example of a patient consent form for oral surgery.

Appendix 5

Antibiotic Overview

Penicillins

The penicillin family, including primarily penicillin V and amoxicillin, has long been the mainstay in the antibiotic treatment of odontogenic infections. Randomized controlled clinical trials comparing a penicillin with other newer antibiotics have found no statistically significant differences in clinical cure rates. (Note that the correct generic name of phenoxymethyl penicillin potassium is penicillin V. It is not penicillin VK.)

The antibacterial spectrum of penicillins includes the gram-positive cocci (except staphylococci) and oral anaerobes. Penicillin G is given parenterally, whereas penicillin V and amoxicillin are preferred for oral administration. The penicillins have little toxicity except for allergic reactions, which occur in about 3% of the population.

Amoxicillin and ampicillin are semisynthetic penicillins that are more effective against gram-negative rods compared with penicillin. Amoxicillin has the advantage of a longer serum half-life than ampicillin and penicillin, making its effective duration and its dosage interval longer. The costs of amoxicillin and penicillin are similar. Although both penicillin and amoxicillin are effective in treating odontogenic infections, amoxicillin is often preferred to penicillin because its longer dosage interval improves patient compliance. Amoxicillin is given three times per day; penicillin V and ampicillin are given four times per day.

Penicillinase-resistant penicillins such as methicillin and dicloxacillin were effective in the past for penicillinase-producing staphylococci. Since more than 85% of staphylococcus strains, especially methicillin-resistant *Staphylococcus aureus*, have become resistant to this class of penicillins, their usefulness has diminished.

Clindamycin

The antibacterial spectrum of clindamycin includes gram-positive cocci and almost all anaerobic bacteria. Clindamycin is effective against streptococci, some staphylococci, and anaerobes. The drug is four to five times more expensive than penicillin, and rising clindamycin resistance rates of oral streptococci are of concern. Therefore clindamycin is best used for therapeutic and prophylactic indications only in penicillin-allergic patients.

Antibiotic-associated colitis, resulting in persistent and possibly life-threatening diarrhea, has been associated with clindamycin and many other antibiotics. Its cause has been identified as the elaboration of an exotoxin by *Clostridium difficile*, which is resistant to clindamycin and several other antibiotics. It most typically occurs in medically debilitated patients. After diagnosis based on a stool assay for the *C. difficile* exotoxin, the treatment includes antibiotic therapy with oral vancomycin or metronidazole.

Metronidazole

Metronidazole is only effective against obligate anaerobic bacteria. Metronidazole has no effect on bacteria that are aerobic or facultative (growing both in the presence and in the absence of oxygen). Most oral streptococci are facultative and thus resistant to metronidazole. Conversely, the oral *Prevotella* and *Porphyromonas* bacteria are obligate anaerobes; they are sensitive to metronidazole. This antibiotic is sometimes used in periodontal disease therapy; it may also be useful in the management of anaerobic odontogenic infections alone or in combination with other antibiotics such as penicillin.

Macrolides (Erythromycin Family)

Older macrolide antibiotics such as erythromycin have lost much of their effectiveness against the main pathogens of odontogenic infections, oral streptococci, and oral anaerobes. This family of antibiotics has also had significant disadvantages because of gastrointestinal intolerance and frequent drug interactions involving the liver microsomal enzymes responsible for the metabolism of many drugs and foods.

Azithromycin is a newer member of the macrolide family that has been shown to be effective against odontogenic infections when combined with appropriate surgery. It is also better tolerated by the gastrointestinal tract. Its metabolism involves a slightly different pathway from those of other macrolides, which eliminates most of the drug interactions commonly seen with the macrolides. Azithromycin may be a good antibiotic choice in patients who can tolerate neither penicillins nor clindamycin.

Tetracyclines

Tetracyclines are available for oral and parenteral administration and are generally considered broad-spectrum antibiotics. However, bacterial resistance to these drugs is common. At this time, tetracyclines are considered clinically useful only against anaerobic bacteria, and this is the basis for their use in odontogenic infections.

The toxicities of tetracyclines are generally low but include staining of developing teeth if given to children or to pregnant or lactating women. Doxycycline is preferred because it is taken only once daily, which improves patient compliance.

Tetracyclines have an anticollagenase effect. This activity may make them useful for treatment of periodontal and peri-implant

disease. This has prompted the use of topical preparations of tetracyclines placed into periodontal pockets and for the prevention of dry sockets.

Cephalosporins

Cephalosporins are a group of β-lactam antibiotics that are effective against gram-positive cocci and many gram-negative rods. A large number of cephalosporins are available and are roughly divided into four generations on the basis of their activity against gram-negative organisms. First-generation cephalosporins have a similar activity to penicillin, including activity against gram-positive cocci and some strains of gram-negative bacteria such as *Escherichia coli, Klebsiella,* and *Proteus mirabilis.* First-generation cephalosporins, however, are not as effective against oral anaerobes as are the penicillins.

Second-generation cephalosporins have broader activity against gram-negative bacteria and increased activity against anaerobic bacteria. The second generation has less activity against gram-positive cocci compared with the first generation.

Third-generation cephalosporins are much more active against enteric gram-negative rods but are decidedly less active than first- and second-generation cephalosporins against gram-positive cocci.

Fourth-generation cephalosporins are designed to be effective against enteric gram-negative rods, especially *Pseudomonas aeruginosa*, which is not generally encountered in odontogenic infections.

Two oral cephalosporins are effective in odontogenic infections: (1) cephalexin and (2) cefadroxil. Although neither of these is the drug of first choice for treating odontogenic infections, they may be useful in certain situations in which a bactericidal antibiotic is necessary and the first-line antibiotics cannot be used.

The toxicity of the cephalosporin group is primarily related to allergy. Patients who are allergic to penicillin drugs should be given cephalosporin antibiotics *with caution.* Patients who have had anaphylactic reactions (hives, angioneurotic edema, respiratory distress, shock, or all of these) in response to penicillin should not be given cephalosporins.

Fluoroquinolones

The fluoroquinolone family of antibiotics includes ciprofloxacin, levofloxacin, and moxifloxacin. Fluoroquinolones are broad-spectrum, bactericidal, orally taken antibiotics. The first two generations of the fluoroquinolone drugs are only marginally effective against streptococci and have little or no effect against anaerobic bacteria.

Moxifloxacin, however, is a fourth-generation fluoroquinolone that is effective against oral streptococci and anaerobes. However, it has multiple side effects, including toxicity to developing cartilage, muscle weakness, and drug interactions that can be fatal. Like the other fluoroquinolones, therefore, moxifloxacin is avoided in persons under 18 years of age and in combination with multiple other drugs. The fluoroquinolones are used only with caution when first-line antibiotics cannot be used.

Antifungal Drugs

Mucosal candidiasis, or oral thrush, should be treated with the topical application of antifungal agents. The two antibiotics of choice are nystatin and clotrimazole. Both drugs are available as lozenges that are held in the mouth until they dissolve. The patient should use one lozenge four to five times daily for 10 days for effective control and to prevent relapse of the candidiasis. Clotrimazole is often better tolerated because of its more pleasant taste.

Newer azole antifungal agents such as fluconazole, itraconazole, and voriconazole are generally reserved for immunocompromised patients because of their effectiveness against resistant fungi, potentially severe drug interactions, and significantly greater cost. Even newer antifungal antibiotics such as the echinocandins and lipid-based amphotericin preparations are similarly reserved for treating systemic fungal infections in severely immunocompromised patients such as those who have had bone marrow transplantation and those with acquired immunodeficiency syndrome.

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