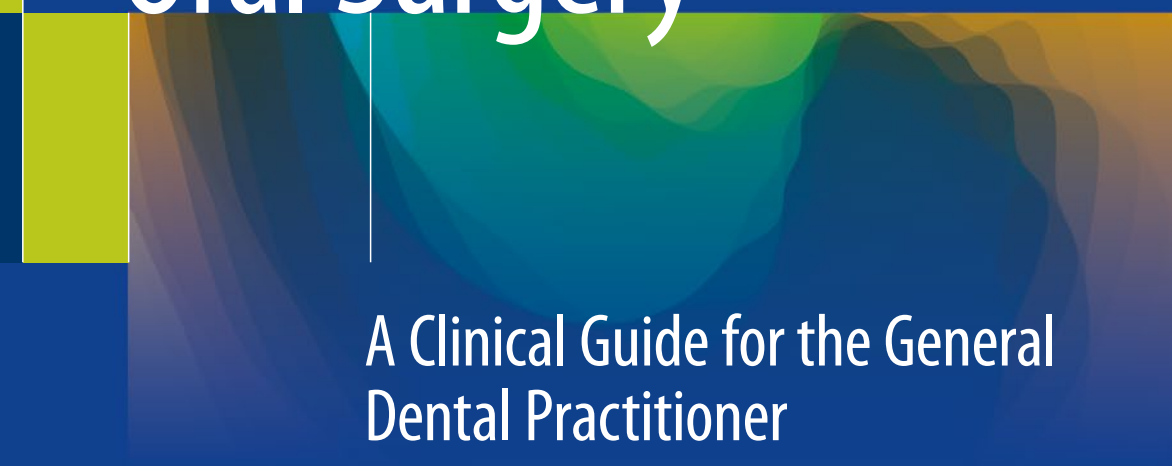
Evidence-Based Oral Surgery



A Clinical Guide for the General Dental Practitioner

Elie M. Ferneini
Michael T. Goupil
Editors

Springer

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Foreword

Evidence-based dentistry integrates a practitioner's clinical expertise and judgment, the needs, desires, and preferences of the patient, and current, clinically relevant evidence. The intersection of these domains is a critical component of an effective, patient-centered approach to care. The American Dental Association defines evidence-based dentistry (EBD) as "an approach to oral healthcare that requires the judicious integration of systematic assessments of clinically relevant scientific evidence, relating to the patient's oral and medical condition and history, with the dentist's clinical expertise and the patient's treatment needs and preferences." Since introduced at McMaster University in the 1980s to improve the quality of healthcare delivery by closing the gap between scientific-based knowledge and commonly found practice patterns, evidence-based dentistry has continued to advance and is now widely accepted as a best practice.

This text is intended to provide the general dentistry community with clear, concise, focused guidance on the delivery of evidence-based, patient-centered surgical management and care. Drs. Goupil and Ferneini are leaders in the practice of evidence-based oral and maxillofacial surgery, with extensive experience in academic, military, and private practice settings. The text covers a spectrum of topics pertaining to oral and maxillofacial surgery, including patient assessment, exodontia, pain management, oral pathology, trauma, temporomandibular joint dysfunction, and implant therapy—all of which are discussed using the principles and parameters of evidence-based healthcare. Collaborating with over twenty authors, they have developed the quintessential guide for general dentists to apply translational science and knowledge into everyday clinical practice. All general dentists will find information in *Evidence-Based Oral Surgery: A Clinical Guide for the General Dental Practitioner* to be of great value and relevance to their practice.

Farmington, CT, USA — Steven M. Lepowsky

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Part I

Patient Assessment

Evidence Based Dentistry: What, Why, How

1

Michael T. Goupil and Linda Elder

"Now we will take another line of reasoning. When you follow two separate chains of thought, you will find some point of intersection which should approximate the truth."
Sherlock Holmes in—The Disappearance of Lady Frances Carfax

Abstract

The concept of evidence-based medicine {EBM} and evidence-based dentistry (EBD) is not new. EBM traces its origins back to the 1980s when the evidence-based process was developed at McMaster University, Ontario, Canada. This concept should be commonplace with the current generation of graduating dentists. Yet there continues to be barriers to fully implement EBD. This chapter focuses on the what, why, and how of EBD.

1.1 Introduction: What Is EBD

The American Dental Association defines evidence-based dentistry as "an approach to oral health care that requires the judicious integration of systemic assessments of clinically relevant scientific evidence, relating to the patient's oral and medical condition and history with the dentist's clinical expertise and the patient's treatment needs and preference" (Sakaguchi 2010). In other words dentists are expected to provide the best possible health care for their patients as possible.

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The concept of EBD can best be demonstrated through a Venn diagram consisting of three intersecting circles of equal value (Fig. 1.1). The circles represent (1) the current clinical situation of the patient and the patient's values, (2) current and relevant scientific evidence, and (3) the clinical experience and judgment of the dental provider. The area where all three of the circles intersect represents evidence-based dentistry or more aptly labeled evidence-based practice. There is a misconception that evidence-based dentistry is based solely on the dental or medical literature. Rather all three areas need to be considered, and depending on the circumstance of a specific situation or patient, each of these areas may take on more or less importance. There are a number of factors that need to be considered in each of these domains.

1.2 The Patient

First consider the clinical patient circumstances. Obviously this includes an appropriate hard and soft tissue examination of the head and neck region. But one also needs to consider the patient's past dental history including past and current oral hygiene practices and opportunities. Equally important is the past and current medical health history including past and current medications. Several questions need to be addressed. How might the medical history have contributed to the patient's oral health? Will the patient's medical status have an impact on any planned treatment? Does the patient have any physical impairment that might affect the delivery of the proposed treatment, and equally important, are there impairments in the patient's ability to maintain her or his oral health? (See Chap. 3.) Once the physical data have

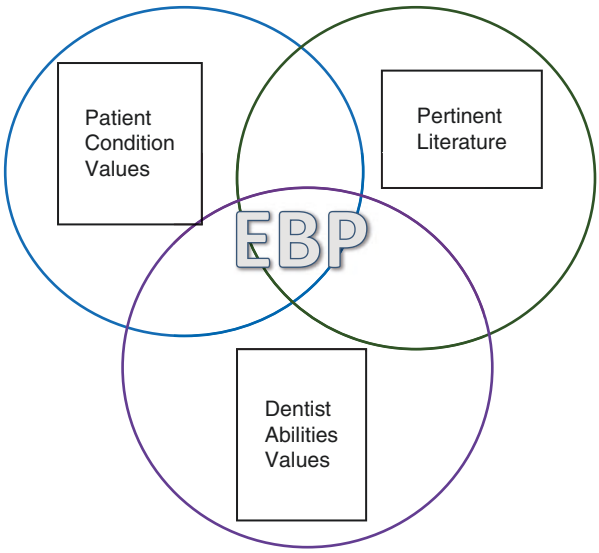


Fig. 1.1 Venn diagram demonstrating the components of evidence-based dentistry [EBD]

been obtained, treatment plan options can be formulated for the patient, which addresses their oral health in context with their more general medical health.

Next consider the patient's preferences and their values. What is the patient's overall perception of oral health and its impact on general, overall health? Does he or she eat to live or live to eat? What kind of esthetic concerns does the patient have? Is a bright, white smile with straight teeth necessary? What is the patient's financial situation, and what time and financial investments do they want to make toward their oral health?

There needs to be a recognition and acknowledgment that the patient's value system and the dental practitioner value system may be worlds apart. This does not mean that the provider shouldn't try to influence the patient's value system through education, but in the final analysis, it is the patient's preferences that should drive the final treatment choices. These preferences and values may change over time and need be reassessed periodically. How patients view the world when they are young and on the dating scene may be very different than when they are in their later years and enjoying a few final pleasures like eating. From an ethical point of view, the dental provider is not required to provide treatment that is not in the best interest of the patient just because the patient wants a certain treatment plan, for example, the young adult patient with a reasonable healthy and easily restored dentition that wants a full-mouth extraction and complete dentures to avoid going to the dentist in the future. This is really not a justifiable and ethical option despite the patient's preference.

1.3 Scientific Evidence

As treatment plans are developed, it is paramount to consider what the literature states about current materials and methods. Technology continues to advance rapidly, providing ever-expanding options for providing health care. The literature must be evaluated both critically and carefully, and especially for applicability, before changing tried and true methods.

The notion of a "universally true" concept in dentistry is myth. Depending on when an individual has graduated from dental school, some of the concepts that were taught and "written in stone" have not survived the test of time. These "universally true" concepts should be reassessed periodically in light of advanced and advancing understandings of disease and the human condition.

The clinician should look for the best scientific literature available that represents the clinical situation as closely as possible. This literature then needs to be evaluated in a systematic fashion to assess both its value and applicability to the patient.

1.4 The Dental Provider

Lastly but equally important is the clinician's experience and judgment. The scientific literature is frequently based on looking at the results of an intervention on a reasonably homogenous population. The results of a study must be assessed in the

context of how closely a specific patient matches the population studied. As a clinician gains more experience she/he is better able to make predictions on how successful the treatment might be in a given situation.

Not all clinicians have an equal ability to perform certain specific tasks, although there usually is an acceptable minimum standard that needs to be met. Frequently one hears and perhaps even says "in my hands this works in such and such a way." That is a very important concept in assessing both the results in the literature and the formulated treatment plan. Dental providers should accurately assess and honestly face the results of their skills on a periodic basis. Treatment outcome assessments should be part of every practice to ensure oral health care is provided at the highest level. These outcome assessments can then be compared to current literature results.

In summary there are at least three components to evidence-based dentistry: (1) the patient's needs and desires, (2) what good current scientific literature states, and (3) what the clinician knows that works well in her/his hands. Each of these components is important and must be considered if one wants to deliver evidence-based care. The relative importance of each of these components may change based on circumstances for a specific patient. The influence of each of these components may change and must be adjusted for each individual patient. The influence of the literature may vary based on what is available and how applicable the literature is to a specific patient. The clinician's influence should improve over time, based on experience and continuing education. Evidence-based dentistry entails using the current literature within the context of one's own expertise and applying this knowledge to provide the best possible health care to dental patients.

1.5 Why Do EBD?

Evidence-based decision-making is the best approach to dentistry because it offers the best chance at successfully helping our patients achieve reasonable goals in terms of their dental care. The practitioner should continually ask the questions—"What would I want if I were facing these dental issues?" "What would I want for my family member?" One does need to be cautious though when applying this dictum to specific patients. As mentioned, part of the evidence-based dentistry model entails respecting the desires and values of the patient.

Oral health values are based on education and previous clinical experience and modified by the practitioner's own personal value system. This may lead the practitioner to believe that a certain treatment plan is the "best" or the "ideal treatment plan" and, indeed, the proposed plan may be the best for the provider, but it may not be the best for the patient. The practitioner needs to again consider the patient's value system. As mentioned above the best procedure may be able to modify the patient's choice through education. In any case, the provider needs to be mindful that current ethical philosophy focuses on patient autonomy, as opposed to the "doctor knows best" paternalism of the past.

Another way of looking at evidence-based dentistry is that it represents or is part of the informed consent process. Informed consent is a process that evolves over

time through an open dialogue with the patient. Components of the informed consent process include the patient's condition as well as potential methods for how this condition may best be addressed. What are the best treatment options, including possibly no treatment at all? What risks and benefits of each of the reasonable treatment options exist—including no treatment? How competent is the provider ability to deliver these options?

In today's litigiousness society, a recurrent theme is lack of informed consent. Probably one of the best ways to avoid these legal consequences is to apply the evidence-based dentistry model, incorporate EBD into the informed consent process, and then, of course, document the process.

1.6 How Can EBD Be Accomplished?

In certain regards, evidence-based decision-making within dentistry can be implemented relatively easily. In most cases the patient's condition can be assessed through the clinical examination and a review of the medical history that has been captured earlier through questionnaires and verified through patient dialogue. Directed questions to the patient to determine what he or she is looking for in terms of health in general, and oral health more specifically, will help assess the patient's desires and personal values. Initial evaluation inferences may change, when various treatment options are discussed with the patient as part of the informed consent process. Individual practitioners are aware of their own experiences and expectations, and they should realize, as mentioned previously, that these experiences and outcomes must be evaluated objectively. Given the inherent problem of intellectual arrogance in all human thought, it must be remembered that a provider's success rate may not be as high as one perceives it to be. Ideally, expectations change over the course of time based on further experience, developed skills, and continuing education. Periodic objective clinical practice outcome assessments should be part of any EBD-based practice.

Incorporation of the scientific literature can be a little more complicated, but, hopefully, with practice this need not be overly time-consuming. The scientific evidence is limited to given research in reputable journals. But other essential information is relevant to evidence-based dentistry. To name a few information sources relevant to EBD (in addition to those already mentioned):

- Formal as well as informal learning and training through dental programs and dental degree programs
- Discussions with colleagues
- Given Standards of Dental Societies
- Community Standards
- Professional Meetings

None of these sources, in and of themselves, should be considered to offer definitive "facts" and instead must be evaluated using a systematic critical thinking approach.

To some, evaluation of the scientific evidence may be the most intimidating; but there are ways to make the process less daunting. First and foremost, one should already be taking an active approach to keep abreast of the current, as well as classic, scientific literature. Most states and hospital organizations already require mandatory continuing education hours, to encourage this process (ADA n.d.). There are hundreds of medical/dental journals available, and in fact it is impossible to keep abreast of all of them. For general dentists in the United States, the journal considered by most scholars in the field to be required reading is the *Journal of the American Dental Association*. This journal contains frequent updates on important changes in the standards of the dental profession. We also recommend *Dental Abstracts*, a journal that supplies easy-to-read summaries of potentially relevant articles from a wide variety of journals that, in all likelihood, are not part of one's routine reading. Accordingly *Dental Abstracts* may offer exciting, new, and innovative ways of thinking about dentistry and therefore can help keep you on the cutting edge of our field.

In reviewing a patient's medical history, the odds are that several disease entities and/or medications will crop up where one's knowledge base may be weak. A quick *Google Scholar* search and a few minutes time in all likely will answer the question—"Will this disease or medication have a modifying effect on the treatment I am contemplating?" It would be beneficial to make a quick note in the patient's chart on the conclusions. An annotation of the information source and date is also advisable. Again, remember that your conclusions may change with the development of further information, given that, considered from one point of view, dentistry is still in its infancy in terms of its potential.

As one considers an individual patient, certain key questions should also come to mind:

- Is this the best treatment option?
- Is there another way?
- Is there a better way?
- How long will this last?
- Why didn't that treatment work?
- Is there a more efficient way?
- Is there a more cost-effective way?

To effectively and efficiently address these questions, one needs to consider the type of answer desired. Are we looking for generalities and opinion or, more likely, specific, concrete information that will answer our questions and help direct the patient's care?

One method that is widely proposed is the use of the acronym **PICO** or more commonly called the PICO statement. This method narrows the question and

therefore should guide you to a more precise search of the literature, hopefully resulting in the most relevant and significant articles, focused on the specific information you are seeking.

"P" stands for the patient, problem, and the population with whom we are concerned. Rather than looking for "What is the success rate of dental implants?", the search needs to be narrowed and focused on a specific relevant population, articulated in a specific question, such as: "What is the success rate of dental implants in a young, healthy male population?" "What is the success rate of dental implants in a geriatric partially edentulous patient, with Type II diabetes, who is being treated for osteoporosis?" You should be able to appreciate the differences in the responses of search engines to each of these questions. The generalized question potentially will return hundreds of responses, whereas the other two questions may only return very few, but more relevant, articles.

"I" stands for intervention. What treatment options are you contemplating?

"C" stands for comparison. This is an optional component to the PICO statement. Are reasonable alternative treatment options available?

"O" stands for outcomes, which refers to anticipated results for treatment option options.

Example of a PICO Statement
P: For patients undergoing the removal of impacted third molars,
I: does the use of prophylactic antibiotics,
C: as opposed to no antibiotics,
O: help prevent postoperative complications, i.e. infection, alveolar osteitis

A variety of scientific sources are available for beginning to find answers. Primary sources, such as research articles in scientific literature, are usually considered to have the best answers for EBD. A hierarchy exists in terms of value of the literature; meta-analysis of randomized controlled trials (RCTs) is considered to be at the top of the pyramid. Other significant and relevant sources of information should be also considered. Textbooks, lectures, and input from colleagues may also be utilized, providing a critical analysis and assessment of the information are performed.

The more specific the question, the better the literature search is likely to answer the question at the heart of the clinical process. The downside of an overly specific question is that search engines might not find any literature that can answer the question.

The type of question and the kind of information required will determine the best place to start the search. When dealing with questions concerning the medical history of a client, a drug app on a smartphone may be all that is needed. A simple Internet search, entering only the drug name or medical condition, will frequently provide sufficient information. Even Wikipedia may provide the relevant answer, but of course one must always use caution in using this source.

The University of Texas at San Antonio has championed evidence-based practice in a real practice environment for a number of years, and consequently they developed the medical literature search engine SUMSearch [sumsearch.uthscsa.edu]. SUMSearch 2 {http://sumsearch.org/} is now hosted by the University of Kansas. The University of South Carolina hosts an evidence-based dentistry search engine [http://musc.libguides.com/EBD/searching] that is designed to readily accept your PICO question.

If the question at issue doesn't readily adapt to using the PICO method, another way of formulating questions is the use of WIN-, WIS-, and WIR-type questions that are used in problem-based learning pedagogy. These stand for "What is the nature of_____? What is the significance of_____? What is the relation of_____? Using this process entails selecting the most applicable question and filling in the blank with the information relevant to the clinical case. These questions can be easily used with other search engines.

PubMed is a frequently used and readily available search tool. Another search engine to be considered is the Trip database [www.tripdatabase.com]. This database will provide you with established practice guidelines which can help in the decision-making process.

Part of the acquisition of the evidence is ensuring that the source of the information is reliable. It must be clear that any information acted upon will be in the best interest of the patient. If the information is outdated or not from a trusted source, there is significant potential that the information is no longer valid.

There are a couple of choices though that need to be made as part of the search process. Some of the search engines noted previously should accommodate these choices. One of the choices is "Do you want to select a specific journal?" Some ranking systems attempt to assign a score to indicate the potential value of an article found in a specific journal. One method commonly used is the "impact factor." The impact factor (IF) is calculated on the number of times each article in a journal is cited by authors for other articles. The impact factor is based on this calculation over a 2-year period and obviously may change from year to year. One implication is that the higher the IF, the more important is the value of an article published in that journal. Thus, one would expect a journal like *Cancer* to have a higher IF value than a throw away journal like *Dental Economics*. Remember though this is a guideline and should be used with caution. Depending on the information you are seeking, an obscure information source with a lower IF value may be more relevant to a specific patient condition. The top five dental journals with consistently high impact factors are the *Journal of Dental Research*, *Journal of Clinical Periodontology*, *Clinical Oral Implants Research*, *Dental Materials*, and *Periodontology 2000* (Sillet et al. 2012).

A more recent method for ranking scientific journals is the Eigenfactor. In this method the journal is still evaluated by the number of citations for each article, but now the citations are weighted based on the relative importance of where the citation is being used. The top five journals in this ranking system have now changed to the *Journal of Dental Research*; *Journal of Periodontology*;

Journal of Oral and Maxillofacial Surgery; *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology (quad O and E)*; and *Dental Materials*. The *Journal of the American Dental Association*, which has an impact factor of 1.9 and ranks #24 now moves to #14 using the Eigenfactor (Sillet et al. 2012).

Just as journals may differ in relative value or significance, so may individual articles within a specific journal. As mentioned previously a hierarchy exists of study design or clinical evidence which is commonly described as "levels of evidence," ranking from Level 1 studies which contain the strongest evidence to Level 5 which contain the weakest (Fig. 1.2). Level 5 entails editorials or opinions, and Level 4 contains case reports; Level 3, case-controlled studies; Level 2, cohort studies; and Level 1, randomized controlled trial and/or meta-analysis systematic reviews. Several of the previously mentioned search engines can be judged according to the level of evidence required. Obviously, one would prefer to have Level 1 evidence answer the question; but in many, if not most instances, this type of evidence may not be available to answer the question. In most situations the provider will have to settle for the best information currently available, at whatever level this exists.

Cochrane reviews are an excellent source of high-level, comprehensive, clinical-based literature. Their evaluations are designed to provide both the practitioner and the patient relevant information for making informed health-care decisions (Sandhu 2012).

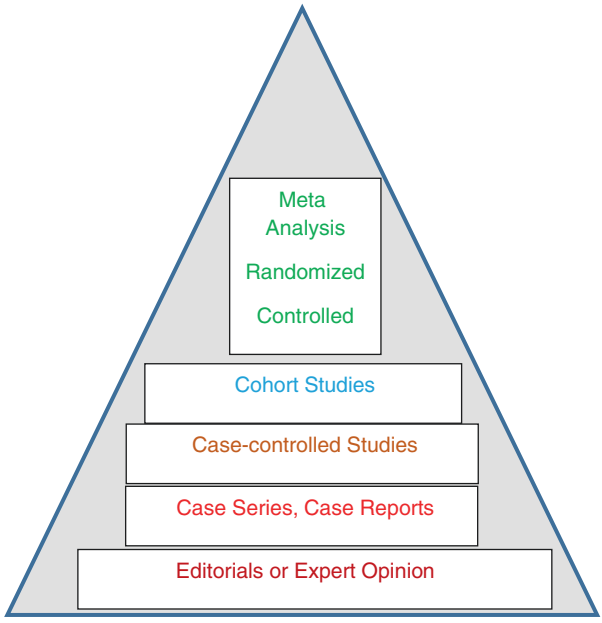


Fig. 1.2 Hierarchy of levels of evidence

Another choice that must be decided upon is how far back in the literature to go. In most cases probably no more than 5 years would be appropriate. Decisions should be made on the best and most current literature that is available.

Just because something is in print doesn't necessarily make it true. A statistic to keep in mind is that studies that have a significant difference are more likely to be published than studies that don't have a significant difference (Smyth et al. 2011). Thus when reviewing the literature, be mindful that what is being read already contains some form of bias. A critical evaluation of the information is of paramount importance.

When reading a scientific article, there are a couple of things need to be checked in the method section. Is the sample size large enough to truly indicate whether the statistical difference is truly valid? Was a power analysis conducted to ensure that the sample size is appropriate? Unfortunately, this is frequently missing in the dental literature. Also note, if the test groups are compared over time, was the time interval long enough? A difference noted may initially be found to be "statistically significant," but when followed for a longer more appropriate period of time, this difference may in fact disappear, with the end result that indeed there was no difference in the intervention being studied.

The *p*-value or statistical significance should be assigned before the study is conducted. In most dental literature, a *p*-value of 0.05 is used to indicate significance. A term creeping into the literature is "the results are approaching significant." An outcome is either significant or not. Significant results may also be indicated by a confidence level (CL) that implies the probability that the true result falls within a defined interval.

A large and varied body of literature is available, dealing with critical thinking. Critical thinking is now required in the curriculum in all US dental schools. In the field of dentistry, the concepts critical thinking and evidence-based dentistry are essentially being used synonymously. However, while evidence is a significant part of critical thinking, it represents only one part.

Further, some people believe that critical thinking is confined to given subjects such as literature and the humanities. However this would be incorrect. Critical thinking is in fact relevant to all subjects and disciplines in which people reason, including dentistry; critical thinking can and should be applied to all facets of life where best decisions need to be made and issues need to be reasoned through.

There isn't a single definition capturing all components and complexities of critical thinking. According to Dr. Richard Paul, a world-renowned authority on this subject, "critical thinking is thinking about your thinking while you are thinking in order to improve your thinking." This offers just one simple way into the concept. In the remainder of this chapter, we will attempt to provide the basic format of the Paul-Elder Critical Thinking Model™ (Fig. 1.3). It is up to dental professionals to apply this method to our continuing education seminars and professional meetings and even to other interpersonal interactions.

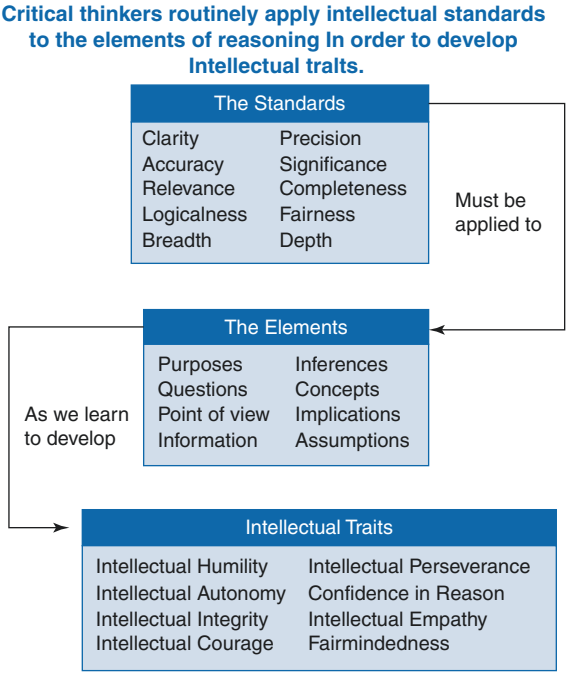


Fig. 1.3 The Paul-Elder Critical Thinking Model™ (Paul and Elder 2015)

1.7 Paul-Elder Approach to Critical Thinking

The Paul-Elder Framework for Critical Thinking™ offers a unique approach to analyzing an article, lecture, case study, patient interaction, etc. into eight component parts. The eight component parts are based on *reasoning* and are as follows: purpose, key question, point of view, assumptions, information, concepts, inferences, and implications (Fig. 1.4).

It is important to realize that there is no hierarchy to the eight parts of reasoning; they all are open to analysis; and they function in a dynamic relationship with one another in the mind of all humans. Therefore the provider need not analyze reasoning (either one's own or a patient's) in a specific order. From a practical point of view though, it may be easier to conduct the analysis in the order given above. Consistent use in this order will ensure that all eight components have been considered when reasoning through a given issue. An advantage of using this mode of analysis for most peer-reviewed literature is that at least half of the components can usually be identified in the article's abstract.

This analysis is useful in analyzing any form of reasoning in any context—a lecture, an article, a book, and a conversation. The use of the *Checklist for Clinical Reasoning* taken from *The Thinker's Guide to Clinical Reasoning* (Hawkins et al. 2010) simplifies the process (Fig. 1.5). The following helpful diagrams from this guide illustrate the analysis and assessment process in clinical practice.

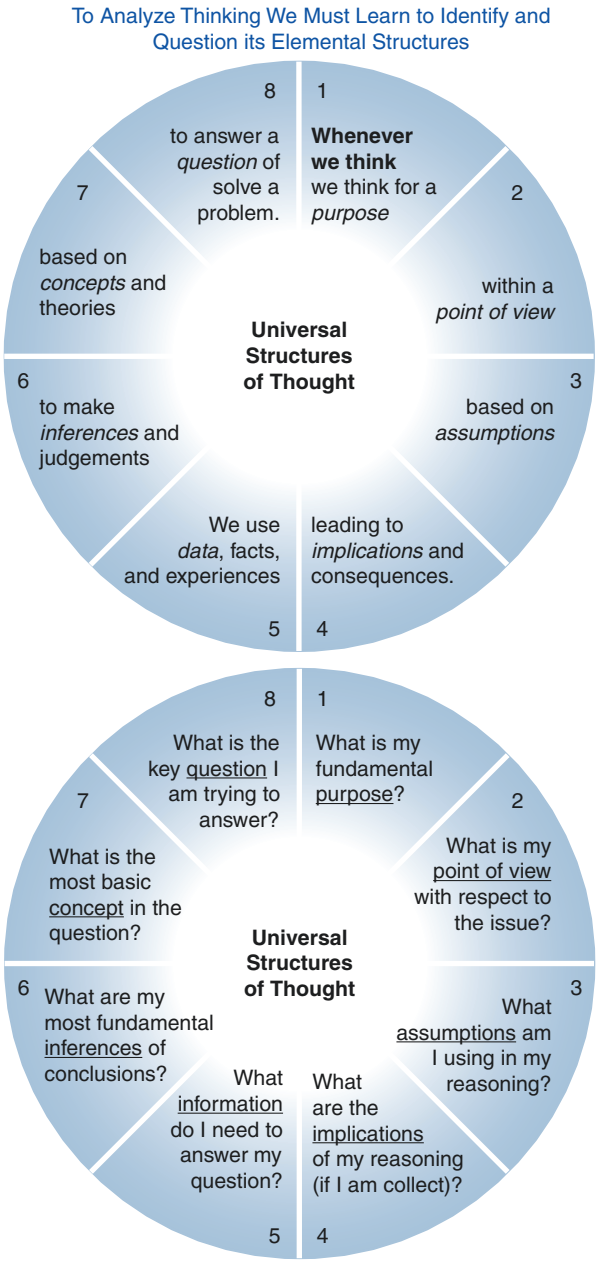
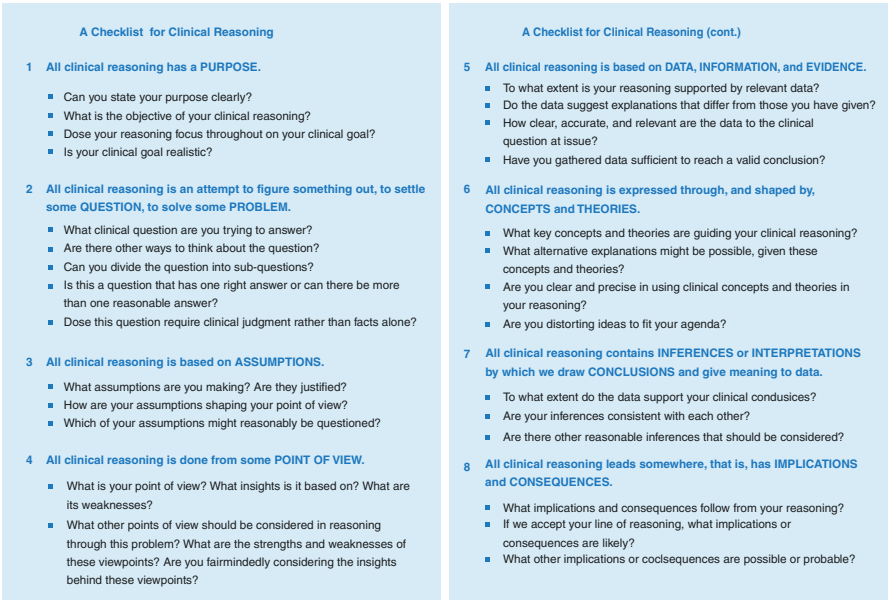


Fig. 1.4 Elements of critical thinking (Elder and Paul 2010)



A Checklist for Clinical Reasoning

1 All clinical reasoning has a PURPOSE.

- Can you state your purpose clearly?
- What is the objective of your clinical reasoning?
- Dose your reasoning focus throughout on your clinical goal?
- Is your clinical goal realistic?

2 All clinical reasoning is an attempt to figure something out, to settle some QUESTION, to solve some PROBLEM.

- What clinical question are you trying to answer?
- Are there other ways to think about the question?
- Can you divide the question into sub-questions?
- Is this a question that has one right answer or can there be more than one reasonable answer?
- Dose this question require clinical judgment rather than facts alone?

3 All clinical reasoning is based on ASSUMPTIONS.

- What assumptions are you making? Are they justified?
- How are your assumptions shaping your point of view?
- Which of your assumptions might reasonably be questioned?

4 All clinical reasoning is done from some POINT OF VIEW.

- What is your point of view? What insights is it based on? What are its weaknesses?
- What other points of view should be considered in reasoning through this problem? What are the strengths and weaknesses of these viewpoints? Are you fairmindedly considering the insights behind these viewpoints?

A Checklist for Clinical Reasoning (cont.)

5 All clinical reasoning is based on DATA, INFORMATION, and EVIDENCE.

- To what extent is your reasoning supported by relevant data?
- Do the data suggest explanations that differ from those you have given?
- How clear, accurate, and relevant are the data to the clinical question at issue?
- Have you gathered data sufficient to reach a valid conclusion?

6 All clinical reasoning is expressed through, and shaped by, CONCEPTS and THEORIES.

- What key concepts and theories are guiding your clinical reasoning?
- What alternative explanations might be possible, given these concepts and theories?
- Are you clear and precise in using clinical concepts and theories in your reasoning?
- Are you distorting ideas to fit your agenda?

7 All clinical reasoning contains INFERENCES or INTERPRETATIONS by which we draw CONCLUSIONS and give meaning to data.

- To what extent do the data support your clinical condusices?
- Are your inferences consistent with each other?
- Are there other reasonable inferences that should be considered?

8 All clinical reasoning leads somewhere, that is, has IMPLICATIONS and CONSEQUENCES.

- What implications and consequences follow from your reasoning?
- If we accept your line of reasoning, what implications or consequences are likely?
- What other implications or coclsequences are possible or probable?

Fig. 1.5 Checklist for clinical reasoning (Hawkins et al. 2010)

1.8 Reasoning Through the Logic of This Chapter

We can take the eight elements of reasoning and use them to figure out the logic of this chapter we are writing for this book, as follows:

Purpose—*What is the author trying to accomplish?* For instance, the purpose of this chapter is to give the dental practitioner a reasonable and defensible rationale behind evidence-based dentistry and suggested ways to easily accomplish this goal.

Key Question—*What essential question does this chapter, article, or lecture address?* For instance, a key question in writing this chapter was: What is a feasible approach to addressing implementation of EBD?

Point of View—*From what direction is the question being viewed and answered? What are you looking at and how are you seeing it?* Focusing on point of view can help define potential bias when one is evaluating a piece of research, lecture, or interaction. One of the authors [MG] has been a dentist for the past 40 plus years and in this capacity has provided direct patient care as an oral and maxillofacial surgeon; for the past 15 years, he has been involved in teaching critical thinking skills to dental students. The other author [LE] has made

teaching of critical thinking her life's work and is the one of the developers of Paul-Elder Framework for Critical Thinking™. Each author therefore brings a different point of view to this chapter, and both viewpoints enhance the other. To take a different example, when considering the point of view in the context of EBD, one must consider not only how a dental provider is looking at an issue but very importantly how the patient may view the same issue; in many situations, there also must be a consideration of how a third-party payer may be looking at the same issue.

Assumptions—*What is being, or should be, taken for granted in the clinical context?* One assumption being made by the authors of this chapter is that the readers want to be more facile in applying evidence-based dentistry to their practice and therefore would see this chapter as useful and valuable. The readers, in turn, should assume that the authors have been vetted and are therefore sufficiently expert in their fields to write intelligently about the issues in this chapter.

Information—*What data is being used in the article or chapter?* The information used in this chapter offers the basics of what, why, when, and how of EBD. It also offers a rich conception of critical thinking for the reader, through which EBD can be best implemented.

Concepts—*Concepts are the rules, laws, and principles used to interpret the information in order to ultimately derive a conclusion.* The primary concepts used in this chapter include our idea of what constitutes EBD and how it may be reasonably understood in the dental field. This chapter also introduces the Paul-Elder Framework for Critical Thinking™, as a primary conceptual tool for engaging in EBD.

Conclusions—*What primary conclusions do the authors of this chapter want the reader to accept?* At the end of this chapter, our expectation is that the reader will conclude that evidence-based dentistry has value and that there are powerful conceptual tools available for engaging in effective EBD.

Consequences—*What happens if one acts or fails to act on the conclusions offered in this chapter?* A desired consequence of this chapter is that the reader will incorporate critical thinking, not only throughout their practice in client care but also in their daily life. If EBD is considered valuable, then as a result of using EBD, one will be in a better position to make reasonable and sound decisions—based on fact and not myth. If the concepts of EBD and critical thinking are not accepted by the reader, the reader may not see the value of progressing as a thinker in dental care and hence keep doing the same thing year after year, never advancing as a dental provider.

1.9 Analyzing and Assessing Clinical Research Using the Tools of Critical Thinking

The essence of this textbook entails the idea that the best treatment option for a patient should be supported by the best available scientific data. The eight parts of reasoning are very useful in analyzing and assessing research in the field of dentistry (Fig. 1.6).

Analyzing & Assessing Clinical Research

Use this template to assess the quality of any clinical research project or paper.

1) All clinical research has a fundamental PURPOSE and goal.

- Research purposes and goals should be clearly stated.
- Related purposes should be explicitly distinguished.
- All segments of the research should be relevant to the purpose.
- All research purposes should be realistic and significant.

2) All clinical research addresses a fundamental QUESTION, problem or issue.

- The fundamental question at issue should be clearly and precisely stated.
- Related questions should be articulated and distinguished.
- All segments of the research should be relevant to the central question.
- All research questions should be realistic and significant.
- All research questions should define clearly stated intellectual tasks that, being fulfilled, settle the questions.

3) All clinical research identifies data, INFORMATION, and evidence relevant to its fundamental question and purpose.

- All information used should be clear, accurate, and relevant to the fundamental question at issue.
- Information gathered must be sufficient to settle the question at issue.
- Information contrary to the main conclusions of the research should be explained.

4) All clinical research contains INFERENCES or interpretations by which conclusions are drawn.

- All conclusion should be clear, accurate, and relevant to the key question at issue.
- Conclusions drawn should not go beyond what the data imply.
- Conclusions should be consistent and reconcile discrepancies in the data.
- Conclusions should explain how the key questions at issue have been settled.

5) All clinical research is conducted from some POINT OF VIEW or frame of reference.

- All points of view in the research should be identified
- Objections from competing points of view should be identified and fairly addressed.

6) All clinical research is based on ASSUMPTIONS.

- Clearly identify and assess major assumption in the research.
- Explain how the assumptions shape the research point of view.

7) All clinical research is expressed through, and shaped by, CONCEPTS and ideas.

- Assess for clarity the key concepts in the research.
- Assess the significance of the key concepts in the research.

8) All clinical research leads somewhere (i.e., have IMPLICATIONS and consequences).

- Trace the implications and consequences that follow from the research.
- Search for negative as well as positive implication.
- Consider all significant implications and consequences.

Fig. 1.6 Analyzing and assessing clinical research (Hawkins et al. 2010)

1.10 The Importance of Universal Intellectual Standards in Evidence-Based Dentistry

Once the eight parts have been analyzed, then a critical assessment of the article, lecture, event, etc. can be accomplished. For this, we must understand, internalize, and adhere to *universal intellectual standards* on a daily basis. Essential intellectual

standards include *clarity*, *accuracy*, *precision*, *relevance*, *significance*, *depth*, *breadth*, *logic*, and *fairness* (Fig. 1.7). From a practical standpoint, certain parts of the analysis and assessment can be accomplished at the same time. Using only a few of the analysis and assessment items, a quick determination as to the potential value of a given piece of research can often be accomplished.

Universal Intellectual Standards Essential to Sound Clinical Reasoning

Universal intellectual standards are standards which must be applied to thinking Whenever one is evaluating the quality of reasoning about a problem, issue, or situation. To think cirtically one must have a command of these standards. While there are a number of universal standards, we focus here on some of the most significant:

Clarity

Could you elaborate further on that point? Could you express that point in another way? Could you give me an illustration? Could you give me an example?

Clarity is a gateway standard. if a statements is unclear, we cannot determine whether it is accurate or relevant. infact. In fact, we cannot tell anything about it (except that it is unclear) because we don't yet know what it is saying.

Accuracy

Is that really true? How could we check that? How could we find out if that is true? What evidence is there to support the validity of your clinical thinking?

A statement can be clear but not accurate, as in "Most creatures with a spine weigh more than 300 pounds."

Precision

Could you give me more details? Could you be more specific?

A statement can be both clear and accurate, but not precise, as in "The solution in the beaker is hot." (We don't know how hot it is.)

Relevance

How is that connected to the question? How dose that bear on the issue?

A statement can be clear, accurate, and precise, but not relevant to the question at issue. If a person who believed in astrology defended his/her view by saying "Many intelligent people believe in astrology." their defense would be clear, accurate, and sufficiently precise, but irrelevant to clinical reasoning.

Depth

How dose your answer address the complexities in the question? How are you talking into account the problems in the question? Are you dealing with the most significant factors?

A statement can be clear, accurate, precise, and relevant, but superficial (that is, lacks depth). For example, the statement "Just Say No" which is often used to discourage children and teen from using drugs, is clear, accurate, precise, and relevant. Nevertheless, it lacks depth because it treats an extremely complex issue, the pervasive problem of drug use among young people, superficially. It fails to deal with the complexities of the issue.

Fig. 1.7 Analyzing and assessing clinical research (Hawkins et al. 2010)

Breadth

Do we need to consider another point of view? Is there another way to look at this question? What would this look like from the point of view of a conflicting theory, hypothesis or conceptual scheme?

A line of reasoning may be clear, accurate, precise, relevant and deep, but lack breadth (as in a well-reasoned argument from either of two conflicting theories which ignores insights into the conflicting theory).

Logic

Does this really make sense? Is this consistent with what we know about this issue or problem?

When we think, we bring a variety of thoughts together into some order. When the combination of thoughts is mutually supporting and makes sense in combination, the thinking is "logical." When the combination is not mutually supporting, is contradictory in some sense, or does not "make sense" the combination is "not logical." In clinical reasoning, new conceptual schemes become working hypotheses when we deduce from them logical consequences which can be tested by experiment. If many of such consequences are shown to be true, the theory (hypothesis) which implied them may itself be accepted as true.

Significance

Is the most important problem to consider? Is this the central idea to focus on? Which of these facts are most important?

When dealing with a complex issue it is essential to consider relevant variables but some are more significant than others. The most significant variables should be considered first. Secondary relevant variables come next in order of importance.

Fairness

Do we nhave a vested interest in this issue? Am I represnting the viewpoints of others in a way that is fair and balanced?

We naturally think from our own perspective, from a point of view which tends to privilege our position. Fairness implies the treating of all relevant viewpoints alike without reference to one's own feelings or interests. Because we tent to be biased in favor of our own viewpoint, it is important to keep the standard of fairness at the forefront of our thinking. This is especially important when the situation may call on us to see things we don't want to see, or give something up that we want to hold onto.

Fig. 1.7 (continued)

In assessing the quality of this chapter, using essential intellectual standards, the reader should find the following to be true:

Clarity—Hopefully the reader has found this chapter relatively straightforward and easy to read. Diagrams and charts were included to illustrate the material to help the reader better understand the text. The chapter itself has been used to provide an example on how to use the Paul-Elder Framework for Critical Thinking™ in EBD.

Accuracy and Precision—Terms were defined, and figures were taken from published materials. Appropriate literature was cited.

Depth and Breadth—The depth of the chapter is appropriate for the stated purpose (see above). Should the reader desire more depth, there are numerous articles

and texts devoted to the topic of evidence-based practice available through the sources indicated in this chapter. Similarly the breadth of the chapter was limited to only one literature review technique—the Paul-Elder Approach to Thinking™. This is also in keeping with the stated purpose.

Relevance—The concept of evidence-based practice is now an established part of contemporary dental practice. The Paul-Elder Critical Thinking Model provides a structured method for analyzing and assessing the scientific literature.

Significance—EBD is essential for reasonable dental practice in today's complex information society.

Logic—The chapter starts with defining EBD and flows from why to how. EBD is logically connected with the richer concept of critical thinking.

Fairness—Evidence and ideas in this chapter have been presented objectively and without bias.

1.11 Conclusion

To sum up this chapter, we may return to our question: *What is evidence-based dentistry?* First and foremost, it does not entail simply "doing an intervention" just because some given piece of research may offer "correct" course of action. Rather, evidence-based dentistry involves a *critical appraisal* of appropriate research and other information that addresses a patient's specific circumstances, as well as her or his value system, interpreted through the clinician's knowledge, experience, and expertise.

Why do it? Because it takes into account the worldview of the dental patient as well as the best knowledge available at a given time, in the field of dentistry.

How can EBD be reasonably accomplished?

1. Listen to patients to determine what they want.
2. Make an honest assessment of the dental situation in context.
3. Critically review the literature most relevant to the specific situation.
4. Then using personal experience, determine the best options to address the specific situation. There is usually more than one way to reach a satisfactory result. Conduct a cost-benefit, risk-benefit discussion with the patient. This is the informed consent process; make sure it is documented.

This chapter encourages the use of Paul-Elder's Framework for Critical Thinking™. It is one of the many ways to select and critically assess the literature. But it has been chosen for inclusion here because it provides an excellent method for reasoning through specific decisions, using the richest tools of criticality extant. And we have recommended that the reader apply this approach to all aspects of life. In starting this critical thinking process, consider beginning with assumptions. What assumptions have you or others made about others that resulted in a course of action detrimental or not in the best interest of your client?

The tools of critical thinking can be easily documented in the best thinking in dental practice. But dentists have yet to embrace, as a profession, a robust conception of fair-minded critical thinking. This will be required if the best evidence-based dental practices are to be achieved.

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Office Environment

2

Melissa E. Ing and Peter Arsenault

"I fear that if the matter is beyond humanity it is certainly beyond me."

—The Adventure of the Devil's Foot

Abstract

The dental profession is predisposed to various occupational hazards including blood-borne pathogens, chemical agents, and particulate projectiles which can cause skin and eye safety issues and musculoskeletal disorders. Oral surgery procedures can cultivate these occupational hazards. This chapter discusses these problems, their implications, and subsequent approaches to create a safe and functional work environment. In addition, this chapter focuses on how to incorporate proper ergonomics to prevent musculoskeletal disorders, thereby helping dentists maintain a healthy, long-term career.

2.1 Office Environment/Office Design

A dental office environment with thoughtful attention to details allows for patient comfort as well as employer and employee satisfaction. The practice should look professional and organized, with up-to-date technology, as superior office design can be an excellent marketing tool. The workplace is an expression of the dentist's personality and should make a positive impression on the patient. Particular attention should be given to make the waiting area appealing and reassuring to anxious patients. Furthermore, treatment areas should have soundproof walls to drown out loud noises such as those from turbine-driven handpieces.

Dentists will always have their personal vision of what the office space should consist of. However, an office's clinical function will dictate its layout and ergonomic considerations.

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The floor plan should have good traffic flow. There should be areas that are accessible to patients and private areas designated only for the staff.

Dental professionals can be exposed to numerous occupational hazards including exposure to blood-borne pathogens, chemical agents, and musculoskeletal disorders due to ergonomic setups. The office environment should provide protective mechanisms and a systematic approach to safe practices.

2.2 Blood-Borne Pathogens

Dental offices must vigilantly follow the Centers for Disease Control and Prevention (CDC) and the Occupational Safety and Health Administration (OSHA) guidelines for proper infection control and safe work practices. While the CDC is a government agency within the US Public Health Service, it is not a regulatory authority (Cuny and Collins 2013). However, creating infection control recommendations according to evidence-based research is one of the CDC's many tasks. OSHA is part of the US Department of Labor, and their duty is to protect the health and safety of workers within the USA. OSHA creates regulations such as the Bloodborne Pathogens standard to reduce the risk of occupational exposure to blood-borne pathogens (Cuny and Collins 2013).

The blood-borne pathogens that are of concern to dental health-care personnel (DHCP) are hepatitis B (HBV), hepatitis C (HCV), and human immunodeficiency virus (HIV). HBV vaccinations became routine in 1982 and universal precautions have been recommended since 1987.

Due to hepatitis B vaccinations and universal precaution recommendations, transmission of blood-borne pathogens in the dental setting has rarely been reported during the last decade. In the 1990s, there was one case where a dentist with autoimmune deficiency disease (AIDS) was found to have transmitted HIV to five of his patients after invasive procedures (Ciesielski and Marianos 1992). At this time, there are no known patient to patient reports of HIV transmission.

Yet, a 2016 review of the literature cites three reports of blood-borne pathogen transmissions of hepatitis B and hepatitis C from 2003 through 2015 (Cleveland 2016). The article described an incident from 2002 as a single HBV transmission from one patient to another patient that occurred in an oral surgery office. The article described a 2009 occurrence as the first documented patient to patient HBV transmission which occurred in a large portable free dental clinic setting. The third reported incident occurred in 2013 at an oral surgery office and is considered the first documented case of patient to patient transmission of HCV in an American dental setting. In the 2002 case, investigators speculated that there was a breach in cleaning the environmental surfaces that resulted in cross contamination of blood with the source patient who had chronic HBV with a high viral load at the time of the surgery (Cleveland 2016). In the 2009 documented case, five HBV transmissions occurred from a portable free dental clinic that was held in a gymnasium. Multiple failures in infection control were cited retrospectively as the cause of the transmission of HBV to three other patients as well as to two DHCP. It was reported that the

utilized handpieces were not heat sterilized; unwrapped sterilized instruments were utilized, and patients were allowed to transport partially used anesthetic cartridges in metal syringes to another station for later reuse (Cleveland 2016). Investigators speculate that the 2013 patient to patient transmission of HCV occurred due to the failure to administer IV sedation by licensed, trained dental personnel, due to the use of improperly sterilized equipment, and due to the reusing of contaminated medication vials, needles, and syringes (Cleveland 2016).

Lesson gleaned from the above reporting is that even though blood-borne pathogen transmissions are infrequent, they can happen from routine restorative and oral surgery procedures. There are several potential routes for the spread of infection in the dental clinic. These include (1) direct contact with bodily fluids of an infective patient, (2) contact with contaminated instruments or environmental surfaces, and (3) contact with infectious airborne particles from an infective patient (Harrel and Molinari 2004).

HBV and HCV can survive on blood-contaminated environmental surfaces for long periods of time. Bond et al. demonstrated that the HBV virus can survive in dried blood at room temperature on environmental surfaces for at least 1 week (Bond et al. 1981). Furthermore, Paintsil et al. demonstrated that HCV infectivity can remain on dry surfaces for up to 6 weeks (Paintsil et al. 2014). HIV can survive in dried blood at room temperature for 5–6 days if placed in an ideal pH level. For long-term survival, HIV cannot have a pH below 7 nor a pH above 8 (Tjotta 1991).

In 2003 the CDC published the Guidelines for Infection Control in Dental Health Care Settings. To this day, this remains the standard for offices and institutions to follow (CDC 2003). More recently, the CDC also published the Summary of Infection Prevention Practices in Dental Settings: Basic Expectations for Safe Care. This includes a handy infection prevention checklist that DHCP can use to evaluate infection control compliance (CDC n.d.-a). Offices should designate an infection control officer to be in charge of assessing annual safe practice policies and updating a written manual. Dental offices should ensure each DHCP hire and current employees have yearly OSHA training.

Clinicians should always keep in mind that all patients could be carriers of an infectious disease. Therefore, universal precautions should always be followed. Since oral surgical procedures can increase the risks of local or systemic infection, it would be prudent to have an extra vigilant infection prevention routine in place.

2.3 Spatter and Aerosols

In the dental operatory, a visible spray is created each time high-speed rotary handpieces, ultrasonic scalers, or air-water syringes are utilized. Water is often used as coolant with handpieces and ultrasonics to prevent overheating of tooth structure. Studies show that when high-speed rotary handpieces are used, the air can be contaminated for a period of time until the particles settle (Harrel and Molinari 2004). In oral surgery, Hall drills, Stryker drills, and high-speed and low-speed drills are often used to section teeth for easier extraction and for implant placement.

The water spray alone that is generated from the rotary equipment may not be harmful, but once mixed with the patient's oral fluids such as saliva, blood, bone fragments, human tissue, bacteria, and debris, it can turn into a potential health hazard.

This visible spray contains larger and smaller particles. The larger particles, in the size of 50 μm or more, are called "spatter" (Harrel and Molinari 2004; Micik et al. 1969). Since spatter particles are large and heavy, they traverse short distances, landing fairly quickly on operatory surfaces, equipment, the clinician, and the patient.

In contrast, aerosols are defined as a collection of solid or liquid particles which are less than 50 μm in size (Harrel and Molinari 2004; Micik et al. 1969). Since aerosols are much smaller particles, they remain suspended in air much longer than spatter before finally contacting surfaces (Harrel and Molinari 2004). In fact, aerosols can stay suspended in the operatory air for up to 30 min (Harrel and Molinari 2004). Some of the smaller aerosols that range in size from 0.5 to 10 μm can potentially travel to and penetrate into the pulmonary passages (Harrel and Molinari 2004). Harrel and Molinari noted that if DHCP remove face shields upon completing the procedure to talk with the patient, there is potential contact with aerosol contaminants which are floating in the environment (Harrel and Molinari 2004).

Studies have demonstrated that the ultrasonic scaler produces the greatest amount of airborne contamination followed by the high-speed handpiece. The air-water syringe also produces a great deal of aerosols (Harrel and Molinari 2004).

Investigators have demonstrated that during scaling and root planing, blood is always present in the ultrasonic scaler aerosols (Harrel and Molinari 2004). Harrel and Molinari deduced that blood is most likely present in aerosols where any rotary instrumentation was used within an operating field containing blood. This would include any subgingival, periodontal, and oral surgery procedures (Harrel and Molinari 2004).

2.4 Infection Control Measures

The most logical and first precautionary measure to reduce spatter and aerosols is to ensure that DHCP wear OSHA-approved personal protection equipment (PPE) while treating patients as well as when preparing and breaking down the operatory.

PPE consists of and should be donned in the following sequence: (1) fluid resistant clinic gowns, (2) face masks, (3) safety eyewear, and (4) gloves.

Clinic gowns should have high necks and long sleeves, with ribbed cuffs at the neck and at the wrists. The gowns should at least cover the operator's knees when seated. Rutala et al. studied the cost differences between disposable and reusable gowns and found that reusable gowns did not always save money due to the fact that the gowns would be damaged during the handling and laundering process thus rendering them useless (Rutala et al. 2001). Rutala also demonstrated that some

reusable gown materials proved more superior than others. Gowns with a laminated coating of polypropylene provided the most superior resistance to blood and other liquids seeping through. A single-layered non-woven fabric was found to be the next best performing reusable gown fabric. 50 cotton/50 polyester was not very effective in preventing blood strike through, and 100% cotton offered the least amount of protection (Rutala et al. 2001).

If masks become soiled or wet during the procedure, they should be replaced. Clinicians should always avoid touching masks during the course of treatment to prevent cross contamination. All dental mask styles provide protection of covered facial areas (nose, mouth, and portions of the cheeks) against splash and projectiles.

Dental masks are available in a variety of designs and profiles. Pleated-type dental masks are preferred by dental practitioners since they are easy to wear and have low resistance to breathing. Most pleated masks contain an inner layer of melt-blown filtration material (Arsenault and Tayebi 2016). However, since there is no effective seal between the perimeter of the mask and the wearer's face, air leakage occurs through the perimeter of the mask, and hence, the mask fails to provide effective respiratory system protection. The National Institute for Occupational Safety and Health (NIOSH), which is part of the CDC, utilizes research to promote safer recommendations for workers. In comparison to NIOSH-approved respirators, most pleated masks lack the seal between their perimeter and the wearer's face and hence would not meet NIOSH approval requirements (Arsenault and Tayebi 2016). Masks that are fitted with a full-face transparent shield such as an up visor or a full down visor may be particularly desirable when an oral surgery procedure generates excessive blood splashes, fluids, or particulates.

The CDC recommends that prior to oral surgical procedures, a fast-acting antimicrobial soap with a broad spectrum of bactericidal activity is utilized for handwashing. For oral surgery procedures in the operating room, sterile gloves should be used. If gloves become wet and torn or are deemed defective, they should be promptly replaced. Scrupulous handwashing after the procedure is completed must take place.

In 2006, Rautemaa et al. studied how far aerosols travel from a patient after the use of high-speed rotary instrumentation is utilized in the operatory. Investigators placed agar plates in distances varying from 0.5 to 2 m from the patient. The agar plates were samples before and after dental procedures. At the same time, they also sampled the facial masks of the DHCP before and after the procedure. The most commonly found bacteria in the agar plates were *Viridans streptococci* and staphylococci. Significant contamination was found from agar plates at all distances. Face masks were found to be equally contaminated when high-speed rotary instruments were used. Rautemaa's study substantiates how aerosols spread beyond the area and equipment used for the procedure (Rautemaa et al. 2006). Thus, all PPE needs to be removed as soon as the DHCP leave the operating area to prevent cross contamination. This study also substantiates the need to wear PPE when cleaning, preparing, and breaking down operatory surfaces and equipment (Rautemaa et al. 2006).

In addition, Rautemaa's work demonstrates that all environmental surfaces, even if not used for the procedure, must be thoroughly disinfected at the beginning of the workday, in between each patient, and at the end of the workday. Rautemaa's study also suggests that only necessary equipment items needed for the procedure at hand be placed within the operatory work surfaces to minimize contamination and that all other items be placed within a closed cupboard (Rautemaa et al. 2006). Furthermore, Rautemaa et al. (2006) suggest protection of the exposed skin and hair to prevent bacterial spread.

As a second precautionary measure, having patients use an antiseptic preoperative rinse such as 0.01% chlorhexidine for 1 min prior to the procedure can lower overall bacterial counts in the operating environment (Harrel and Molinari 2004).

A third essential method in reducing airborne aerosols is to use an efficient high-volume evacuator (HVE) to prevent aerosols and bacteria from escaping the immediate operating site. An HVE suction system is defined as one that removes a large volume of air within a short period of time. Most HVE used in dentistry are attached to an evacuation system and will have an 8 mm or greater opening and are able to remove up to 100 cubic feet of air per minute. Since a saliva ejector has a very small opening, it cannot remove enough volume of air to be classified as an HVE. Studies demonstrated that an HVE with a good suction system can reduce up to 90% of operatory area contamination (Harrel and Molinari 2004; Micik et al. 1969). A study done by Noro et al. in Japan demonstrated that the use of a high-speed vacuum aspirator effectively reduced the spread of streptococci bacteria (Micik et al. 1969; Noro et al. 1995).

It is important that each dental unit suction hose be flushed twice daily with disinfecting agent and routinely cleaned according to manufacturer's instructions. The water in each unit should be flushed for any utilized handpieces, ultrasonic scalers, and air-water syringes for 30 s after each patient.

Whenever possible, single-use devices such as aspirator tips and drill burs should be used. Disposable instruments and equipment eliminate the risk of patient to patient contamination once it is discarded after one-time use. Items such as patient bib clip chains are sources of cross contamination. The University of North Carolina cultured bib chains in a study and found strains of *Pseudomonas*, *E. coli*, and *Staphylococcus aureus*. These bacteria can put immunocompromised populations at even greater risk for respiratory disease transmission. Disinfecting the napkin holders does not eradicate the bacteria completely, so disposable holders should be considered instead (Molinari 2010). The CDC recommends that one-time-use gauze, irrigating syringes, syringe needles, and scalpel blades used for oral surgery procedures be sterile (CDC n.d.-b).

At the end of the appointment, the CDC recommends the following sequential order for instrument processing (Cuny and Collins 2013; CDC 2003). Sharps, including syringe needles, burs, and scalpel blades, need to be carefully discarded into specially marked puncture-resistant sharps containers. Next, single-use disposable materials and waste should be discarded. Biohazard waste must be disposed of in specially marked biohazard containers in accordance with state

regulations. The equipment and instrument cassettes should be transported to a centrally located cleaning and sterilization area that fosters one-directional work flow which will prevent cross contamination (Cuny and Collins 2013). There should be separate areas for receiving dirty instruments and cassettes as well as areas for decontamination, packaging for sterilization, and sterilization. There should be a separate storage area to place sterile packaged instruments until ready for the next procedures.

The CDC has made three categories of criteria to determine how instruments should be sterilized. These categories are (1) critical, (2) semi-critical, and (3) non-critical. Critical instruments are those that penetrate soft tissue, contact the bone, or have entered the bloodstream. Critical instruments used in oral surgery procedures would include dental burs, elevators, forceps, and scalpel blades. Semi-critical instruments are those that contact mucous membranes but have not penetrated soft tissue or bone and have not entered the bloodstream. These instruments would include dental mouth mirrors and dental handpieces. Noncritical instruments are those that contact intact skin, and this equipment would include blood pressure cuffs, pulse oximeters, and radiographic tube heads. The CDC stipulates that all critical instruments be heat sterilized as well as all dental handpieces even though they are considered semi-critical (Cuny and Collins 2013; CDC 2003).

Utilized handpieces should be lubricated after use to prolong the life of the equipment prior to sterilization. Hand instruments should be cleaned thoroughly with either a washing disinfecting machine or an ultrasonic soak. The pre-cleaning helps to remove blood or debris that could potentially harm the DHCP that is packaging the cassettes for sterilization. Used handpieces and hand instruments must be inspected thoroughly for any left on particles of blood, tooth, and bone debris. Debris must be removed so as not to compromise the sterilization process. A metal cleaning brush can be used to clean off caked on debris. Equipment should then always be prepared for sterilization by wrapping and sealing in special pouches or bound in sterilization appropriate sheeting that are labeled to show the date of sterilization, which sterilizer was used, and the load or cycle.

Quality assurance of the instrument sterilization process must be upheld for patient safety. It is crucial that sterilization machines are not improperly loaded. Overloading is a common reason for sterilization failure. Utilizing a combination of biological and chemical indicator methods ensures that adequate sterilization conditions have been achieved (Cuny and Collins 2013).

The biological indicator method is also commonly referred to as “spore testing.” Spore testing is recommended at least once a week for private practice offices and institutions. Spore testing is the most widely accepted method of testing sterilization efficacy since it can kill highly resistant microorganisms such as *Geobacillus* and *Bacillus* (Cuny and Collins 2013; CDC 2003).

Since spore testing might only be done once a week and takes some time to obtain the results, it is prudent to also utilize a chemical indicator method. Chemical indicators can provide more timely indications if sterilization equipment malfunction were to occur (Cuny and Collins 2013; CDC 2003).

Peel and seal sterilization pouches specially marked with sensitive chemical indicators will change color if the contents have been sterilized to correct temperature and time. It is also possible to place chemical indicating tape over wrapped instruments. If a color change does not occur after the sterilization process, this indicates that the sterilization process has been compromised, so the instruments should be repackaged and sent through sterilization again (Cuny and Collins 2013; CDC 2003).

Furthermore, chemical indicating devices, called "multiparameter integrators," are highly suggested to be placed within the instrument pouches to determine optimal sterilization conditions. The integrators verify that the sterilization process has penetrated the instruments within the packaging (Cuny and Collins 2013; CDC 2003). Multiparameter integrators indicate if the contents of the peel and seal pouch have been exposed to the correct time, temperature, and pressure during autoclaving procedures (see Photo 2.1).

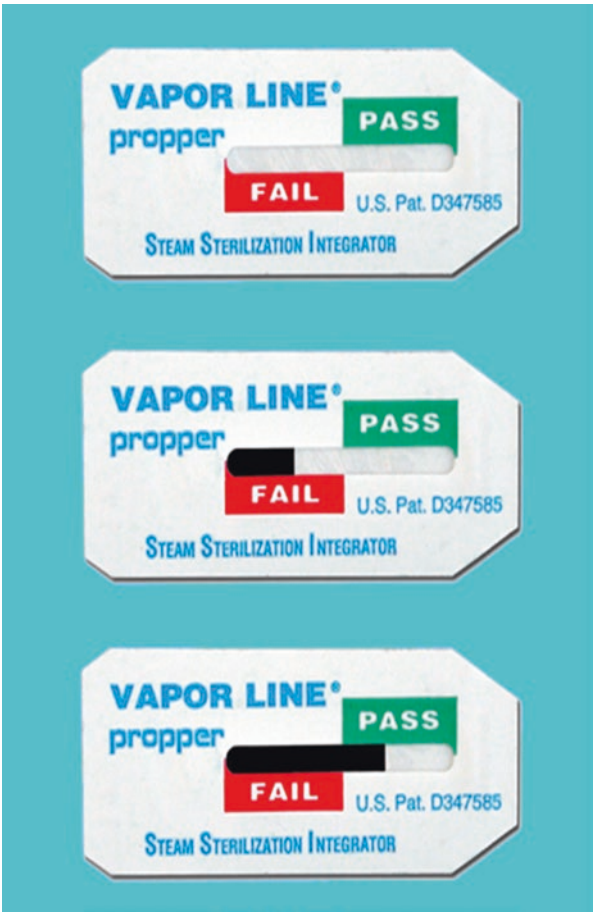


Photo 2.1 Example of a chemical multiparameter integrator (courtesy of Vapor Line)

2.5 Eyewear Safety Considerations

OSHA Standard 1910.133(a) (1) states:

> "The **employer** shall ensure that each affected employee uses **appropriate** eye or face protection when exposed to **eye** or face hazards from **flying particles**, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation."

By their nature, dental procedures involving drilling at very high speeds (180,000–500,000 rpm) generate debris that can travel at speeds of up to 50 mph (Arsenault and Tayebi 2016). Such debris could include pieces of amalgam, tooth enamel, calculus, pumice, and broken dental burs. In the absence of a protective means, such debris may find its way to the eyes of the practitioner, the staff, or the patient.

CDC and OSHA mandate that dentists wear protective eyewear (either glasses or loupes, prescription or nonprescription) while performing dental procedures. Most often, dental assistants wear either prescription or nonprescription safety eyewear.

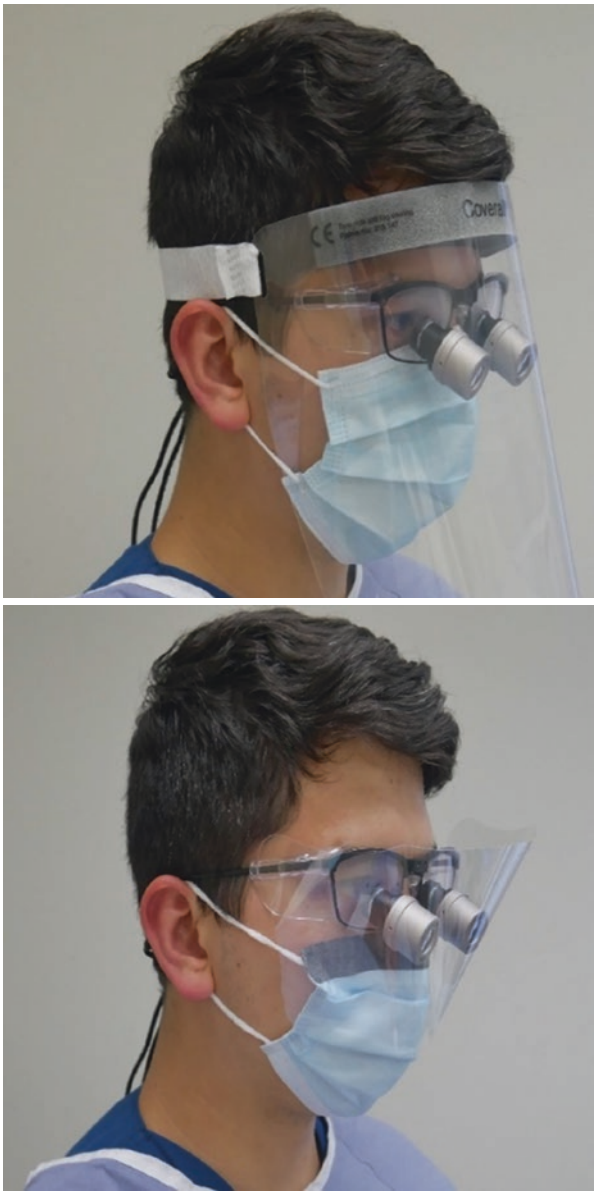
Masks with full-face shield or a mask and visor combination provide the most effective facial and eye protection to date against projectile and spatter hazards (see Photos 2.2 and 2.3). However, their use by dental practitioners is limited due to their higher cost, reflective glare, fogging, and optical distortion caused by the unavoidable curvature of the face shield when the mask is worn and hotness of the air in the zone between the face shield and the wearer's face. This results in discomfort and inconvenience.

There are three possible routes dental debris may follow in order to reach the eye of a practitioner not wearing a full-face shield mask or mask and visor combination.

(a) Frontal entry route by debris traveling perpendicular to the dental professional's face. Glasses provide the necessary protection against such debris. Not only do the glasses need to meet OSHA Standard 1910.133(a) (1), but they also must meet ANSI Standard (Z87.1) (Arsenault and Tayebi 2016). ANSI is the American National Standards Institute which supervises the development of safety standards from products, systems, and services in the USA. By choosing eyewear that meets both OSHA and ANSI, fewer eye injuries are caused by flying debris.
(b) Sideway (right to left or left to right) entry routes by debris traveling tangential to the face. Side shields provide effective protection against such debris and are specifically required by OSHA Standard 1910.133(a) (2), which states:

> "The **employer** shall ensure that each affected employee uses **eye protection** that provides **side protection** when there is a hazard from **flying objects**. Detachable side protectors (e.g. clip-on or slide-on side shields) meeting the pertinent requirements of this section are acceptable."

Photos 2.2 and 2.3
Up visor and down visor prevent bottom gap space breach



(c) Bottom gap entry routes (see Photo 2.4) by debris traveling vertically and tangential to the face. Such debris may reach a practitioner's eye through the open gaps (bottom gaps) between the lower rims of the lenses of the protective eyewear and the upper edge of the mask worn by the practitioner (Arsenault and Tayebi 2016).

Since frontal entry route and sideway entry routes are effectively blocked by the use of OSHA-required protective eyewear (OSHA Standard 1910.133(a) (1)) and side shields (OSHA Standard 1910.133(a) (2)), the bottom gap entry routes are the most frequent, yet unaddressed, routes of eye-injury-causing debris.

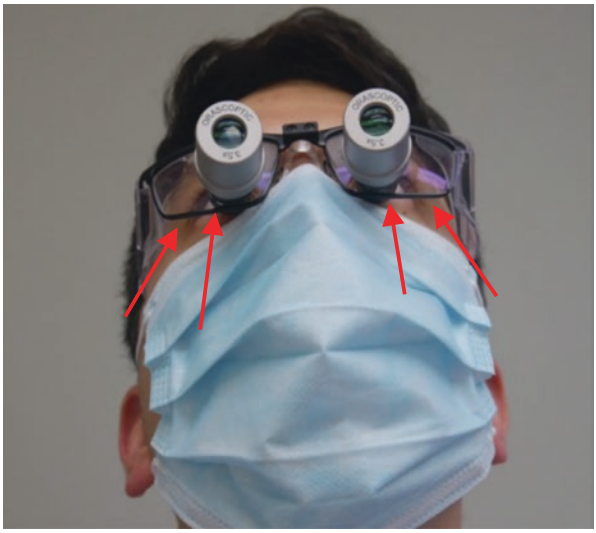


Photo 2.4 Bottom gaps

Arsenault and Tayebi demonstrated in their studies that there is a major inadequacy and breach in protecting the dental care provider's eyes using the present dental mask and standard/typical eyewear combination. Closing the bottom gaps is essential and should be considered "appropriate" when defining adequate or appropriate personal protective equipment standards as noted by OSHA (Arsenault and Tayebi 2016).

It is inherent and unavoidable in the process of wearing a non-full-face shield dental mask or mask/visor combination and deforming the mask's nose clip to fit over the wearer's nose that bottom gaps are generated; therefore, the currently used combination of protective eyewear and standard dental mask does not provide the "appropriate" eye protection required by OSHA. Also, the unavoidable generation of the bottom gaps renders the combination of regular protective eyewear and standard mask combination to be a potentially dangerous combination since it is reasonably foreseeable that dental debris may reach the eyes of the dental practitioner or dental personnel through such open bottom gaps.

It is also important to consider protection for the patients' eyes. Instruments can be sharp and heavy and could inadvertently fall into the patient's face or eyes so it is imperative to provide appropriate safety eyewear with side shield protection for all patients. It would be prudent to pass instruments either around the back of the patient's head or below their chin areas instead of over their faces.

At the end of the procedure, all protective eyewear should be wiped down with a hospital-approved disinfectant, then rinsed off, and allowed to air-dry.

2.6 Extracted Teeth

The CDC guidelines state that extracted teeth can be returned to patients upon request (CDC n.d.-c). If a tooth is returned to a patient, then OSHA regulations do not apply since OSHA regulations are set forth to protect the employees. If the tooth

is given to the patient, OSHA does not consider it a risk to DHCP since they do not need to transport, clean, or dispose of human tissue. However, if extracted teeth are to be discarded in the dental office, then OSHA compliance must be followed as the teeth would be considered potentially infectious waste. Extracted teeth must be disposed of in specially marked medical waste containers (CDC n.d.-c).

Teeth containing amalgam must not be disposed of in the same medical waste containers that use an incineration process. Clinicians should be familiar with their state laws regarding amalgam disposal.

Often, dental offices will be approached by dental students who wish to collect teeth to be used in educational and research settings. The CDC suggests that collected teeth be stored in 1:10 bleach to water in a sealed container upon leaving the dental office. Per CDC recommendations, the students should autoclave the teeth prior to using for the teaching exercises or research purposes (CDC n.d.-c).

2.7 Handling and Shipping of Biopsy Specimens

Often tissue is biopsied at the dental office and sent to a laboratory facility for pathology evaluation. Any time materials are handled in the dental laboratory, OSHA-approved PPE should be worn. The preservatives used to store the tissues are considered potentially hazardous materials by the US Federal Department of Transportation (DOT) or the International Air Transport Association (IATA), so great care must be given to packaging and shipping.

Most clinicians use 10% formalin as a tissue preservative. 10% formalin is prepared by diluting a 37% formaldehyde solution. A 10% formalin solution contains 3.7% formaldehyde. It is considered within regulatory limits to store a specimen in a solution that contains 10% or less of formaldehyde.

The shipper is responsible for any spills while in transit. Should the package break open and require an emergency cleanup, the DOT or the Federal Aviation Administration will fine the shipper. Dental offices should triple package the specimens using leakproof containers with watertight lids. The specimen must be placed in a primary leakproof container, affixed with a biohazard label, which goes into a secondary leakproof container. In between the primary and secondary containers, there should be enough absorbent materials and bubble wrap to absorb all the liquids in case anything breaks. This should all be placed inside a rigid box that is concisely marked with the number of items contained within. In addition, the outside of the box needs to be labeled with the following specific words for biopsy specimens: “Exempt Human Specimens” along with the addressed “To” and “From.” In addition, there should be arrows indicating the orientation of the test tubes or containers upright position. Once packaging is completed, the box should be able to sustain a drop of several feet without the container boxes breaking apart. It is important that the outside packaging not be contaminated. Consideration should be given to the shipping personnel that will be handling the package and not wearing PPE once the package leaves the office premises (see Fig. 2.1).

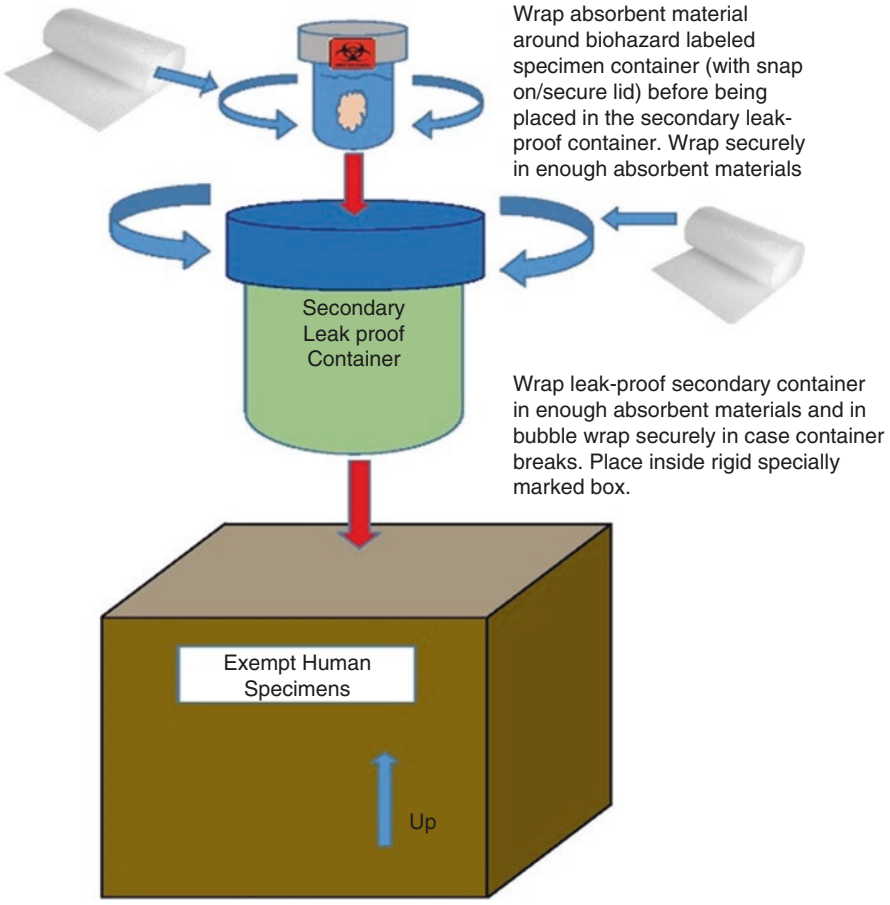


Fig. 2.1 Triple packaging of biopsy specimens. Drawn by Melissa E. Ing, D.M.D., and Ms. Patricia DiAngelis

The shipper should use their best practices professional judgment and always follow the triple packaging principles.

2.8 Musculoskeletal Disorders and the Dental Surgeon

Musculoskeletal disorders (MSDs) are injuries or disorders of the soft tissues that can include the muscles, tendons, ligaments, joints, cartilage, and nerves. DHCP are prone to work-related MSDs, which are MSDs that are made worse when exposed to certain work conditions and risk factors. Dentists commonly report MSDs in the areas of the neck, shoulders, back, and arms (Valachi and Valachi 2003a). While treating patients, dental surgeons tend to work in static seating or standing postures, often bending over to peer into the patient's oral cavity. In addition, dentists are

prone to tightly grasp small hand instruments and use vibrating handpieces for prolonged periods. Repeatedly straining to visualize with little movement of joints and muscles while working in a very confined oral cavity spaces predisposes dentists to MSDs.

MSDs can result in reduced productivity and lost wages due to healing time. Michalak-Turcotte estimated that American dental professionals report an annual income loss of approximately 41 million dollars due to MSDs (Michalak-Turcotte et al. 2000).

MSDs have long been described by dental clinicians. In 1946, at a time when all dentistry was done in an upright standing position, F.E. Biller reported that 65% of dentists reported back pain (Biller 1946). Decades later, the advent of four-handed dentistry has decreased operator stress and increased office efficiency. Dental equipment has ergonomically evolved as well, yet, there is no less reporting of MSDs (Valachi and Valachi 2003a; Shaik et al. 2011; Ayatollani et al. 2012). Studies conducted from 1987 until 2000 showed that up to 81% of dental professionals report pain in the back, neck, shoulders, or arms (Shaik et al. 2011). Most clinicians favor a standing rather than sitting position without back support when performing present-day oral surgical procedures such as extractions. Anecdotally, when oral surgeons are asked why they choose standing over sitting, they most often will answer: "It's tradition." Most general dentists prefer a seated position when performing restorative procedures. Valachi and Valachi (2003a) compared pain statistics of the 1946 standing dentists to the present-day seated clinicians and found that the seated position made little difference in how frequently MSDs were reported. Instead, the investigators found that pain reporting fluctuates to different areas of the body depending on whether clinicians chose a seated or standing position. Clinicians that favored a seated position reported pain in the back, neck, shoulders, and arms. Clinicians that favored a standing position reported lower back pain, varicose veins, and flat foot (Valachi and Valachi 2003a).

Pejcic et al. demonstrated that it is best to alter sitting and standing positions while performing dentistry (Pejcic et al. 2016). Different sets of muscles are used when standing versus sitting, so alternating the positioning will give one set of muscles the chance to rest while the workload is turned over to another set of muscles (Biller 1946). Furthermore, Catovic et al. (1991) found that a seated position is preferred when visually intensive or precise work is being done, while a standing position may be more ideal for maximizing gripping forces.

In addition, the University of California at Los Angeles Ergonomics Group demonstrates that alternating standing and sitting during a workday of tasks is a better way to prevent MSDs of the back and may help to maintain a neutral spine position. Neutral spine is also referred to as a healthy spine or good posture. When viewed from the side of the body, there are three natural curves in maintaining a healthy spine. These consist of the neck or cervical spine area which gently curves inward, the mid-back or thoracic area which curves outward, and the lower back or lumbar area which curves inward (see Photo 2.5).

The dental professional spends much of their day in a forward leaning position. While trying to get closer to the patient for better access and vision, the

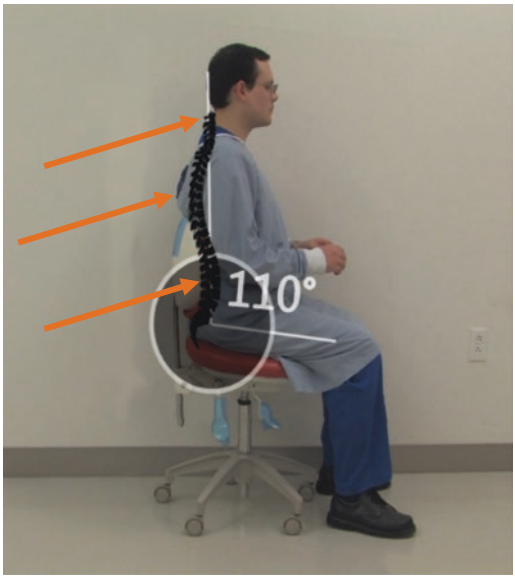


Photo 2.5 Operator chair with five castor wheels and proper lumbar support allowing neutral spine. Operator thighs at approximately 110° waterfall

tendency is to slouch. Due to the forward flexion slouching assumed during most of the workday, many DHCP report back pain. It is important to work on building strong core muscles which can help stabilize and protect the spine (Valachi and Valachi 2003b).

Arm, wrist, and hand ailments are commonly reported by dental professionals. Common complaints to hand surgeons include carpal tunnel discomfort, trigger finger, and wrist tendonitis.

The median nerve and several tendons loop through a small passageway in the wrist called the carpal tunnel. The median nerve controls movement and sensitivity in the thumb and the first three fingers. Prolonged wrist flexure positioning and gripping instruments too tightly can cause carpal tunnel syndrome (CTS). CTS can cause pressure and swelling of the median nerve. Symptoms can include numbness, tingling, weakness of the thumb area, and pain that can run from the hand, up the wrist, and to the elbow. It is reportedly mostly in the dominant hand but can also be bilateral (Ashworth 2016).

In addition, exceedingly firm and awkward ergonomic grips on instruments can cause a stenosing tenosynovitis of the digits, which is also called "trigger finger." Trigger finger is characterized by pain on the palm side of the hand involving the metacarpal heads of the digits. A true trigger finger can cause the fingers to lock up so that movement is staggered and painful. Furthermore, there is wrist tendonitis. The most common is De Quervain's tendonitis which consists of inflammation of the first dorsal compartment tendons located behind the thumb area. Prolonged deviation and repetitive activity increase the risk of ulnar neuropathy. Other tendonitis ailments affecting dentists involve the radial, ulnar, and dorsal regions of the wrist (Shehab and Mirabelli 2013; Tallia and Cardone 2003).

Due to long procedures where dentists are engaged in static and repetitive strain, the best advice is to give hands and arms a rest in between procedures. Rotating tasks and releasing forceful instrument grasps may prevent CTS, trigger finger, as well as wrist ailments.

2.9 Selecting Equipment to Fit Clinicians' Ergonomic Needs

Ergonomics is the science of fitting the environment to the worker. Ergonomic equipment and office design can impact MSDs. Properly selected operator chairs, patient chairs, and delivery systems can promote better posture. The physical stature of the clinician should be considered when purchasing these three pieces of equipment so as to maintain neutral spine (Michalak-Turcotte et al. 2006).

The operator chair should be sturdily supported on five castor wheels. It should provide back support and seat contour to allow for a neutral spine position at all times. When seated, the clinician's buttocks should be snug against the back of the chair (Valachi and Valachi 2003b). The clinician's feet should be positioned flat on the floor, and they should not be resting on the castor wheels for support. The seat height should be adjusted high enough so that the thighs make a gentle downward waterfall (Valachi and Valachi 2003b). It is important that the operator chair is adjusted prior to adjusting the patient position (Valachi and Valachi 2003b; Michalak-Turcotte et al. 2006) (see Photo 2.5).

The patient chair should allow the clinician close proximity to the patient, so they do not have to overreach to get to his or her equipment. It is crucial that the dentist does not need to lean into the oral cavity. The patient chair should also consist of a small and thin headrest so that the clinician's legs and thighs can fit comfortably under the patient chair without obstruction (Valachi and Valachi 2003b; Michalak-Turcotte et al. 2006).

Delivery systems can be side mounted to the patient chair or rear mounted. Most delivery systems are designed for four-handed dentistry. Operators that work on their own may find themselves twisting their torsos or overreaching to obtain desired instruments (Michalak-Turcotte et al. 2006).

Clinicians should research, try out, and then invest in the best equipment to protect their muscles and spines.

2.10 Magnification Aids

Most dentists have the tendency to lean their heads and necks forward by 30° for about 85% of the time while operating, thereby accounting for the approximate 70% of reported neck pain (Marklin and Cherney 2005; Lehto et al. 1991). The forward positioning results in an unsupported spine as well as muscles that can easily fatigue and can cause a painful disorder called tension neck syndrome (TNS). TNS can include headaches and pain that radiates through the neck and shoulders and down the arms (Valachi and Valachi 2003b).

Magnification aids such as loupes can improve vision of the operating field as well as clinician posture, if chosen properly. It is important to understand several

concepts before purchasing magnification devices. Prior to ordering a pair, the clinician should try out different brands of magnifying loupes. Glass frames may rest differently on each operator depending on facial features. Manufacturers should calculate the proper working distance and angle of declination for clinicians.

Working distance is defined as the distance from the clinician's eyes to the working area. Working distance can vary based on the dentist's height. If the clinician is shorter, then the working distance will probably be around 14 in. away, whereas a very tall provider may have a working distance of 20 in. or more (Valachi and Valachi 2003b). Declination angle is defined as that angle the eyes are inclined downward toward the work area (see Photos 2.6 and 2.7) This is a very important aspect for cervical health. Well-designed magnification loupes prevent the head from leaning forward more than 25°. If loupes have a steep enough declination angle, there is minimal need to lean forward. Valachi et al. believe that in general, flip-up style loupes allow for a steeper angle of declination and therefore less neck flexion (Valachi and Valachi 2003b).

2.11 Illumination Considerations

Proper illumination of the operating field enhances critical details and prevents eye strain. Operatory lights are offered in different configurations. Those that are mounted on a ceiling track or wall unit may be less cumbersome as they allow clinicians' arms to have free movement as opposed to those lights that are self-mounted to patient chairs. Lights that are attached to chairs could cause clinicians to overreach when adjusting.

Dr. Lance Rucker, an ergonomic specialist from the University of British Columbia, gives the following advice to eliminate shadows while working with

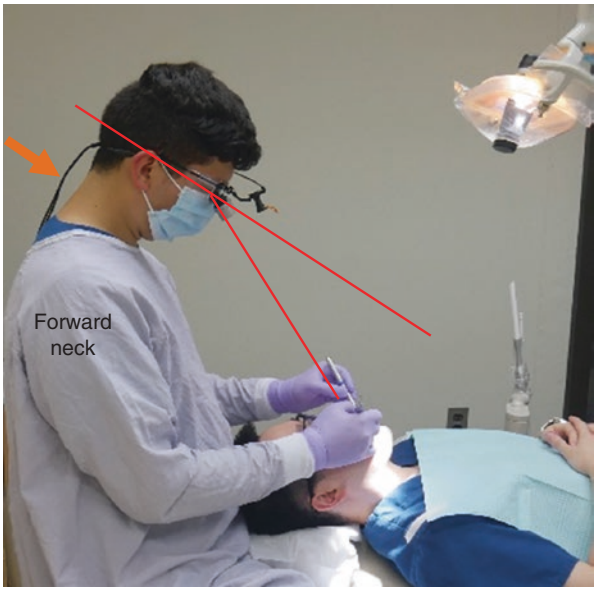


Photo 2.6 Less declination angle

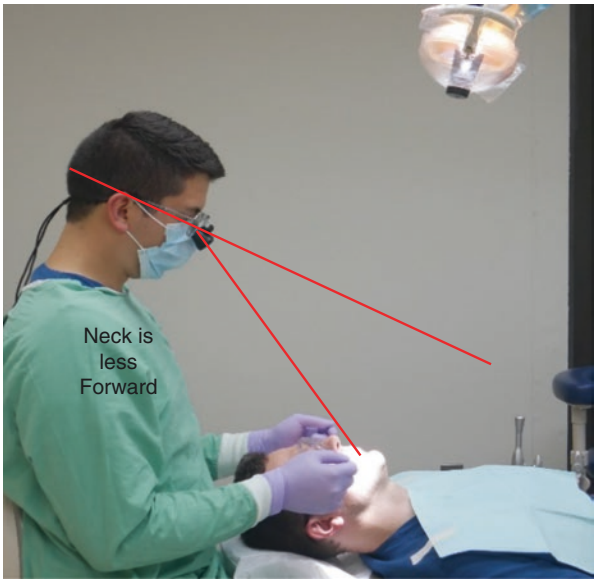


Photo 2.7 Steeper declination angle with flip-up loupes

illumination sources. Dr. Rucker advises that the operatory light should always be parallel to or within 15° of the operator's line of sight (Rucker et al. 1999). In many cases, this would necessitate the operatory light be behind the operator's head, which may be difficult with ceiling track systems. Headlamps mounted to loupes or to the forehead can provide direct and parallel lighting to the operator's line of sight, significantly minimizing shadows (Rucker et al. 1999).

By the year 2020, it is estimated that most light sources will consist of light-emitting diode (LED) lighting. LEDs have advantages over incandescent as well as other light sources. LEDs have a longer life span and better energy efficiency and are more cost-effective. Currently, loupe headlamps are mostly of the LED variety, and overhead lighting is also switching over to LED.

However, LEDs contain blue light, which at 445 nm is part of the visible light spectrum. Blue light affects the back of the eye, and research has shown that it could cause retinal damage, possibly leading to macular degeneration, over time. The macula is the central portion of the retina which is responsible for the ability to focus, to read, and to see objects in fine detail. The eye responds easily to LED exposure. Clinicians have reported blurry vision, headaches, and eye strain while using LED headlamps (Ing et al. 2015).

It is recommended to turn off the headlamp when not in use. In addition, it is recommended to purchase loupes with adjustable headlamp settings and to keep it on the lowest intensity that allows for the most comfortable illumination (Ing et al. 2015).

2.12 Prevention Before Intervention

In addition to selecting proper ergonomic equipment, clinicians should adopt an injury prevention program. This should include the incorporation of proper seating and positioning while working, stress reduction, and regular aerobic and daily ergonomic exercises as part of their routine.

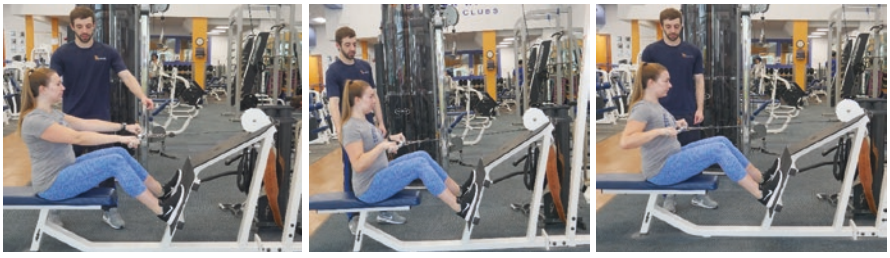
To maintain neutral spine and to prevent MSDs, it is important to position the patient in a position far enough back so that the patient's face is at the operator's elbow. The elbows should not be elevated more than 30° to prevent the dentist's shoulders and arm muscles from elevating and fatiguing (Valachi and Valachi 2003b).

In general, when performing mandibular procedures, the patient should be placed in a semi-supine position. In general, when performing maxillary procedures, the patient should be placed in a supine position (Valachi and Valachi 2003b).

When performing precise tasks, arm rests can be used to stabilize the hands and help maintain the static position without causing fatigue. Dentists should not grip or grasp handpieces and hand instruments such as extraction forceps with undo force while performing procedures. After griping instruments for periods of time, clinicians should shake out the hands, to allow the hand, wrist, and arm muscles to relax. After intense gripping, stretch the hand, especially the area between the thumb and first finger. Experts agree that rotating tasks will give muscles a break.

Prevention before intervention is key. Clinicians should seek medical assistance before pain and muscular symptoms get worse. A physician, a physical therapist, or a trainer can make helpful evaluations and recommendations for preventative exercises to target the neck, shoulder, arms, and upper and lower back regions. Exercise programs should be preapproved by a physician. As people age, muscle mass is lost. Muscle loss typically starts around age 35 or 40 and picks up speed by the age of 50. Weights or resistance training at the local gym can help maintain stronger muscles. The following are good exercises for strength and resistance training that can be done at the gym.

1. The seated row machine: This works the upper and mid-back muscles (rhomboids, trapezius, with assistance of rear deltoids, and the biceps.) sit in upright neutral spine and pull bar straight back, holding.



8-10 repetitions position for 5-10 seconds. Do

2. The rear deltoid machine: This works on the upper back muscles including the deltoids and the trapezius. Sit upright with chest up against the pad to stabilize, and with hands on machine, steadily pull back and then hold for approximately 5–10 s. Do 8–10 repetitions.

Below are two floor exercises that help with stabilization/hyperextension.

1. Cross crawl core stability exercise: Get onto hands and knees with knees directly under hips and hands placed under shoulders. Ensure that there is equal amount of weight at all four points. Slowly extend one arm out in front toward the ceiling while at the same time lift the opposite leg up behind toward the ceiling. Hold position for about 10 s and then repeat on other side.

2. The superman exercise: This is a great exercise for working out the back as well as strengthening the shoulders, glutes, and hamstrings. Lay down on the floor with legs extended behind and arms stretched out in front. The neck should be relaxed. Gaze should be a few feet in front. Lift up chest, arms, and legs off the floor all at once, aiming to balance only on the pelvis. Hold position for about 10 s. Lower body. Do 8–10 repetitions.

The following preventative exercises are designed to open up the chest muscles and can be done while you are in the dental office. They are simple to do and require little to no special equipment and should be done with neutral spine positioning and with the chin tucked in. It is recommended to do the exercises several times a day.

1. The door frame stretch to open up chest muscles: Have arms at shoulder level against the sides of the door. The head should be gently tucked down. Lean into the door, and at the same time squeeze the shoulder blades together as if there is a ball between the trapezius muscles. This should stretch the pectorals. Count to 30 and repeat.

2. The cervical rotations to help stretch neck muscles: Sit in upright neutral spine position. Keep the chin tucked gently and turn the head to the left and hold for 10–15 seconds and then back to the center. Then turn the head to the right and hold for 10–15 seconds and repeat.

3. The upper trapezius stretch: Sit in upright neutral spine position and ensure that the chin is gently tucked. Start with arms at the side and then place the hand under the chair seat to anchor the arm from raising. Bend the ear toward the shoulder and hold for 30 s. Repate on the alternate side.

4. The chin tuck strengthens muscles that pull the head back into alignment over shoulders: This will stretch the suboccipital muscles. Assume upright neutral spine position. Place the finger on the chin to dip the chin gently. This is only a 10–15° movement. Making a "double chin" is also correct. You should feel the muscles of the upper cervical spine engage.

2.13 Conclusions

The general dentist spends an average of 35 plus hours in the office performing a variety of procedures including oral surgery. The dental profession is predisposed to occupational hazards. Self-awareness of these hazards and understanding how to handle them will allow for an optimally functional office environment as well as a healthy, prolonged career.

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Medical Assessment of the Oral and Maxillofacial Surgery Patient

3

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"It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts."

—A Scandal in Bohemia

Abstract

Gathering data: the preoperative medical assessment is arguably the most important visit for proper patient care. The dentist should review the patient's medical history and do a thorough review of systems and a proper physical exam. If necessary appropriate testing should be done such as blood glucose or INR. This chapter is designed to improve outcomes by teaching clinicians how to perform a proper medical assessment through evidence-based guidance and provide recommendations for altering care with certain medical conditions.

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3.1 Introduction

An accurate and effective medical assessment is necessary with every patient. A thorough understanding of the patient's medical history is invaluable while treating and managing intermediate- and high-risk patients, especially those with cardiovascular issues, bleeding disorders, compromised immune status, and endocrine disorders. This chapter is designed to improve outcomes by teaching and guiding clinicians how to perform a proper medical assessment through evidence-based guidance.

The goal of a medical assessment is to gather information about the patient in order to formulate an appropriate treatment plan. As always, the clinician must weigh the risks of each treatment option with the benefits, as well as educate the patient as to his/her options. An accurate medical assessment allows the clinician the ability to identify patient needs and foresee potential complications. A good medical history interview is tailored to the individual patient, but the basic rubric has been well accepted across the medical community. Interestingly, although the basic components are cited in many books and journals, few studies explore the effectiveness of these components. More importantly is to follow a format that allows the patient to tell his/her story and ensure the clinician does not forget important questions/topics (Haidet and Paterniti 2003). A proper medical assessment includes a thorough medical history, review of systems, and physical exam.

3.2 Medical History

Medical care starts with the patient's story, and thus the diagnosis tends to hide within the patient's history. Information in the medical history is subjective. Although the patient's story is subjective, the medical history has objective components. Although the story is subjective, it is a clinician's most useful information; it allows the provider to predict how any medical condition could potentially interfere with patient's ability to tolerate a certain procedure. The risk for serious medical complications from surgery is reported as less than 0.1% in healthy patients but increases significantly in medically complex patients (Cohn 2016). Closer attention is needed for patients with a more complex medical history (Miloro et al. 2012). High-risk patients who undergo medical optimization prior to surgery have decreased mortality rates (Kern and Shoemaker 2002; Williams and Bergin 2009; Cecconi et al. 2013). Interestingly, dentists are routinely asked to eliminate dental disease before the patient has stents placed or other procedures. The general dentist is often asked to provide care prior to patient optimization because of the concern of postoperative infections associated with the dental disease after the non-dental procedure.

Medical history should be updated at each patient encounter. Any inconsistencies in a patient's history should be reviewed further with a proper discussion with the patient. Most practices use health history forms as an initial means of collecting the medical history. These forms are a good starting point but discussion with the

patient is vital. The forms should be written in layman terms and in a concise fashion. When conducting the medical history interview, consider using the following formula:

1. **Identify the source of information.**
2. **Biographic data.**
3. **Chief complaint.**
4. **History of present illness.**
5. **Past medical history.**
6. **Past surgical history.**
7. **Social/family history.**

3.3 Review of Systems

The review of systems is a technique used to structure and organize a complete head-to-toe review of the body to hopefully identify any underlying issues not already diagnosed or those missed in the medical history as well as define the extent of a known disease (Hupp et al. 2014; Collins et al. 1995):

1. **General examination**: alert and oriented x4 (to person, time, place, event)
2. **Head**: fainting spells, headaches, and dizziness
3. **Ears:** otorrhea, tinnitus, and changes in hearing
4. **Eyes**: ocular movements, pupil accommodation, double vision, and blurry vision
5. **Nose**: epistaxis and rhinorrhea
6. **Throa**t: oral pain, pathology, dental evaluation, and jaw range of motion
7. **Cardiovascula**r: chest pain, orthopnea, and exercise tolerance quantified by metabolic equivalent of tasks (METs), murmurs, or rheumatic fever
8. **Respiratory**: cough, wheeze, and shortness of breath
9. **Gastrointestina**l: abdominal pain, unintentional weight loss, difficulty swallowing, and any nausea/vomiting
10. **Genitourinary**: incontinence and menses
11. **Neurologic**: special senses
12. **Psychiatric:** depression and sleep patterns
13. **Hematologic/lymphatic**: anemia, history of excessive bleeding after extraction, and anticoagulant/antiplatelet therapy
14. **Allergies**: history of anaphylaxis and allergic reactions

3.4 Physical Examination

The physical exam starts to collect objective information. The examination should start with vital signs; this both serves as a screening device for unsuspected medical problems and gives a good baseline for future assessments. Next follows a systemic

approach that contributes to a smooth, flowing process that gathers information that is pertinent to the patient's status. The provider should be observant and ensure that signs are not overlooked, e.g., lower extremity edema, evidence of IV drug abuse in the arms, gait when they walk to the office, abdominal girth, skin lesions, etc.

Physical examination usually involves four primary means of evaluation:

1. Inspection: facial symmetry and proportions, eye size, sclera color, movements, nares patency, skin lesions, skin turgor, oral mucosa, the tongue, and floor of the mouth
2. Palpation: TMJ function and range of motion, presence of enlarged lymph nodes, and areas of swelling or tenderness
3. Percussion: nasal sinuses resonance, dental fractures, and periodontal status
4. Auscultation: TMJ derangements (click, crepitus, pop)

Table 3.1 American Society of Anesthesiologists classification of physical status (American Society of Anesthesiologists 2017)

Classification	Definition	Examples, including, but not limited to:
ASA I	A normal healthy patient	Healthy, nonsmoking, no or minimal alcohol use
ASA II	A patient with mild systemic disease	Mild diseases without substantive functional limitations. Examples include (but not limited to) current smoker, social alcohol drinker, pregnancy, obesity (30 < BMI < 40), well-controlled DM/HTN, mild lung disease
ASA III	A patient with severe systemic disease	Substantive functional limitations; one or more moderate to severe diseases. Examples include (but not limited to) poorly controlled DM or HTN, COPD, morbid obesity (BMI ≥40), active hepatitis, alcohol dependence or abuse, implanted pacemaker, moderate reduction of ejection fraction, ESRD undergoing regularly scheduled dialysis, premature infant PCA <60 weeks, history (>3 months) of MI, CVA, TIA, or CAD/stents
ASA IV	A patient with severe systemic disease that is a constant threat to life	Examples include (but not limited to) recent (<3 months) MI, CVA, TIA, or CAD/stents, ongoing cardiac ischemia or severe valve dysfunction, severe reduction of ejection fraction, sepsis, DIC, ARD, or ESRD not undergoing regularly scheduled dialysis
ASA V	A moribund patient who is not expected to survive without the operation	Examples include (but not limited to) ruptured abdominal/thoracic aneurysm, massive trauma, intracranial bleed with mass effect, ischemic bowel in the face of significant cardiac pathology, or multiple organ/system dysfunction
ASA VI	A declared brain-dead patient whose organs are being removed for donor purposes	

Once the practitioner has gathered all of this data, it is important to classify the patient. The more medically complex the patient is, the greater the risk for perioperative complications. Most surgeons use the American Society of Anesthesiologists classification of physical status (Cohn 2016; Dripps et al. 1961) (Table 3.1).

3.5 Common Medical Problems

3.5.1 Cardiac Issues

The Centers for Disease Control and Prevention states that heart disease is the leading cause of death globally. Cardiac issues may be congenital and asymptomatic but can cause serious complications. The underlying pathophysiology varies greatly depending on the disease. The general dentist must be mindful of his/her limitation and level of comfort. Patients with very complex medical conditions, especially complex cardiac conditions, might be better suited in a hospital setting (Table 3.2).

3.5.1.1 Hypertension

One of the most common medical conditions the general practitioner will run into is hypertension. One third of the US population has hypertension (defined as systolic blood pressure >139 mmHg or a diastolic blood pressure >89 mmHg) (Mozaffarian et al. 2015). It is vital that the provider recognizes hypertension before treatment in order to foresee potential medical emergencies such as hypertensive crisis. The risk of stroke increases as blood pressure rises from >115/75 mmHg. The practitioner must also be mindful of true hypertension vs white coat hypertension. White coat hypertension is a situation in which a person experiences high blood pressure at a doctor's office. It is recommended to defer treatment and refer the patient to the primary care physician, emergency room department (ER), or cardiologist if the patient presents with severe hypertension.

The use of local anesthesia with vasopressors is shown to be safe for patients with controlled hypertension (Uzeda et al. 2014). The only true contraindications

Table 3.2 Hypertension classification according to the American Heart Association 2017 Guidelines

Blood pressure category	Systolic mmHg (upper #)		Diastolic mmHg (lower #)
Normal	Less than 120	and	Less than 80
Prehypertension	120–139	or	80–89
High blood pressure (hypertension) stage 1	140–159	or	90–99
High blood pressure (hypertension) stage 2	160 or higher	or	100 or higher
Hypertensive crisis (emergency care needed)	Higher than 180	or	Higher than 110

of using epinephrine are uncontrolled hyperthyroidism, uncontrolled diabetes, unstable angina, and pheochromocytoma (Pérusse et al. 1992). It is important to aspirate before injecting local anesthesia to ensure the vasopressor is not injected directly into the blood vessel. Although epinephrine is found to leak into the systemic vasculature, local anesthesia with vasopressors has been demonstrated to cause only transient hemodynamic alteration (Patil and Patil 2012; Serrera Figallo et al. 2012; Bader et al. 2002; Nakamura et al. 2001). When epinephrine is contraindicated, anesthetics such as carbocaine or prilocaine should be considered (Milam and Giovannitti 1984). More information on local anesthetics will be discussed in Chap. 7.

3.5.1.2 Ischemic Heart Disease and Acute Myocardial Infarction

Ischemic heart disease is defined as a partial or total reduction in coronary blood flow. Chest pain arises when there is occlusion of the vessels but prior to myocardial necrosis. Coronary artery disease (CAD) progresses silently. Acute myocardial infarction (MI) usually develops from a rupture of a vulnerable atherosclerotic plaque. Myocardial necrosis is therefore the consequence of ischemia (Ambrose et al. 1988).

A patient experiencing chest pain is a true medical emergency. The provider should immediately contact emergency medical services and the patient be transported to the emergency department. Current guidelines recommend supplemental oxygen, 162–325 mg aspirin, and administration of sublingual nitroglycerin (0.3–0.4 mg may be repeated in 5 min two times if needed) (Anderson and Morrow 2017; Antman et al. 2008; Braunwald et al. 2000). Monitoring patient vitals is important; do not give a second dose of nitroglycerin if blood pressure falls under 90 mmHg. If the patient becomes unresponsive, assess for a pulse. If the patient has no palpable pulse, do CPR.

According to the most recent literature, dental care appears to be safe 30 days after an ischemic vascular event in optimal conditions and suggests the traditional recommendation of delaying care 6 months should be reassessed (Niwa et al. 2000). The time the provider should wait for safe care of a patient post MI depends on the procedure being performed. More invasive procedures may require more healing time following an ischemic vascular event. Although most practitioners still choose to defer for at least 6 months after an MI episode although little evidence exists to support this decision. Patients with a past medical history of an MI are at an increased risk for a subsequent episode, and therefore supplemental oxygen and nitroglycerin should be readily available (Skaar et al. 2012).

3.5.1.3 Congestive Heart Failure (CHF)

This disease occurs when the heart is unable to pump efficiently to maintain blood flow and blood begins to pool up. Most congestion is seen in the lungs and liver. Signs and symptoms commonly include shortness of breath, chest pain, swelling in ankles and legs, pleural effusion, coughing, and excessive fatigue. Patients with CHF are usually on an assortment of medications to limit fluid resorption. Chronic management of these patients includes diuretics, digoxin, ACE inhibitors,

beta-blockers, and calcium channel antagonists in an attempt to control and maintain blood flow (Neubauer 2007).

Ejection fraction is an important measurement via echocardiogram to determine the severity of systolic heart failure. It measures the fraction of blood ejected from a ventricle with each heartbeat, i.e., an ejection fraction of 60% means that 60% of the total amount of blood in the left ventricle is pushed out with each heartbeat.

A normal ejection fraction ranges between 50% and 70%, and measurement of <40% may be evidence of congestive heart failure (Redfield 2016). Patients that are being treated with digoxin may be at higher risk of complications when undergoing an extraction. It is recommended to use cardiac monitoring in these high-risk patients (Malamed 2009). Monitoring is likely not required for all patients on digoxin therapy but may be beneficial especially in those patients with other comorbidities. Before prescribing/recommending postoperative NSAIDs, the practitioner must be mindful that patients taking long courses of NSAIDs can have renal impairment that can lead to dangerous increases in digoxin levels.

3.5.1.4 Arrhythmias

Patients who are at risk of or have cardiovascular arrhythmias more often than not have a background marked by ischemic coronary disease requiring different dental management techniques. Patients who suffer from atrial fibrillation typically are on blood thinners, which will be discussed later. It is important for the dentist to make this association.

A large number of patients have pacemakers/defibrillators and pose no contraindication to oral surgery other than limiting the use of electrocautery.

Common medications and adverse effects on dentoalveolar surgery are the following:

- Non-cardio-selective beta-blockers: increased risk for accentuation of epinephrine effect.
- Calcium channel blockers: increased risk of gingival hyperplasia.
- Central agents: clonidine—risk of xerostomia.
- Alpha blockers: epinephrine reversal; vasodilation with resultant excessive bleeding and decreased efficacy and duration of local anesthetics.
- NSAIDs can diminish the therapeutic effects of antihypertensive medications (Pavlicević et al. 2008).

3.5.2 Bleeding Disorders

Bleeding is one of the most common complications that occur in most minor oral surgery procedures the general dentist will perform. A patient can have genetic bleeding disorders, decreased platelet production, splenic sequestration of platelets, or increased destruction of platelets. For most patients the reason for their increased bleeding is medication induced.

3.5.2.1 Anticoagulants

There is a growing number of patients who are prescribed anticoagulation therapy. Evidence strongly suggests no indications to discontinue anticoagulant therapy for dental extraction (Beirne 2005; Jeske et al. 2003; Alaali et al. 2012). Although many new medications exist, many patients are still taking warfarin. Warfarin inhibits synthesis of vitamin K-dependent factors. Many conditions are managed with an INR between 2 and 3. This range is generally considered safe for exodontia and should be checked within 24 h (Nematullah et al. 2009; Salam et al. 2007). The INR should be checked within 24 h because different foods/medications can alter warfarin's effects (Table 3.3).

Many of the newer direct thrombin inhibitors do not have a test such as the INR, so it is difficult to assess the patient's anticoagulant state (Curto et al. 2017; Turpie et al. 2012). However, little evidence suggests delaying or stopping these newer medications (Napeñas et al. 2013).

Some of the newer medications are listed below (Table 3.4).

3.5.2.2 Decreased Production of Platelets

Decreased production can be caused by dehydration, vitamin deficiencies, or bone marrow disorders. The general dentist should be watchful for hereditary syndromes such as von Willebrand, hemophilia, and Wiskott-Aldrich. A medical consult with a hematologist is always recommended. Consider delaying treatment if platelet count is decreased until the patient's condition is stabilized to minimize bleeding.

3.5.2.3 Medication-Induced Platelet Destruction/Inhibition

Thrombocytopenia is defined as a low concentration of platelets <150,000 per mm^3 either inherited or acquired. Abnormal or spontaneous bleeding can occur if platelets fall below 50,000. Some patients may show signs of external bleeding that can be manifested through nosebleeds, gingival bleeding, bruising, or in some women

Table 3.3 Medications that may alter the therapeutic effects of warfarin

Increased warfarin effect	Decreased warfarin effect
Acetaminophen	Carbamazepine
Allopurinol	St. John's wort
Azithromycin	Barbiturates
Celecoxib	Vitamin K
Ciprofloxacin	Rifampin
Erythromycin	Sucralfate
Metronidazole	Phenytoin −/+
SSRIs	
Omeprazole	
Ethanol	
Fluconazole	
Amiodarone	
Cefazolin	
Phenytoin ±	
Rosuvastatin	
Trimethoprim-sulfamethoxazole	

Table 3.4 Assessment methods for patients on medications that may affect coagulation

Drug class	Drug names
Anticoagulant Pt/INR is the standard for monitoring effect	• Warfarin (Coumadin®)
Antiplatelet agents Ivy bleeding time, optical aggregometry, VerifyNow®, and PFA100 may offer some assessment No good gold standard for monitoring	• Clopidogrel (Plavix®) • Ticlopidine (Ticlid®) • Prasugrel (Effient®) • Ticagrelor (Brilinta®) • Aspirin
Target-specific oral anticoagulants Efficacy of these drugs can be measured by ECT (ecarin clotting time) Doses are modified by renal and liver function	• Dabigatran (Pradaxa®) • Rivaroxaban (Xarelto®) • Apixaban (Eliquis®) • Edoxaban (Savaysa®)

abnormal menses. Some medications may induce thrombocytopenia which is a relatively common disorder. Rapid identification and discontinuation of certain medications can prevent significantly lower risk of infection.

Aspirin irreversibly inhibits platelet binding to cyclooxygenase. Aspirin in most cases does not need to be discontinued (Eapen et al. 2017). There is a rebound hypercoagulability when antiplatelet medications are discontinued.

3.5.2.4 Increased Destruction of Platelets

Increased platelet destruction may be related to some immune or infectious conditions, for example:

- Idiopathic thrombocytopenic purpura.
- Thrombotic thrombocytopenic purpura.
- Hemolytic-uremic syndrome.
- Disseminated intravascular coagulation (DIC): factors are depleted from excessive clotting that block small vessels that usually evolves from toxic substances in the bloodstream.
- Paroxysmal nocturnal hemoglobinuria.
- Systemic lupus erythematosus: as an autoimmune chronic inflammatory disease, bleeding can occur because of antibodies reacting to lipids involved in the coagulation cascade known as antiphospholipid syndrome.
- Posttransfusion purpura: production of alloantibodies to the introduced platelets' antigens. These alloantibodies destroy the patient's platelets leading to thrombocytopenia.
- Dengue fever.
- Gaucher's disease.

- Zika virus: limited evidence shows Zika may also be transmitted through platelet transfusion.
- Septicemia.
- HIV/AIDS: immune-mediated destruction and toxic effects of medication cause generalized myelosuppression.

3.5.3 Patients on Bisphosphonates

The United States in the past decade has seen a surge of bisphosphonates prescribed. Bisphosphonate-related osteonecrosis of the jaw (BRONJ) was first reported by Marx in 2003 (Marx 2003). It is defined by exposed bone in the maxillofacial region for 8 or more weeks and a history of bisphosphonates with the absence of radiation therapy. The incidence of BRONJ increases with age and is more prevalent in the mandible. Patients who were on bisphosphonates for greater than 3 years are also at higher risk (Jeong et al. 2017). The AAOMS position paper reclassified BRONJ as medication-related osteonecrosis of the jaw (MRONJ) (Ruggiero et al. 2014). For patients at high risk of MRONJ, it is recommended to give antibiotic prophylaxis especially if the patient has a history of MRONJ. For patients who are taking oral and/or IV bisphosphonates and who have no prior history of osteonecrosis, current research indicates that antibiotic prophylaxis may help reduce the risk of developing osteonecrosis (Bermúdez-Bejarano et al. 2017).

Whenever possible, the patient should receive his/her dental care at least 3 months before starting bisphosphonate therapy. Vandone et al. reported that the incidence of developing ONJ was reduced by 50% in patients who received preventive dental care before initiating drug therapy (Vandone et al. 2012). The ADA Council on Scientific Affairs stated in 2011 and suggested that patients receiving lower cumulative doses of bisphosphonate (<2 years) or denosumab may continue antiresorptive therapy during invasive dental treatment (Hellstein et al. 2011). According to the AAOMS position paper, there is currently no evidence that interrupting bisphosphonate therapy alters the risk of ONJ in patients following tooth extraction (Ruggiero et al. 2014) (Table 3.5).

Reports indicate late implant failure can be caused by oral bisphosphonates. Failure is associated with a sort of localized osteonecrosis. Theories include a greater mastication force displaced across the implant and surrounding bone due to the absence of a periodontal ligament. This increased force requires greater bone turnover which can be inhibited by the initiation of bisphosphonate therapy (Pogrel and Ruggiero 2018). If dental implants are placed, informed consent must be obtained related to the possible long-term implant failure and the low risk of developing osteonecrosis of the jaw (Ruggiero et al. 2014). The patients should be placed on regular recall schedule.

Table 3.5 Recommendations for patients with a medical history of oral bisphosphonate usage

Oral bisphosphonate for less than 4 years and have no clinical risk factors	No alteration or delay in the planned surgery is necessary. This includes any and all procedures common to oral and maxillofacial surgeons, periodontists, and other dental providers
Oral bisphosphonate for less than 4 years and have also taken corticosteroids or antiangiogenic medications concomitantly	The prescribing provider should be contacted to consider discontinuation of the oral bisphosphonate (drug holiday) for at least 2 months prior to oral surgery, if systemic conditions permit. The antiresorptive therapy should not be restarted until osseous healing has occurred. These strategies are based on reports that corticosteroid and antiangiogenic agents, in combination with antiresorptive therapy, may increase the risk of developing MRONJ and that a drug holiday may mitigate this risk. Long-term, prospective studies however are still required to establish the efficacy of drug holidays in reducing the risk of MRONJ for these patients
Oral bisphosphonate for more than 4 years with or without any concomitant medical therapy	The prescribing provider should be contacted to consider discontinuation of the antiresorptive therapy for 2 months prior to oral surgery, if systemic conditions permit. The bisphosphonate should not be restarted until osseous healing has occurred. The risk of long-term oral bisphosphonate therapy requires continued analysis and research

Adapted from the AAOMS © 2014 Position paper on MRONJ

3.5.4 HIV Status

According to the Americans with Disabilities Act of 1990, adult or pediatric HIV-positive patients are able to receive routine dental care at any dental practice. Most if not all patients with HIV are able to tolerate routine dental care. HIV virus and antiretroviral therapies have a myelosuppressive effect and may be associated with abnormal bleeding, glucose intolerance, hyperlipidemia, reduced platelet count, or white blood cell neutrophil.

Indiscriminate use of antibiotics may predispose patients to adverse drug reactions, superinfection, and drug-resistant microorganisms. Especially in this patient population, the use of antibiotics must be judicious. Baseline viral load and CD4 counts are the most commonly referred to values and can be useful in determining stability of treatment and susceptibility for opportunistic infections, but neither test is necessary to provide care. Both values do not predict how well a patient will tolerate a dental procedure and must not be used to determine the need for antibiotic prophylaxis before dental therapy.

Currently there are no specific guidelines in the literature regarding the need for antibiotic prophylaxis; some authors state that patients with severe neutropenia (<500 cells/mm^3) might benefit from a therapeutic antibiotic regimen starting with a loading dose at the time of the procedure and followed by 5–7 days of postoperative antibiotics (Patton et al. 2002). There is little evidence to support use of antibiotics in these patients despite the risks of oral complications after dental procedures. There are no restrictions on the dental treatment of stable patients on regular antiretroviral therapy (Robbins 2017). This is similar to rehabilitation using dental

Table 3.6 Important blood count values that would determine modification to surgical treatment plan

Type	Normal	Minimum	
Absolute neutrophil count (ANC)	2500–7000 cells/mm^3	500 cells/mm^3	<500 cells/mm^3 antibiotic prophylaxis recommended
Platelets	150,000–450,000 cells/mm^3	50,000 cells/mm^3	100,000–70,000: local hemostatic measures are indicated 70,000–50,000: transfusion may be needed and considered

implants regardless of $CD4^+$ counts. The literature has shown no increased rate of infection and indistinguishable osseous integration in patients with well-controlled HIV as compared with a non-HIV population as well as similar healing from sinus lifts and bone augmentation surgeries (Diz et al. 2013) (Table 3.6).

Most other HIV-associated oral conditions are caused by opportunistic infections. These may include candidiasis, bartonellosis, cryptococcosis, cryptosporidiosis, and histoplasmosis. Opportunistic viral infections may predispose patients to human papilloma virus (condyloma or cancer); Epstein-Barr virus can lead to oral hairy leukoplakia; human herpesvirus may develop into Kaposi's sarcoma; cytomegalovirus may lead to cytomegalovirus oral ulcers. Herpesvirus infection may also lead to necrotizing periodontitis. Conventional periodontitis is found in up to 30% of HIV-positive adults.

3.5.5 Pregnancy

Dentoalveolar surgery for the pregnant patient should be focused on the relief of pain and elimination of any infection or malignant neoplasm. If treatment must be performed, the patient should not be placed in the supine position (especially in the third trimester). The supine position increases the risk of developing deep vein thrombosis by compression of the inferior vena cava. The ideal position for pregnant patients in the dental chair is the left lateral decubitus position with the right hip elevated by 15°.

Some elective and dentoalveolar surgery procedures are more safely performed in the second trimester (Dellinger and Livingston 2006).

Multiple NSAIDs including ibuprofen, naproxen, and ketoprofen are the most common medications used, but utilization of these medications in early pregnancy has been related with an increased risk of cardiac septal defects (Flynn and Susarla 2007). Also, short-term use of NSAIDs in the third trimester is associated with a significant increase in the risk of premature closure of ductus arteriosus (Koren et al. 2006). Contrary to NSAIDs, opiates have not been related with fetal abnormalities, although they may cause neonatal opiate withdrawal disorder when the mother is dependent on opiates (Pryor et al. 2017).

Infections are the most well-known reason an oral and maxillofacial specialist is approached to treat a pregnant patient. The teratogenic potential has a wide range

depending on the antibiotic of choice. It is recommended to use antibiotics such as amoxicillin or clindamycin in the pregnant patient (Donaldson and Goodchild 2012).

3.5.6 Seizure Disorders

Seizures are reported as the second most common medical incident encountered in the dental chair. These disorders are characterized by an episode of alteration of mental activities, involuntary muscle contractions, and changes in consciousness secondary to abnormal synchronous neuronal activity. The most encountered types of seizures are tonic-clonic and absence attack. These two also present the highest potential for morbidity (Sanders et al. 1995).

Knowledge of the patient's typical seizure triggers, duration, and type allows the provider to recognize early signs of a seizure episode and take precautions. Reduction in fibrinogen and/or an increase in prothrombin time has been reported with the use of sodium valproate, usually without associated clinical signs and particularly with high doses as it has an inhibitory effect on the second phase of platelet aggregation.

3.5.7 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, buffalo 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 surgery. They do not respond to the typical agents administered to correct these signs/symptoms.

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 (Miller et al. 2001).

3.5.8 Diabetes

Several chronic microvascular complications have been reported in connection to diabetes including increased risk for periodontal disease, change in subgingival microbiota, alterations in immune response, altered collagen metabolism, alteration

in oral vascularization, hereditary patterns, altered neutrophil function, reduced phagocytic capacity, and chemotaxis (Fernandes et al. 2015).

The patient is advised to seek urgent medical attention as soon as possible if blood sugar levels continue to rise. If left untreated, this can result in diabetic ketoacidosis and death. Preoperative serum glucose should always be taken at the time of the appointment. As a rule, treatment should be deferred if medical conditions are not well controlled. Certain exceptions are met on an individual patient basis. If the blood glucose is low (<70 mg/dl) or extremely high (>300 mg/dl), the general dentist should consider deferring treatment, if possible, and focus on helping the patient seek appropriate medical treatment to get better glycemic control. The provider should refer the patient to their primary care doctor or endocrinologist and see the patient when their blood sugar becomes more controlled. Helpful values that demonstrate glucose control are the HbA1c that measures a 3-month average of serum glucose levels. The American Diabetes Association's *Standards of Medical Care in Diabetes* recommends an HbA1c of <7.0% in most patients to reduce the incidence of microvascular disease, i.e., mean plasma glucose of ~150–160 mg/Dl (Evert 2014). High blood glucose is associated with delayed healing (Lalla and D'Ambrosio 2001). Some research suggests that antibiotic prophylaxis can be used in patients with poorly controlled diabetes mellitus. Although the current data is not very strong, antibiotics might be indicated in invasive dental procedures (Lockhart et al. 2007; Ship 2003). Obviously delaying care is not always possible, such as instances of pain or infection.

3.6 Antibiotic Prophylaxis

There is a lack of evidence for antibiotic prophylaxis in third molar extractions (Marchionni et al. 2017). A meta-analysis conducted by Moreno-Drada and Garcia-Perdomo did conclude that antibiotic prophylaxis is effective in decreasing the incidence of infections post-tooth extraction and can be considered for high-risk patients (Moreno-Drada and García-Perdomo 2016). Infections following tooth extraction are quite low, and antibiotic prophylaxis is not indicated for most patients (Prajapati and Sathaye 2016; Aragon-Martinez et al. 2016). Antibiotic prophylaxis also shows no apparent difference in postoperative infection for patients who receive dental implants (Keenan and Veitz-Keenan 2015). However, many practitioners will prescribe antibiotics when grafts are placed. Although controversial, some studies have concluded that failure rates of implants are significantly reduced when antibiotic prophylaxis is given. A single dose of preoperative antibiotic therapy is usually sufficient. It is therefore up to the individual practitioner on whether to use antibiotic prophylaxis for implant placement until better research is conducted (Sharaf and Dodson 2011; Deeb et al. 2015; Mazzocchi et al. 2007; Dent et al. 1997). The practitioner must be mindful as to the risks of prescribing antibiotics. One must consider the role in increasing antibiotic resistance as well as the cost to society when prescribing antibiotics.

3.7 When to Postpone Surgery?

Unfortunately, medicine is not an exact science, and outcomes cannot always be guaranteed. Patients will always have different reactions to surgical procedures. The decision to defer patient care should be driven by concern for the safety of the patient. The clinician needs to ask whether the patient would be better managed by a specialist or in a more advanced facility such as a hospital setting. If the patient is suffering from a self-limiting disease, the clinician should consider delaying care until the patient's condition improves.

3.8 Conclusion

"First do no harm" is one of the first things practitioners are told when they embark on their careers. In order to provide safe patient care, it is vital to perform an accurate medical assessment. The goal of this chapter is to help the general dentist realize when he/she needs to change in order to maximize safety in patients with certain medical conditions. It is also important for the general dentist to realize his/her limitations and always act in the best interest of the patient.

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Dental Radiography

4

Aditya Tadinada

"It is the scientific use of the imagination, but we always have some material on which to base our speculation."
—The Hound of Baskervilles

Abstract

Radiographic imaging is an important complement to clinical evaluation in diagnosis and treatment planning of most dental procedures. The appropriate imaging modality for radiographic evaluation should be chosen based on the specific diagnostic task at hand. Several conventional two-dimensional and three-dimensional imaging options are available to the clinician to evaluate the area of interest. Radiographic imaging exams must only be ordered after a comprehensive clinical examination and must follow the guiding principle for radiation safety: "as low as reasonably achievable" (ALARA). It means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practically possible. Clinicians must perform radiographic imaging on patients only when they expect that the information provided by the radiographic examination will provide additional diagnostic information and meaningfully contribute to the treatment plan.

This chapter will focus on an evidence-based approach to imaging the maxillofacial structures for routine dental conditions commonly encountered in the dental office.

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4.1 Dentoalveolar Structures

4.1.1 Routine Radiographic Evaluation of Teeth

The guidelines recommended by the American Dental Association (ADA) and the Food and Drug Administration (FDA) are the recommendations most states use for prescribing dental radiographs (The American Dental Association Council on Scientific Affairs and the US Department of Health and Human services 2012). The guidelines clearly articulate that radiographic exposure should be need based and dependent on clinical judgment. For a new adult dentate or partially edentulous patient being evaluated for oral diseases, the recommendation is to do a panoramic exam with posterior bitewings or selected periapical radiographs and posterior bitewings (Fig. 4.1). A full mouth intraoral radiographic exam (FMX) is recommended when the patient has clinical evidence of generalized dental disease or if an area is being monitored for specific conditions. The recommendation for patients with a high risk for clinical caries is posterior bitewings at 6–18-month interval. Recall patients with no clinical caries and not at increased risk for caries can be imaged using posterior bitewing at 24–36-month intervals. FDA guidelines clearly indicate that if the patient has established clinical conditions like periodontal disease or dental implants, craniofacial pathoses, and restorative or endodontic needs, then the radiographic examination and time intervals between exams are determined based on clinical judgment. The clinician must always consider the risk

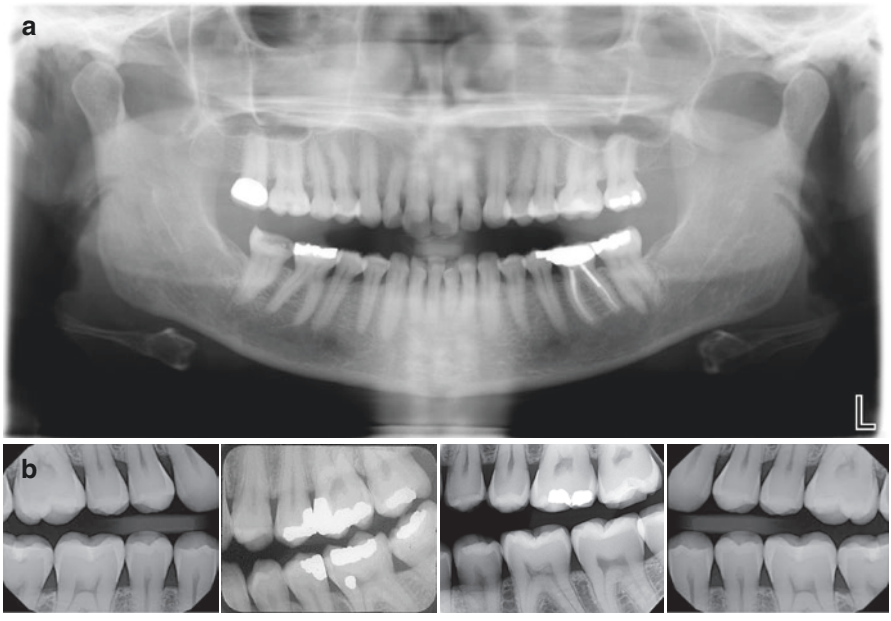

Fig. 4.1 Routine radiographic evaluation of teeth. (**a**) Panoramic radiograph. (**b**) Bitewing radiographs

versus benefit analysis and make decisions based on the best outcomes for the patient while strictly following the principles of "ALARA".

4.1.2 FDA-ADA Recommendation (Table 4.1)

Most dental offices will have patients who present with pain that can arise from hard tissues like the tooth and bone or soft tissues like the gingiva and the periodontium. Pulpal inflammation and associated infections leading to severe pain are frequently a reason for an emergency dental visit. The first step in diagnosis is gathering adequate history about the problem followed by a comprehensive clinical examination. An intraoral periapical radiograph is the initial radiographic exam done to evaluate the tooth, the surrounding periodontal ligament (PDL) space, and the periapical area (The American Dental Association Council on Scientific Affairs and the US Department of Health and Human services 2012). Based on the clinical and the initial two-dimensional radiographic evaluation, the clinician must choose whether it is adequate to make a diagnosis or if there is a need to further evaluate the area by either making a panoramic radiograph or recommending a three-dimensional acquisition like the cone beam CT (CBCT) exam (The American Dental Association Council on Scientific Affairs 2012). If the associated infection warrants a more detailed three-dimensional examination including a study of the soft tissues, a computerized tomography (CT) exam should be considered.

4.1.3 Imaging with Portable X-Ray Units

Dental radiographic examination has traditionally been done in an office setting with the patient sitting upright on a dental chair. A wall mounted X-ray unit with the help of position indicator device is the most common method of intraoral radiographic exposure. With the advent of several procedures that require an intraoperative check radiograph or a postoperative radiograph when the patient is not fully able to follow instructions, a relatively newer option is the portable X-ray unit. These units are battery operated and are typically handheld. Their applications extend from intraoperative imaging and emergencies and on the field where a typical dental office setup is not available. While an entire full mouth series can be acquired with these devices, for ergonomic reasons, it is best to limit the use of these devices to a few exposures. The use of these devices may need additional radiation safety training and certification.

4.1.4 Imaging of the Third Molars

Third molar teeth often fail to erupt due to lack of adequate space and could end up being impacted. Pericoronitis involving erupting, partially erupting, or impacted third molar teeth is a common inflammatory condition that leads to significant pain

Table 4.1 American Dental Association Guidelines for selecting radiographic imaging

Type of encounter	Patient age and dental developmental stage				
	Child with primary dentition (prior to eruption of the first permanent tooth)	Child with transitional dentition (after eruption of the first permanent tooth)	Adolescent with permanent dentition (prior to eruption of third molars)	Adult, dentate, or partially edentulous	Adult, edentulous
New patient Being evaluated for oral diseases	Individualized radiographic exam consisting of selected periapical/ occlusal views and/or posterior bitewings if proximal surfaces cannot be visualized or probed. Patients without evidence of disease and with open proximal contacts may not require a radiographic exam at this time	Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images	Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images. A full mouth intraoral radiographic exam is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment		Individualized radiographic exam, based on clinical signs and symptoms
Recall patient with clinical caries or at increased risk for caries	Posterior bitewing exam at 6–12-month intervals if proximal surfaces cannot be examined visually or with a probe			Posterior bitewing exam at 6–18-month intervals	Not applicable
Recall patient with no clinical caries and not at increased risk for caries	Posterior bitewing exam at 12–24-month intervals if proximal surfaces cannot be examined visually or with a probe		Posterior bitewing exam at 18–36-month intervals	Posterior bitewing exam at 24–36-month intervals	Not applicable

(continued)

Table 4.1 (continued)

Type of encounter	Patient age and dental developmental stage				
	Child with primary dentition (prior to eruption of the first permanent tooth)	Child with transitional dentition (after eruption of the first permanent tooth)	Adolescent with permanent dentition (prior to eruption of third molars)	Adult, dentate, or partially edentulous	Adult, edentulous
Recall patient with periodontal disease	Clinical judgment as to the need for and type of radiographic images for the evaluation of periodontal disease. Imaging may consist of, but is not limited to, selected bitewing and/or periapical images of areas where periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically				Not applicable
Patient (new and recall) for monitoring of dentofacial growth and development and/or assessment of dental/skeletal relationships	Clinical judgment as to the need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development or assessment of dental and skeletal relationships		Clinical judgment as to the need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development or assessment of dental and skeletal relationships. Panoramic or periapical exam to assess developing third molars	Usually not indicated for monitoring of growth and development. Clinical judgment as to the need for and type of radiographic image for evaluation of dental and skeletal relationships	

(continued)

Table 4.1 (continued)

Type of encounter	Patient age and dental developmental stage				
	Child with primary dentition (prior to eruption of the first permanent tooth)	Child with transitional dentition (after eruption of the first permanent tooth)	Adolescent with permanent dentition (prior to eruption of third molars)	Adult, dentate, or partially edentulous	Adult, edentulous
Patient with other circumstances including, but not limited to, proposed or existing implants, other dental and craniofacial pathoses, restorative/ endodontic needs, treated periodontal disease, and caries remineralization	Clinical judgment as to the need for and type of radiographic images for evaluation and/or monitoring of these conditions				

and limitation in mouth opening with a high possibility of becoming a serious infection. Since it is challenging to image the third molars using intraoral periapical examinations, and mouth opening could be a major limitation in many patients, an extraoral examination like the panoramic is recommended (Smith et al. 1997). Panoramic radiographs provide a general overview of the area of interest and its surrounding structures (Fig. 4.2). Based on the panoramic image, a decision about the surgical procedure is often made. Modifications to the surgical approach and evaluation of the location and inclination can be studied with panoramic radiography. Evaluation of the proximity to vital structures like the maxillary sinus in the maxilla and the inferior alveolar nerve canal in the mandible is key to a successful surgical outcome. A white paper written by the American Association of Oral and Maxillofacial Surgeons (AAOMS) states that along with critical anatomic structures, the distal aspect of the second molar and the periodontal health of that tooth are important areas to evaluate and consider prior to third molar removal (Pogrel et al. 2007; Haug et al. 2009). To evaluate these relationships better, a small-volume CBCT is often recommended (Figs. 4.2 and 4.3), but when it is clinically determined that all the four third molars are in very close proximity to a critical anatomic

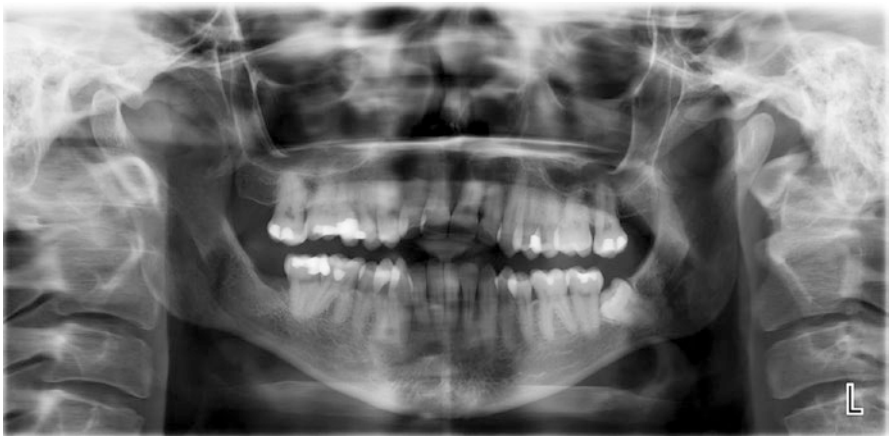

Fig. 4.2 Panoramic radiograph showing impacted third molars. Relationship to the IANC is challenging to evaluate

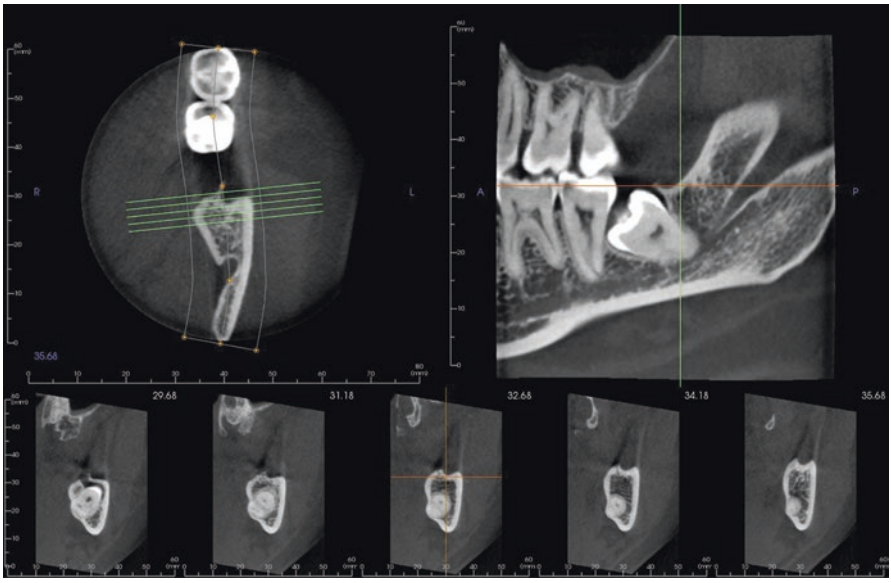

Fig. 4.3 Horizontally impacted tooth #32 in contact with the distal root of tooth #31, clearly demonstrates proximity with lingually positioned inferior alveolar canal

structure or by position are located in a position that is challenging to access, then a bigger field of view CBCT with all the four third molars in one image can be acquired (Haug et al. 2009).

4.1.5 Imaging Dental Infections

The most common dental disease is dental caries. Although the prevalence of dental caries has been steadily decreasing, it continues to be a significant public health problem. Dental caries cannot be detected by clinical examination alone and often needs radiographic evaluation using bitewing radiography to evaluate the crown and interproximal surfaces. Clinically incipient carious lesions are challenging to diagnose, especially if they are located interproximally where direct visual access is challenging. An established carious lesion is seen as an area of demineralization, and the breakdown of the enamel can be clinically observed as a "catch" upon probing with a probe. On radiography carious lesions appear as a dark zone or a radiolucent area with varying radiographic patterns of spread toward the pulp (Wenzel 1998; Wenzel 2004). From a practical perspective, approximately 60–70% demineralization needs to be present for a carious lesion to be visible on radiographic examination. The more severe the clinical involvement is, the more obvious is the radiographic appearance. Radiographic examinations are also representations of a specific time point in the disease process. Unless there are sequential images at regular time intervals, it is not possible to determine if a lesion is active or not. While routine dental caries appears as a radiolucent area with varying degrees of darkness, certain patterns of decay are specific to postradiation therapy cancer patients and in patients having Sjogren's syndrome where the buffering action of saliva compromises the oral environment leading to significant dental decay.

Poor dental hygiene can cause gingival inflammation known as "gingivitis," and when not addressed, it could lead to underlying alveolar bone loss and periodontitis. The hallmark of periodontitis is alveolar bone loss and widening of the periodontal ligament space, which is an important radiographic finding to evaluate periodontal health (Armitage 1999; Douglass et al. 1986). Presence of radiographic calculus is an important radiographic feature indicative of compromised periodontal health. Overhanging restorations are areas that specifically need to be evaluated in assessing the status and prognosis of the periodontium. Bone loss in periodontitis could range from mild to moderate to severe forms and could be localized or generalized. Dental caries in combination with periodontal involvement can lead to endo-perio lesions that involve the pulp and the periodontal tissues leading to dental infections ranging from mild periapical infections to a full-blown abscess or a space infection.

While the key to effective management starts with astute clinical judgment and early detection, radiographic evaluation plays a critical role in determining the extent and severity of the problem and helps in diagnosis, treatment planning, and management. The choice of choosing the appropriate radiographic imaging modality largely depends on the clinician who will determine the purpose of the radiographic examination (Åkesson et al. 1992; Persson et al. 2003). If the task at hand is localized to a single tooth, a vertical bitewing to show the extent of bone loss and an initial periapical radiograph may be adequate, but if the clinical evaluation shows that a larger area is involved, a panoramic radiograph should be made to study the area of interest and to determine the extent of the infection. Panoramic radiography is an extraoral examination, and the resolution of the image is not ideal to assess bone

levels, but a general idea about the overall bone levels and extent of an infection if present can be observed. Based on the panoramic radiograph, a further judgment about the necessity to do any advanced imaging is made. CBCT is adequate to evaluate the bone levels when three-dimensional views of the alveolar bone and periodontal defect are being studied (Misch et al. 2006; Vandenberghe et al. 2007). If the clinical evaluation appears to be a more complicated condition and a space infection is suspected, then a computed tomography (CT) will help in determining the extent and spread of the pathology and also to show the effect on adjacent structures.

Pulpal inflammation leading to infections is a common challenge encountered in the dental office; the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) (Patel et al. 2014; Fayad et al. 2015; Special Committee to Revise the Joint AAE/AAOMR Position Statement on use of CBCT in Endodontics 2015) in a joint position paper state that when the evaluation of the area of interest cannot be achieved by conventional dental radiography, CBCT must be considered. When imaging with CBCT, it is recommended that the smallest possible field of view (FOV) and smallest voxel size and lowest mA must be used to best avail the benefits of the technology while addressing the issue of exposing the patient to ionizing radiation in the most meaningful way (Fayad et al. 2015; Special Committee to Revise the Joint AAE/AAOMR Position Statement on use of CBCT in Endodontics 2015).

4.1.6 Imaging of Inflammation Associated with the Jaws

4.1.6.1 Osteomyelitis, Osteoradionecrosis, and Medication-Related Osteonecrosis of the Jaw (MRONJ)

The strict definition of osteomyelitis is inflammation of the bone marrow. Functionally, osteomyelitis is generally used to indicate a major infection of the bone. Osteomyelitis is always reflected in increased bone destruction and increased bone deposition. The mandible is more susceptible than the maxilla and is likely due to the nature and quality of the bone and blood supply. There are several types of osteomyelitis and can be broadly divided into acute, chronic, Garre's (proliferative periostitis), sclerosing, focal or diffuse, radiation-related, drug-related, rarefying, or condensing osteitis (related to a local periodontal problem). The sources for osteomyelitis in the jaws could be from a dental infection, chronic pericoronitis, fracture, systemic seeding, and radiotherapy or could be drug induced.

In acute stages of osteomyelitis, no early changes are evident on radiographs, at least 30–60% demineralization of the bone to detect on conventional radiographs. The first changes perceptible on conventional radiographs are "unsharpness" of bone trabeculae and overall loss of bone density, reflecting the primary effect as loss of bone mineral content through bone resorptive mechanisms. Occasionally, the first changes will manifest as increased thickness of trabeculae and increased bone density, reflecting the primary effect as increase of bone mineral content through reactive bone formation (Fig. 4.4).

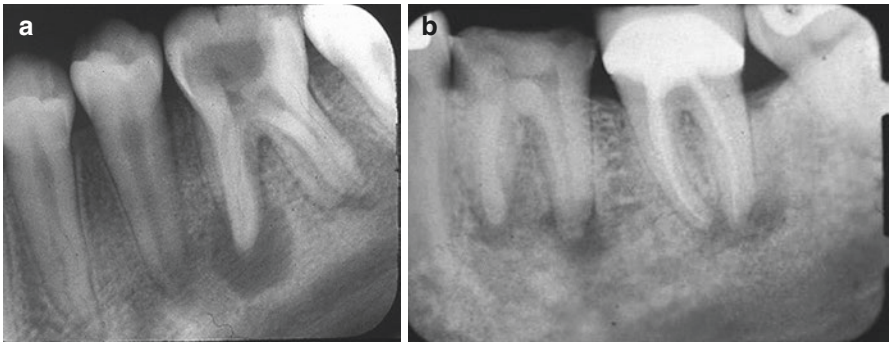

Fig. 4.4 (**a**) PA radiograph showing caries, widened PDL space and a pericarpial radiolucency involving the mesial root of #19. (**b**) Endodontically treated #18 and grossly decayed #19 showing apical pathology/infection with sclerotic changes involving the surrounding trabecular bone

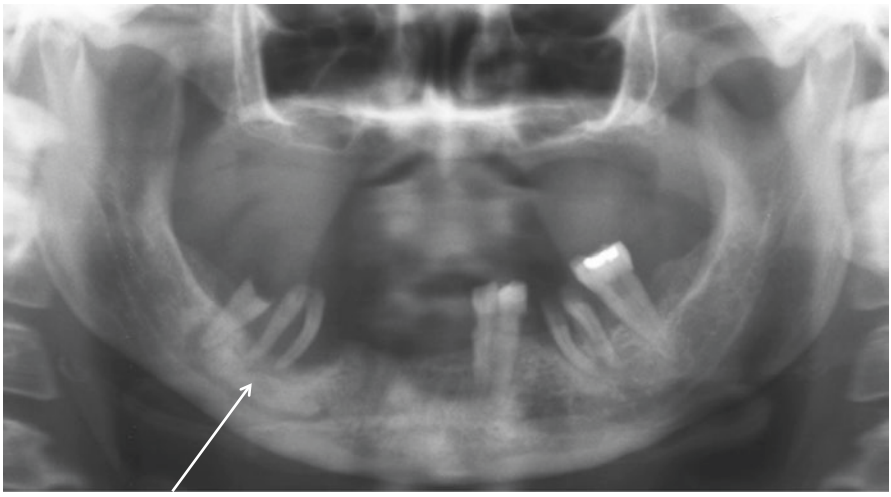

Fig. 4.5 White arrow points to sequestrum formation

Chronic osteomyelitis may or may not be related to acute phase, it is typically longer in duration, and the patient has intermittent to recurrent painful episodes. Paresthesia in the involved area and a draining sinus are common features.

Radiographically the hallmark of osteomyelitis is "sequestrum" formation, and indication of a repair process is periosteal new bone formation (Figs. 4.5 and 4.6). The pathological process of osteomyelitis is when an infection in the bone leads to an increase in intramedullary pressure due to inflammatory exudates; the periosteum becomes stripped from the ostium, leading to vascular thrombosis; bone necrosis follows due to lack of blood supply; and sequestra are formed. As this process continues, involucrum formation may occur as a reparative process; it is a

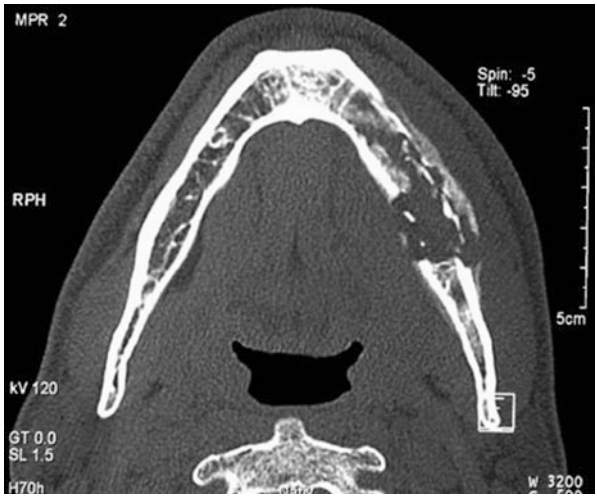

Fig. 4.6 Axial section of head CT sat the level of the mandible showing buccal and lingual bone destruction along with multiple specks of sequestrations

layer of new bone growth outside the existing bone seen in osteomyelitis. It results from the stripping off of the periosteum by the accumulation of pus within the bone and new bone growing from the periosteum.

Osteomyelitis is far more common than osteoradionecrosis and the medically related osteonecrosis (Fig. 4.7) of the jaws (MRONJ) (Fig. 4.8). A thorough clinical history can help in understanding the etiology of the condition. In all of these clinical scenarios, panoramic imaging can help serve as an initial examination, but three-dimensional imaging using cone beam CT will help in understanding the extent of the condition. Nuclear medicine exams using a radiopharmaceutical like technetium-99 will help in understanding the mitotic activity at the site and also in differentiating between an acute phase and a chronic phase and also between osteomyelitis and osteoradionecrosis (Fig. 4.9). Medically related osteonecrosis of the jaws is a fairly recent challenge that general dentists must learn to recognize and be familiar in the management of such cases along with appropriately referring those cases in a timely manner. Conventional 2-D imaging often does not completely show the full extent of involvement of the osteonecrosis. A CBCT scan can help in the staging and treatment planning of the condition; when the infection has a more extensive and deeper involvement, then a multi-slice medical CT should be considered (Fig. 4.6).

4.1.7 Imaging of Cysts

A cyst by definition is a pathological cavity having fluid and is lined by an epithelium surrounded by a connective tissue wall. Cysts are more common in jawbones than in any other bone of the body because of the numerous rests of odontogenic epithelium that remain in the tissues. Most cysts etiologically arise from these cells.

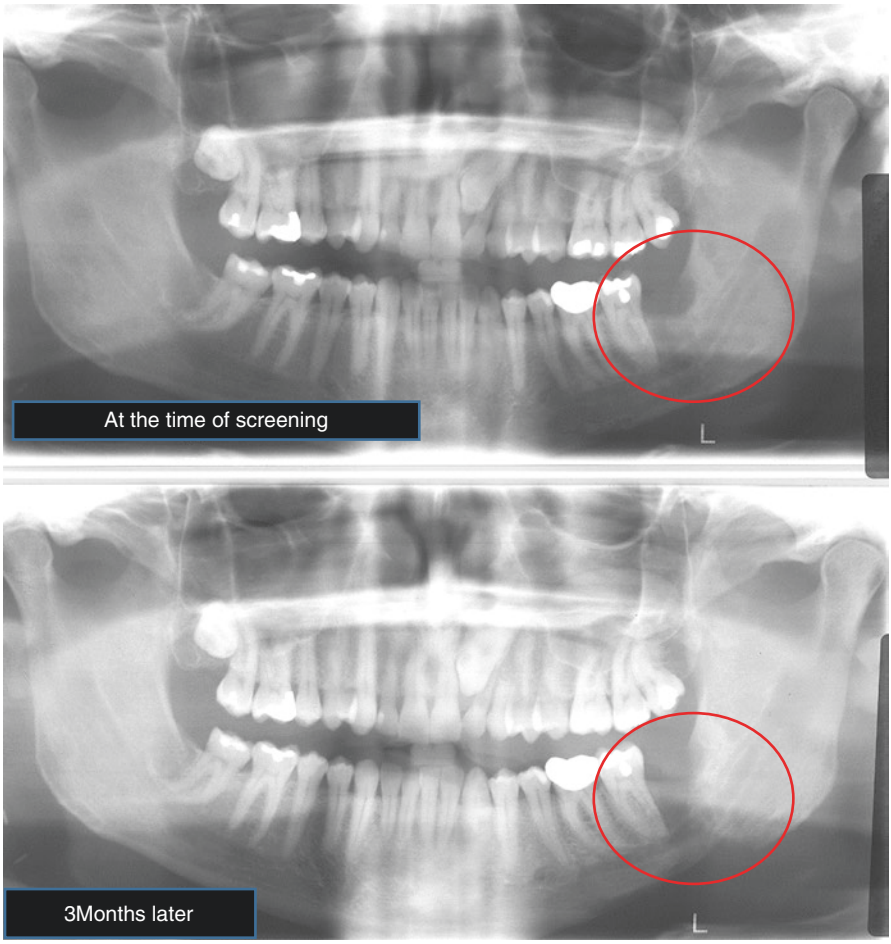

Fig. 4.7 Osteoradionecrosis ("ORN") (radiation osteomyelitis)

Odontogenic cysts affect the tooth-bearing areas; non-odontogenic cysts are usually developmental and are most common in the anterior maxilla. Upon clinical evaluation, odontogenic cysts are noted to be the most common cause of swelling in the jawbones. Patients typically do not have pain unless the cyst is secondarily infected. Cysts in the jaws are most often associated with unerupted teeth. Upon radiography, cysts appear as well-defined, radiolucent lesions arising in the tooth-bearing areas. Cysts are radiolucent entities; they could be unilocular or multilocular. The periphery is a well-defined, well-corticated, and thin radiopaque line. When the cyst gets secondarily infected, this radiopaque rim thickens and appears more sclerotic. Most cysts behave similarly and usually grow slowly and thought to expand by hydrostatic pressure. They usually expand and cause resorption of adjacent structures. The most common type of cyst is the radicular cyst (65–70%) (Fig. 4.10) followed

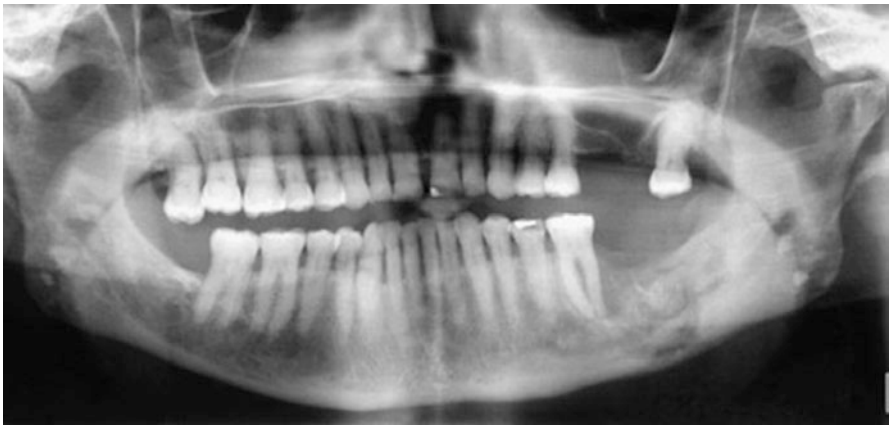

Fig. 4.8 Medication related osteonecrosis of the jaw (MRONJ). This patient was on biphosphonate therapy

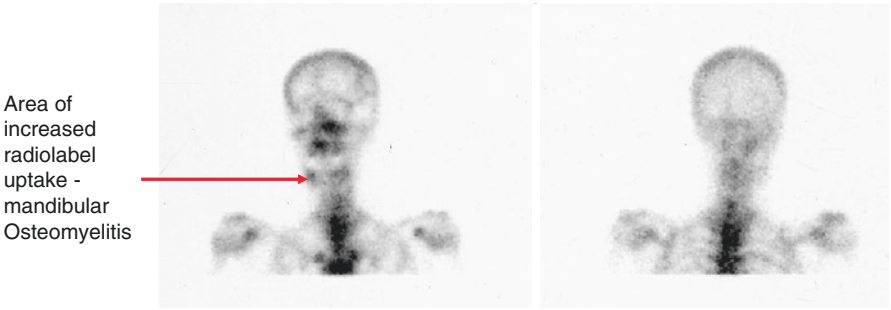

Fig. 4.9 Bone scan to detect acute osteomyelitis

by a dentigerous cyst (15–18%). Odontogenic keratocysts are also a frequent occurrence in older individuals. Panoramic radiography is recommended as the initial image for evaluation (Fig. 4.11). Further imaging like CBCT or a CT is often done to evaluate the full extent in three dimensions, to study the effects on adjacent structures, and also to plan the surgical approach.

4.1.8 Imaging of Benign Tumors and Malignant Tumors

A time-sensitive and key pointer for the general dentist to notice is understanding the clinical and radiographic presentation of a benign and malignant tumor and distinction from an infection and appropriate timely referral to a specialist. It is very valuable for the clinician to recognize the difference between these entities. While a panoramic radiograph may be adequate to do an initial analysis, imaging using CBCT will help in evaluating the characteristics of the lesion to observe the nature

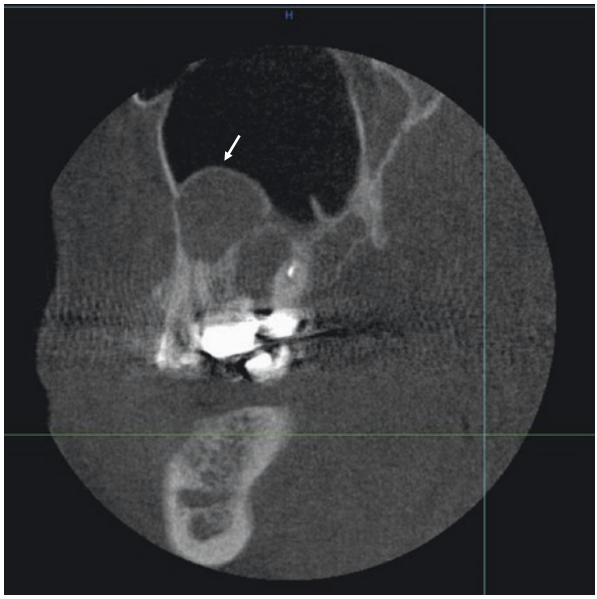

Fig. 4.10 Sagittal CBCT section showing a radicular cyst. Arrow showing the raised floor of the sinus

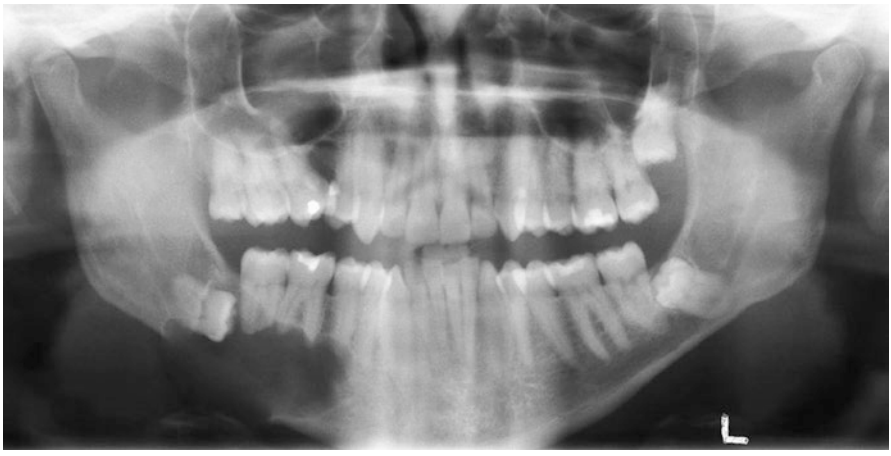

Fig. 4.11 An odontogenic keratocyst involving tooth # 32. Note the undulating cortication

and behavior of the lesion. Based on these observations, a CT exam may be ordered. Radiographically an important point to note is that benign tumors only resorb structures by growth, whereas malignant tumors destroy structures and are fairly quick to cause significant destructive changes. A well-designed approach would be to start with a panoramic radiograph, based on the behavior of the lesion; other advanced imaging options may be considered like CBCT, CT, and a positron emission tomography (PET)-CT. Since timing is critical for the prognosis in these cases, appropriate referrals must be made in a timely fashion.

4.1.9 Imaging of the Paranasal Sinuses

There a total of four paired sets of paranasal air sinuses. Maxillary and ethmoid sinuses are of particular interest to dentists because of the shared borders and proximity to dental structures (Fig. 4.12). Maxillary sinus in particular is of significant importance. The floor of the maxillary sinus is in very close proximity to the premolar and molar teeth. The floor of the maxillary sinus appears as a thin radiopaque line on radiography. It is commonly observed in intraoral radiographic exams and on panoramic radiographs and in 3-D imaging of the maxillofacial complex. Over time pneumatization of sinuses occurs and this is most marked in the maxillary sinus. It has been observed that with loss of a posterior tooth, the pneumatization of the maxillary sinus is more obvious, and the floor of the sinus drops down toward the alveolar bone causing further expansion or pneumatization of the sinus. This aspect is of particular value in dental implant therapy where it is of utmost value to have as much natural bone volume available as possible. One common method of preparing a potential implant site after extraction of the tooth is to graft the site and is referred to as the socket preservation procedure. If the site happens to be a long-standing edentulous site, and pneumatization of the bone has occurred causing inadequate availability of bone volume, a technique called "sinus-lift" procedure is done where the sinus floor is augmented and raised up and grafted to gain adequate bone volume.

Several diseases are associated with the sinuses; the most important sinus that is of interest to the dentist is the maxillary sinus. While the pathology associated with the sinuses can be classified in many ways, a simple way to distinguish the etiology that is meaningful for the dentist is to classify the diseases as those arising from

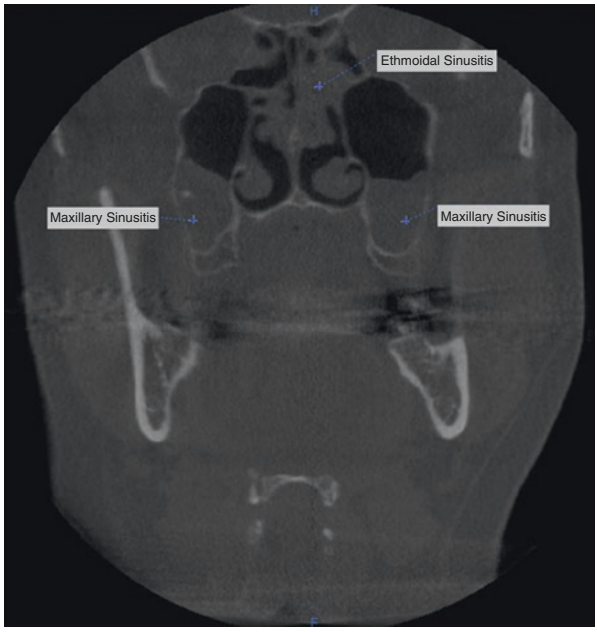

Fig. 4.12 Coronal CBCT image showing maxillary and ethmoid sinuses with marked mucosal thickening

within the sinus tissues (intrinsic) or originating outside the sinus (extrinsic) such as those with an odontogenic origin. Upon clinical examination, pressure and pain during bending and head movement are common signs associated with maxillary sinus disease. Diseases involving the maxillary sinus include inflammation due to infection, allergies, trauma, etc. Since sinuses are air filled, the radiographic appearance is radiolucent, any changes including mucosal thickening to any mass in the sinus will radiographically appear radiopaque, but the density varies depending upon the condition. Sinusitis is a common condition radiographically noted as a radiopaque lining on the floor of the sinus, it could be inflammatory or allergic, and several cases may have an odontogenic involvement. When the infection is due to an odontogenic cause, there may be an oroantral communication and a breach in the continuity of the maxillary sinus. While sinusitis, polyps, antroliths, and mucoceles constitute the inflammatory group of conditions affecting the maxillary sinus, benign neoplasms like a papilloma or an osteoma affect the paranasal sinuses. The most important pointer for clinicians is to identify squamous cell carcinoma largely because they are rare and importantly because they are silent and often are mistaken for inflammatory conditions and are diagnosed at an advanced stage. Malignancy in the maxillary sinus will have facial swelling and nasal obstruction. In most cases the medial wall of the sinus is eroded first leading to nasal involvement and spread. From a dental perspective, it is valuable to know that if there is no odontogenic involvement and there's unexplained swelling, altered sensation of teeth, ill-fitting prostheses (when present), and pain with no obvious odontogenic cause, it is prudent on the part of the dentist to identify the condition as a malignancy arising from the floor of the sinus and that it undergoes a complete workup till proven otherwise.

Several extrinsic conditions may involve the maxillary sinus including odontogenic cysts like dentigerous cyst or an odontogenic keratocyst or an inflammatory cyst like the radicular cyst. All of them push the floor of the maxillary sinus superiorly and when there is a superimposed infection could cause breach or discontinuity of the sinus floor. Another important condition for the clinician to be aware of in this region is fibrous dysplasia which is a condition that alters bone metabolism and turns normal bone into dysplastic bone. This condition is more observed in the posterior maxilla and blends into the adjacent area and may appear as a poorly defined radiopaque entity involving the maxillary sinus.

Intraoral radiography shows the tooth root and floor of the sinus area very well but does not provide the full picture necessary for complicated cases where knowledge of the type and extent of the lesion is important. An extraoral projection known as the "Waters' view" was typically used to compare air-fluid levels in the sinus and internal components of the sinuses in the same image but is slowly becoming obsolete. Panoramic radiography is helpful in studying both the maxillary sinuses and the sinonasal areas in the same image, but the challenge of superimpositions inherent to its acquisition technique may lead to a 3-D examination if the panoramic image is not adequately able to depict the entire sinus and the spread of the condition. CBCT (Fig. 4.13), CT, and MRI are being increasingly used to evaluate the extent and spread of fibrous dysplasia or a malignancy.

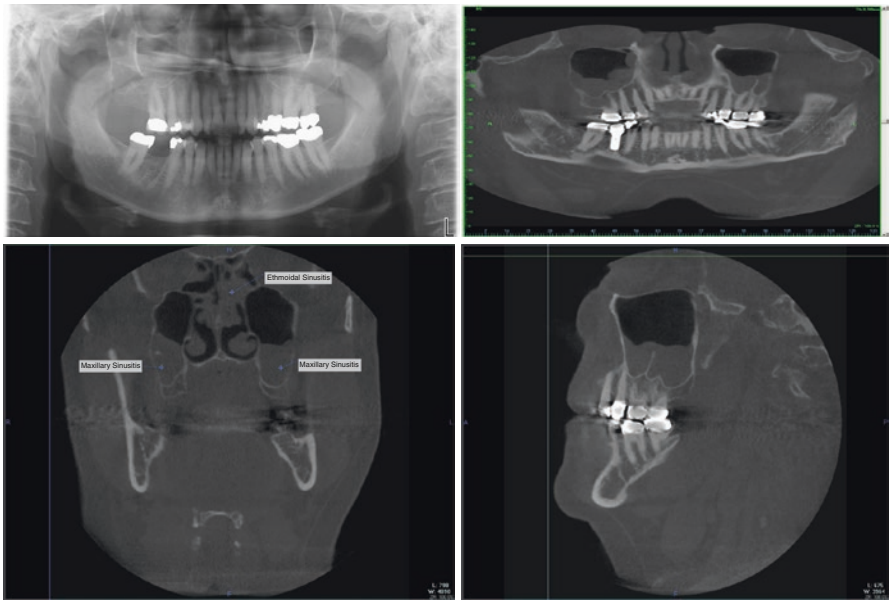

Fig. 4.13 Panoramic and CBCT images showing sinusitis

4.1.10 Imaging of the TMJ

Imaging of the temporomandibular joint is based on clinical findings. Diagnostic imaging of the TMJ is an important adjunct to clinical evaluation. The osseous components of the TMJ can be imaged by panoramic radiography, but because of the unique location of the TMJ, several superimpositions can be noted in this area and often make it challenging to do a complete evaluation of the joint structures. Three-dimensional imaging using computed tomography (CT) or cone beam computed tomography (CBCT) can provide high-resolution images of the condyle and the fossa (Fig. 4.14). It is challenging to image the disc using plain films, CT, or CBCT, and so magnetic resonance imaging is used to evaluate the disc. Several conditions affect the TM joint complex that have a direct impact on esthetics and function, and so it is valuable for the clinician to know and recognize these conditions and to make appropriate and timely referrals. Condylar hyperplasia, condylar hypoplasia, juvenile arthrosis, and bifid condyle are the more common developmental challenges involving the joint complex. The articular disc could be displaced anteriorly or medially or laterally leading to pain and limitation in mouth opening and the range of motion. Disc displacement could be because of a number of reasons like arthritis, trauma, or temporomandibular dysfunction. All changes involving the disc and fluid effusion in the joint space is best recognized on magnetic resonance imaging (MRI) (Fig. 4.15).

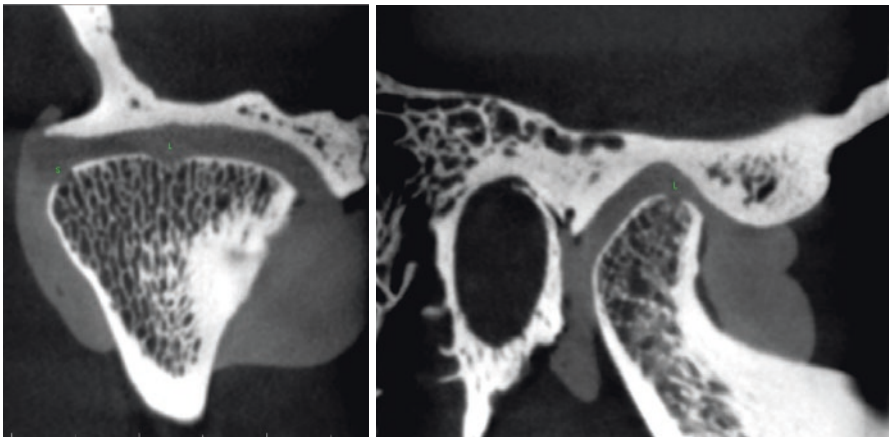

Fig. 4.14 High resolution CBCT images of the TMJ

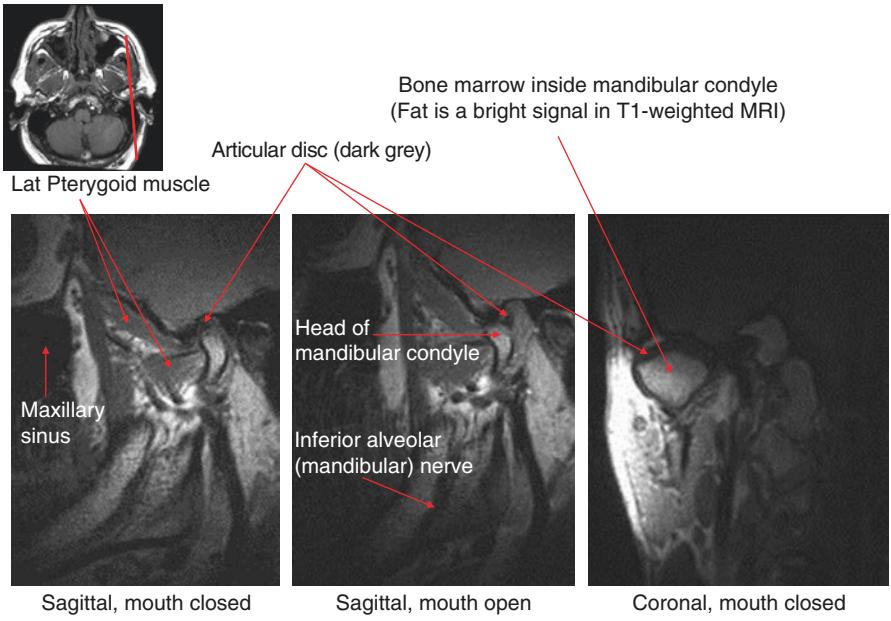

Fig. 4.15 T1-weighted magnetic resonance imaging (MRI) of the TMJ

4.1.11 Imaging of the Salivary Glands

Salivary glands play several important functions including buffering action to enzymatic production. Adequate quantity and quality of salivary flow is critical for normal functioning of many physiological processes in the body. There are

2 submandibular, 2 sublingual, and more than 400 minor salivary glands in the mouth. Upon clinical evaluation the presentation of salivary gland symptoms includes pain and swelling, sometimes associated with eating and drinking. It could also be a painless mass, dry mouth, or bad taste in the mouth. Salivary gland enlargements can be inflammatory, cystic, neoplastic, or nonneoplastic. The most common condition for pain involving the salivary gland is sialolithiasis or formation of a stone in the salivary gland. One way to test the origin of pain when salivary gland involvement is suspected is to administer lime/lemon juice to the patient, and if the salivary gland is involved, typically there is salivary production that could be obstructed by a sialolith and could elicit pain due to obstruction within the gland. Sialoliths are most common in the submandibular gland at its duct known as the Wharton's duct. The high rate of involvement could be because the duct is longer and has a larger caliber and a slower salivary flow rate. Higher pH and calcium circulation could also be possible reasons that could be contributing to the formation of salivary gland stones. Occlusal radiographs are recommended as an initial examination to study the floor of the mouth when a submandibular gland sialolith is suspected. A functional imaging exam known as sialography was very popular to both diagnose and partially treat the obstructed salivary gland, but because of many contraindications like inability to use in acute infections, sensitivity to iodine-based dyes used in the procedure, and evolution of better techniques, this method is slowly being replaced by other advanced imaging methods like magnetic resonance sialography (MR sialography). Sialadenitis is another important condition that the clinician must recognize. It is an acute or chronic bacterial infection; upon clinical evaluation, it presents as a swelling with redness, tenderness, fever, and possible regional lymphadenopathy. Computerized tomographic exams of the salivary gland are valuable when the clinical need is to study the gland in 3-D and also to understand the extent and involvement of the condition. CT exams also have a good contrast resolution that is necessary to study the subtle soft tissue layers. MRI is also being extensively used to study the soft tissues in this area including the salivary gland proper especially to study masses in the salivary gland and also to study the ductal system. While access to the salivary glands using conventional ultrasonography probes is challenging, it is used frequently to differentiate between cystic and solid lesions and is very sensitive for detection of superficial lobe parotid masses. A functional imaging test that is of significant value to the clinician is scintigraphy using 99mTc-pertechnetate. Because of the poor resolution of the image, it cannot accurately depict small tumors and cannot differentiate between benign and malignant tumors, but it is very valuable in diagnosis, treatment, and follow-up of Sjogren's syndrome. CBCT- and CT-guided surgical procedures are fast becoming the preferred method of surgical management. Data generated from the 3-D scans is used as a roadmap to navigate a sophisticated instrument into the area of interest and perform several different surgical procedures (Figs. 4.16 and 4.17).

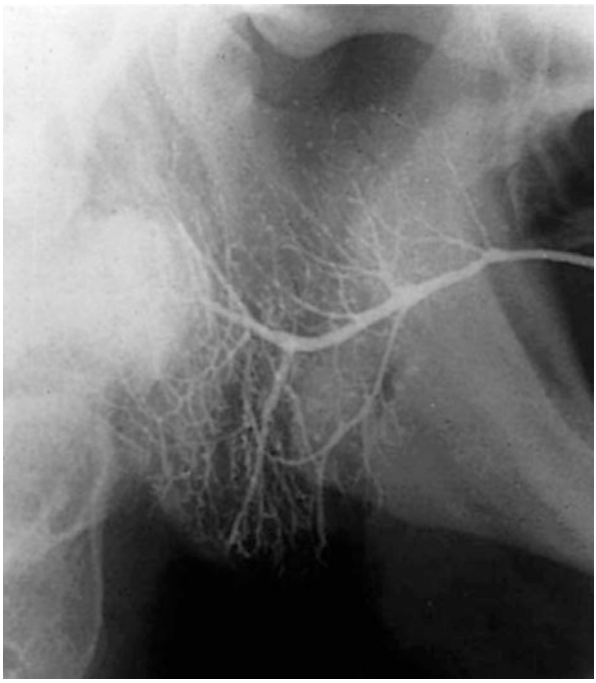

Fig. 4.16 Normal parotid sialogram—water based contrast

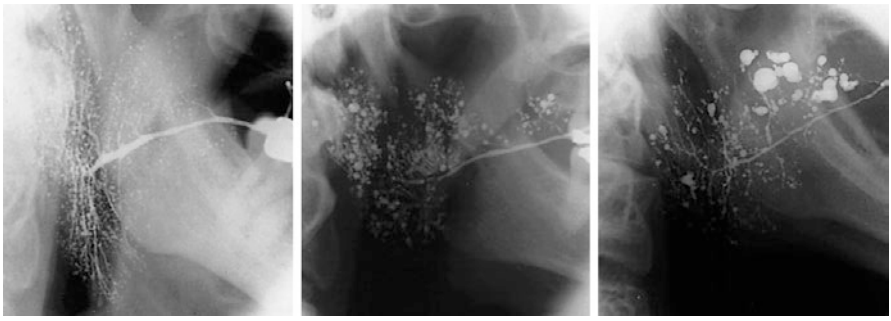

Fig. 4.17 Parotid punctate sialoadenitis with retention of contrast in gland. This is a characteristic appearance of Sjogren's Syndrome

4.1.12 Imaging Involving Dental Implants

With a significant shift in the restoration of edentulous spaces with dental implants, general dental offices are involved in many ways in the treatment planning, placement, and restoration of dental implants. Implant therapy is a multistep process that requires careful planning, case selection, and execution. Several aspects need to be carefully evaluated to facilitate the success of dental implants. Radiographic imaging is key to successful implant placement. While a panoramic radiograph and intraoral radiographs provide adequate initial details, cone beam CT (CBCT) must be considered in cases that require three-dimensional views of the proposed implant site. The International Congress of Oral Implantologists in its consensus report establishes the value and limitations of CBCT in implant treatment planning and also provides guidelines regarding the use of CBCT in implantology. Cone beam CT provides high-resolution, three-dimensional images of the proposed implant site. The most important advantage of CBCT is the ability to provide cross-sectional images of the implant site without any superimpositions. The radiation dose is significantly lower compared to a conventional 3-D imaging option using a multi-slice medical CT. The American Academy of Oral and Maxillofacial Radiology (AAOMR) in its position paper on the use of dental radiography in dental implantology, based on available literature and current evidence, states that cross-sectional imaging should be used for the assessment of all dental implant sites. CBCT scans provide information regarding the proximity of critical structures to the potential implant site and often help in making and/or modifying the treatment plan and surgical approach. There are several ways CBCT scan data is utilized in implant therapy. Typically a radiographic guide is fabricated prior to the CBCT acquisition indicating the desired site for implant placement. The patient is scanned with the radiographic guide in place, and cross-sectional images of the potential implant site are generated using a post-processing CBCT reconstruction program. Height and width measurements of the implant site, morphology of the buccal, lingual/palatal cortical bone contours, and trabecular pattern are recorded along with proximity to any critical structures to aid in implant treatment planning. Since dental implant placement is dependent on the location of the final prosthetic component, many times bone grafting procedures need to be done to gain adequate bone volume at the desired location. CBCT can help determine the location, size, and volume of graft necessary to manage the site. When guided surgery is being considered for implant placement, the DICOM data from the CBCT scan is used in the fabrication of the surgical stent. Overall, radiographic imaging especially cross-sectional imaging using CBCT can contribute toward evaluation of the implant site, need for any grafting procedures at the site, and choosing the type, size, and number of implants providing significant value addition (Figs. 4.18 and 4.19).

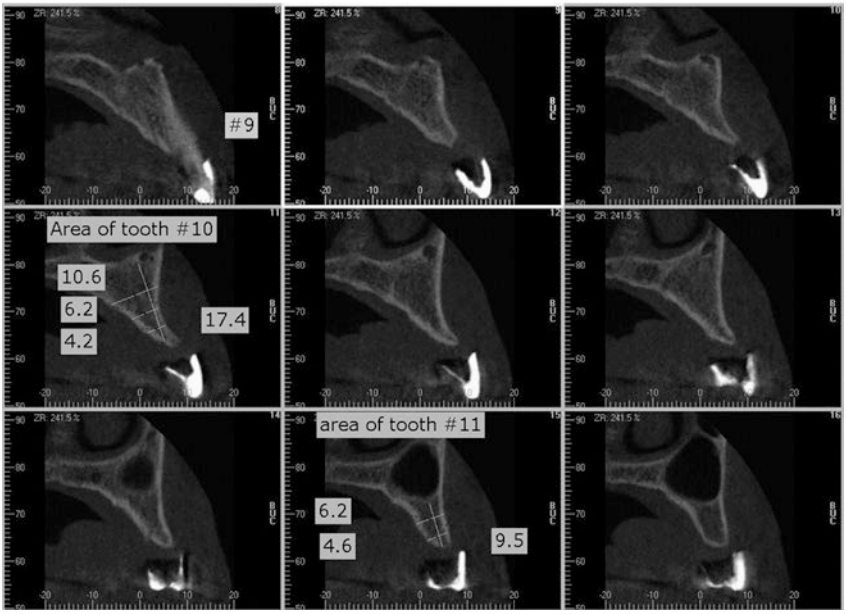

Fig. 4.18 CBCT image of maxillary implant site with radiographic guide

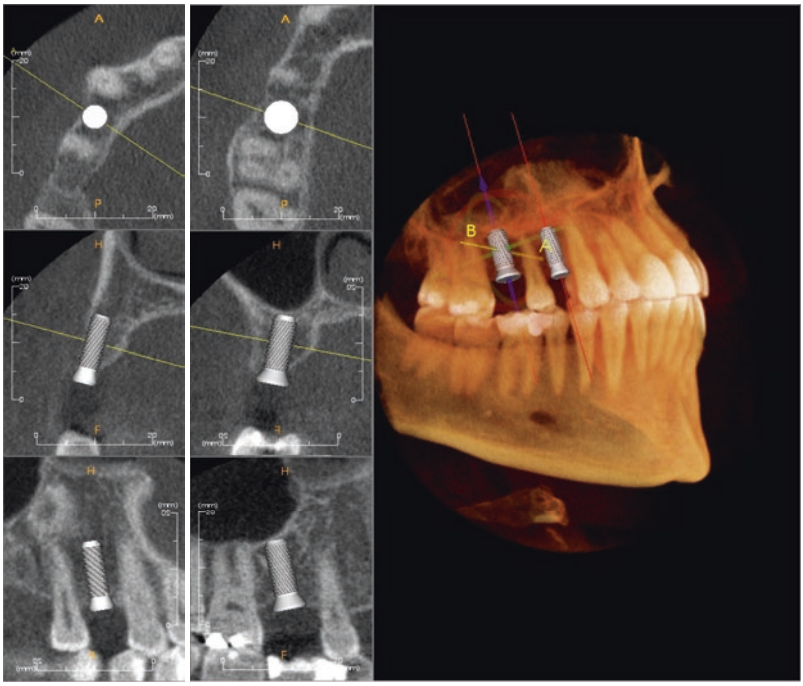

Fig. 4.19 CBCT images showing an implant treatment planning program that allows virtual implant placement

4.2 Summary/Conclusion

Radiographic evaluation of the oral and maxillofacial structures is an important complement to clinical evaluation in diagnosis and treatment planning of most dental procedures. Ionizing radiation in the form of X-rays is the most commonly used source of radiographic imaging. The challenge with ionizing radiation is that it leads to radiation and body tissue interactions that could potentially cause cancerous transformation of cells even at low doses. Because these interactions cannot be predicted easily, due diligence and responsible use of ionizing radiation are advised. Benefits of a radiographic exposure should outweigh the risks, and the information gathered should meaningfully contribute toward the patient's treatment. A key point to remember as a rule of thumb is that younger patients are more sensitive to ionizing radiation and so are some organs like eyes, salivary glands, thyroid gland, etc. No dose is too low to completely avoid the risk induced by ionizing radiation. Proper selection criteria must be followed for radiographic examination. A 2-D examination like an intraoral periapical, a bitewing, or a panoramic must be the initial exam of choice, and if deemed necessary, a 3-D exam with the lowest dose that yields diagnostic quality images must be selected. It is the responsibility of the dental office acquiring the radiographic images/scans to interpret the exams and do the necessary timely referrals. When needed the services of an oral and maxillofacial radiologist may be sought to interpret the images/scans.

Overall it is advisable to have a system in place for a standardized work flow involving selection criteria, image acquisition, patient protection using shielding, electronic health record management, interpretation, and archival of patient data. All the processes in place should help in responsible management of the dental office that follows evidence-based decision-making to enhance patient-centric outcomes.

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Complementary and Alternative Medicine

5

Stephan Goupil and Michael T. Goupil

"Let us get a firm grip of the very little which we do know, so that when fresh facts arise, we may be ready to fit them into their places."

Sherlock Holmes in—The Adventure of the Devil's Foot

Abstract

Complementary and alternative medicine (CAM) techniques are used by a significant part of the population worldwide. Many of these techniques have been used successfully for thousands of years. Current research has tried to evaluate the basis and success of these techniques with mixed results. This chapter provides an overview of this vast topic and provides examples of where these techniques might be employed into contemporary dental practice.

5.1 Introduction

The National Institutes of Health defines complementary and alternative medicine (CAM) as "a group of diverse medical and health care systems, practices, and products that are not presently considered to be part of conventional medicine"

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(Little 2004). It is used by approximately 40% of the US population, and herbalism is the most common medical practice in the world (Barnes et al. 2008; Kummet et al. 2014). A considerable number of patients do not inform their healthcare provider that they are utilizing CAM. The use of CAM, especially the use of herbal products, can have an interactive effect on more traditional Western medicine practices. This chapter provides an overview of many of the popular CAM practices that the dental practitioner may encounter. CAM practices are commonly used in the treatment of chronic pain (Lee and Raja 2011; Ossendorf et al. 2009). Some of these practices can be incorporated into the overall dental treatment plan especially in the area of chronic pain management (Spector et al. 2012). Studies indicate that patients utilize CAM practices in alleviating their temporomandibular dysfunction (TMD) (Myers et al. 2002; Raphael et al. 2003).

5.2 Common CAM Systems

1. **Traditional Chinese Medicine (TCM)** is a broad range of medicine practices sharing common concepts which have been developed in China and are based on a tradition of more than 2000 years, including various forms of herbal medicine, acupuncture, massage (Tui na), exercise (qigong), and dietary therapy.
2. **Ayurvedic Medicine** is a system of healing that originated in ancient India. In Sanskrit, ayur **means** life or living, and veda **means** knowledge, so Ayurveda has been defined as the "knowledge of living" or the "science of longevity." It includes dietary therapy, herbal medicine, and meditative poses that are individualized to the patient's specific medical situation.
3. **Naturopathy** is a system of treating diseases, largely employing natural agents, such as air, water, sunshine, etc., and rejecting the use of drugs and medicines. It uses complementary and conventional medicine techniques to support and promote self-healing.
4. **Homeopathy** is a system of medical practice that treats a disease especially by the administration of minute doses of a remedy that would when given in larger amounts to healthy persons would produce symptoms similar to those of the disease.
5. **Chiropractic** is a system of noninvasive therapy which holds that certain musculoskeletal disorders result from nervous system dysfunction arising from misalignment of the spine and joints. Treatment focuses on the manual adjustment or manipulation of the spinal vertebrae.
6. **Osteopathy** was developed as a manual therapy involving manipulation of the spinal and peripheral joints and soft tissues. Currently in the USA, it includes most of the allopathic therapeutic methods and is considered as part of mainstream healthcare. In some other countries, osteopaths are still considered complementary medicine therapists.

5.3 Herbal Therapy

Herbal therapy may be prescribed by a healthcare provider but is more commonly self-prescribed. In the USA, herbals are considered dietary supplements rather than drugs and are used by approximately 20% of the population (Bent 2008; Kennedy et al. 2008). As dietary supplements, herbals are required to be safe but not necessarily proven to be effective.

One of the problems in conducting research on herbals, and consequently in interpreting the available research, is the "purity" of the herb. Plants are affected by a variety of growing conditions such as weather, soil conditions, geography, etc. Also, the effects of the herbal may differ depending on what part of the plant is being used—root, stem, leaf, or flower. In addition, there are other confounding factors such as when was the herb harvested, how it has been prepared, and how long has it been stored. Despite these drawbacks, there is a considerable amount of literature available on a variety of herbal products; but this literature, both positive and negative, needs to be interpreted with care. An objective assessment as illustrated in Chap. 1 becomes very important. This is also true when looking at other CAM techniques that are discussed later in this chapter.

The quantity of plants used for medicinal purposes worldwide numbers in the tens of thousands. Some of the more commonly used herbals that might be encountered in a dental practice will be covered in this chapter. As part of a patient's medical history, they must be specifically asked if they are taking any herbal products or dietary supplements. In a dental school patient population, Abede et al. reported that only 12.6% of the patients reported using an herbal within the past month (Abede et al. 2011). There are several informational sources available that can be utilized to determine whether these herbs/supplements may influence the treatment planned (see Table 5.1).

5.3.1 Common Herbals

- Arnica (*Arnica montana*), also known as wolf's bane, is considered to have both anti-inflammatory and analgesic properties and is applied topically immediately following injury to reduce bruising and swelling. It has been advocated to reduce

Table 5.1 Complementary and alternative medicine information resources

National Center for Complementary and Alternative Medicine—www.nccam.nih.gov
US Food and Drug Administration—www.fda.goc/consummer
Alternative Medicine Foundation—www.herbmed.org
US National Library of Medicine—www.medlineplus.gov/druginfo/natural

pain and swelling following tooth extraction. It may be a valid alternative to nonsteroidal anti-inflammatory medications (Iannitti et al. 2016). When taken orally it should be in diluted homeopathic doses, as arnica, when taken systemically, can cause cardiac arrhythmias and increase blood pressure (Leonard 2017).

- Black cohosh (*Actaea racemosa, Cimicifuga racemosa*) is one of the top-selling herbs for the treatment of menopausal symptoms. The widespread belief has been that black cohosh acts by way of phytoestrogens. Studies indicate that, instead, it has neurotransmitter-like activity (Wuttle and Seidlová-Wuttke 2015). Case reports have raised a concern about hepatotoxicity. The results of a meta-analysis by Nauser et al. demonstrated that there is no evidence that isopropanolic black cohosh has any adverse effect of liver function (Naser et al. 2011).
- Chamomile (*Matricaria recutita*) has anxiolytic properties (Amsterdam et al. 2009) most likely working at the benzodiazepine receptor sites and is considered to have both antibacterial and anti-inflammatory action. It is used for a variety of inflammatory conditions including the mouth and pharynx and has been advocated for the treatment of oral lichen planus (Jornet and Aznar-Cayuela 2016). It is also used for teething pain. Patients may be encountered that use chamomile tea as an antioxidant or as part of their diabetic control (Zemestani et al. 2016). Chamomile contains coumarins and may have anticoagulant effect (Izzo 2013).
- *Echinacea* (*Echinacea purpurea* and related species) also known as the coneflower is in the aster family and grows wild in North America and Europe. It is commonly used to prevent and treat infections including mouth ulcers. It is contraindicated in patients with autoimmune diseases and may decrease the effects of immunosuppressants. Meta-analysis suggests that *Echinacea* may be associated with a reduction in common colds but not of shortening its duration (Karsch-Völk et al. 2015).
- Feverfew (*Tanacetum parthenium*) has analgesic and anti-inflammatory properties and is used in the treatment of migraine, arthritis, and rheumatic diseases. A number of trials have been conducted that indicate feverfew may have a preventive effect on migraines (Ernst and Pittler 2000). It may interfere with coagulation and the effects of nonsteroidal anti-inflammatory agents.
- Garlic (*Allium sativum*) is a common aromatic herb frequently used in cooking. Although for medicinal purposes, it should be eaten raw or taken in capsule form. Garlic is reported to lower cholesterol and blood pressure and has the potential for cardiac protection (Varshney and Budoff 2016). It interferes with platelet aggregation and can increase bleeding especially when combined with other herbals like *Ginkgo*.
- Ginger (*Zingiber officinale*) root is primarily used for its antiemetic properties to treat nausea, vomiting, and loss of appetite. Research has demonstrated that it is more effective than a placebo for the treatment of postoperative problems (Chalayakunaprul et al. 2006). It increases the effects of anticoagulants and may enhance the effects of central nervous system depressants.

- *Ginkgo* (*Ginkgo biloba*) is one of the oldest known trees with a fossil record dating back millions of years. It has been extensively researched for a variety of conditions most notable for intermittent claudication and dementia where it appears to have a positive effect (Brondino et al. 2013). Its primary methods of action are increasing microcirculation blood flow and inhibition of erythrocyte aggregation. It has an inhibitory effect on platelet-activating factor and may have an additive effect with aspirin, antiplatelet agents, and other anticoagulants which may lead to postoperative bleeding issues.
- Ginseng (*Panax ginseng* or Asian ginseng and *Panax quinquefolius* or American ginseng) is used to prevent illness and promote health, in other words a "cure-all" tonic. According to Bach et al., there is "insufficient clinical evidence to support the use of ginseng supplements on reducing fatigue and enhancing physical performance" (Bach et al. 2016). Ginseng appears to have neutral effects on the vascular system but may have favorable effects on the systolic blood pressure of individuals with diabetes and obesity (Komishan et al. 2016). It has antiplatelet activity and should not be used in combination with aspirin, nonsteroidal anti-inflammatory medications, or other blood thinners.
- Goldenseal (*Hydrastis canadensis*) is a member of the buttercup family. It is widely used in folk medicine as an antimicrobial and antiseptic (Asmi and Lakshmi 2013). When used as a mouthwash, it has the potential to inhibit cariogenic and periodontal pathogen growth. It may have cardiovascular effects and potentiate the risk of bleeding when taken with other blood thinners (Leonard 2017).
- Green tea (*Camellia sinensis*) is a common beverage used throughout the world. It is considered to have antioxidant properties and is used in dentistry because of its antimicrobial activity. Studies have demonstrated that mouthwash containing green tea is effective in treating periodontal and cariogenic pathogens (Hirasaawa et al. 2006; Radafshar et al. 2017). Its vitamin K content may interfere with the anticoagulation effect of Coumadin.
- Kava (*Piper methysticum*) is native to the South Pacific and is used as primarily as an anxiolytic and sedative. It has been banned by many countries because of its hepatotoxicity. The kavalactones modify binding at the GABA receptors and this could potentiate the effects of benzodiazepines and barbiturates (Sarris et al. 2012; Rowe and Baker 2009).
- Saw palmetto (*Serenoa repens*) is a popular herbal remedy primarily used for urinary problems associated with benign prostatic hyperplasia. According to Barry et al. in the *Journal of the American Medical Association*, increasing doses of saw palmetto were no more effective than placebo (Barry et al. 2011). Wyatt found similar findings in patients being treated with radiation therapy for prostate cancer (Wyatt et al. 2016).
- St. John's wort (*Hypericum perforatum*) grows throughout the world and is one of the oldest of the medicinal herbs originally used to ward off evil spirits. Current research indicates that it is effective in the treatment of mild to moderate depression (Gupta and Möller 2003; Ng et al. 2017). It most likely acts as a

serotonin reuptake inhibitor and thus may have an additive effect with drugs with a similar action and may result in serotonin syndrome.

- Valerian (*Valeriana officinalis*) dates back to Hippocrates and is used for insomnia and anxiety. It most likely affects the GABA receptors. Several studies indicate that Valerian is effective both as a sedative/hypnotic and an anxiolytic (Hadley and Petry 2003). Like Kava, Valerian could potentiate the effects of benzodiazepines and barbiturates (Lauder 2009).

5.4 Supplements

- Chondroitin is commonly used for joint-related pathologies and is used for the promotion and maintenance of cartilage. It appears to be useful especially in patients with osteoarthritis. It has anti-inflammatory properties and reduces inflammation by the inhibition of TNF-α. Meta-analyses have concluded that chondroitin sulfate obtained from natural sources is safe (Heller et al. 2006). Although because of the similarity of its chemical composition to heparin, it has been speculated that bleeding complications can occur when chondroitin is taken with other blood thinners (Dahmer and Schiller 2008).
- Glucosamine occurs naturally in cartilage and has become a popular treatment for arthritis frequently in combination with chondroitin. Most clinical trials have been for osteoarthrosis of the knee. Its usefulness has not been confirmed, but no significant drug interactions have been reported (Dahmer and Schiller 2008). Highlight et al. have reported that glucosamine sulfate is more effective and safer than the use of ibuprofen in the treatment of temporomandibular joint osteoarthritis (Haghighat et al. 2013).
- Melatonin is a naturally occurring neurohormone produced in the pineal gland and is involved in the regulation of sleep. Meta-analysis has disagreed on the effectiveness of melatonin as a sleep modifier. These results may have to do with differences in dosing regimens (Arendt et al. 2008). Because of melatonin's sedation properties, it has been studied as a possible premedication for the management of dental anxiety (Perez-Heredia et al. 2015). According to Permuy et al., melatonin "may have important implications for dental disorders, such as periodontal disease, as well as osseointegration of implants, due to its anti-inflammatory and osteoconductive effects" (Permuy et al. 2017).

A variety of herbals and food supplements can interact and alter the effectiveness of many medications that many dental patients routinely take or that the dentists, themselves, may prescribe (see Tables 5.2, 5.3, and 5.4).

Table 5.2 Botanicals and supplements that may increase bleeding potential

Arnica	Horse chestnut
Bilberry	Kelp
Coleus	Papaya
Chamomile	St. John's wort
Feverfew	Turmeric
Fish oil	Watercress
Garlic	Willow
Ginger	Yarrow
Ginseng	

They may have an additive effect when used with warfarin, nonsteroidal anti-inflammatories, and aspirin

Table 5.3 Botanicals that can potentiate central nervous system depressants

Chamomile	Lavender
Hawthorne	Marigold
Henbane	Parsley
Feverfew	Queen Anne's lace
Ginger	Valerian
Horehound	Yarrow
Kava	Yerbe mate

They may have an additive effect when used with muscle relaxants, narcotic pain relievers, and benzodiazepines

5.5 Adjunctive Therapies

1. **Skeletal/muscle manipulations** form the basis of both osteopathy and chiropractic. They may have a place in the care of the chronic pain population. In the Cuccia et al. randomized controlled study, the osteopathic manipulative treatment group required less muscle relaxant and nonsteroidal medications than the conventional therapy group (Cuccia et al. 2010). Osteopathic manipulative treatment has been used for chronic neck pain as well as trigeminal neuralgia and burning mouth syndrome (Haller et al. 2016; Campbell et al. 2012).
2. **Acupuncture** is a Traditional Chinese Medicine (TCM) technique and consists of inserting fine, sharp needles into the skin at specific points to provide preventive or therapeutic therapy. The original concept on how acupuncture works is that acupuncture allows correction of the body's energy flow or qi. Acupuncture does release neurotransmitters like opioid peptides and serotonin, and this may account for some of its positive effects. According to Aung "acupuncture manages pain, controls anxiety…and is a viable treatment of choice for patients who are allergic to anesthesia…" (Aung 1998). Research does support that acupuncture may have a role and a positive influence on the signs and symptoms of temporomandibular joint disorders (Smith et al. 2007; Jung et al. 2011).

Table 5.4 Botanicals that may alter glucose metabolism

All spice	Flaxseed
Bay leaf	Korean ginseng
Burdock	Oregano
Cinnamon	Teas—green and black
Clove	Sage
Dandelion	Witch hazel

They may improve the utilization of glucose and the function of insulin

3. **Yoga** consists of a variety of gentle stretching poses, breath control, and meditation. It has a history dating back over 5000 years. It has proven to be more effective than other modes of physical activity in alleviating musculoskeletal pain in dentists (Koneru and Tanikonda 2015).
4. **Biofeedback** is the use of instruments to monitor and provide feedback on physiologic response to events thus providing information that would allow the patient to modify those responses. According to Crider and Glaros's meta-analysis, five of six controlled trials found electromyographic biofeedback to be superior to no treatment or psychological placebo controls (Crider and Glaros 1999). An exploratory study found that a respiratory rate biofeedback device may be helpful in reducing dental anxiety (Morarend et al. 2011).
5. **Massage** is one of the oldest forms of treatment and consists of treating the soft tissue of the entire body using pressure and traction. For the dental practitioner, this may be an excellent way to combat neck and back pain affecting many practitioners. This is a method that could be considered in the treatment of the chronic pain patient. Although it may not provide a lasting effect, it may be useful in providing immediate pain relief effects (Kong et al. 2013). Massage therapy had no significant effect on electromyographic activity in selected masticatory muscles in patients with temporomandibular disorders. When used in combination with occlusal splint therapy, massage reduces the intensity of the signs and symptoms of temporomandibular disorders and sleep bruxism (Gomez et al. 2014).
6. **Relaxation** therapy consists of a variety of techniques, such as deep breathing, visualization, progressive muscle relaxation, meditation, and guided imagery, used to invoke the relaxation response of the autonomic nervous system. It is frequently used to treat anxiety, stress, and musculoskeletal pain (Atterbury 1984; Kirschneck et al. 2013; Appukuttan 2016).

5.6 Conclusion

The question is not whether a patient is using a CAM practice or taking food supplements, but rather which practices are they using and which supplements are they taking. The botanicals in particular may have significant negative effects on the care the dental provider is going to provide. It is imperative that a thorough heath history

is accomplished and specifically inquiring about food supplements. Many of the CAM techniques available may be used to enhance overall health especially in the area of chronic pain management.

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Medicolegal and Ethical Considerations in Oral Surgery by the General Dentist

6

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"Watson here will tell you that I never can resist a touch of the dramatic."

—The Naval Treaty

Abstract

Medicolegal and ethics issues that face the general dentist in their practice of oral surgery frequently overlap with those issues faced throughout the practice of general dentistry. Given that overlap, this chapter discusses medicolegal and ethical issues in two broad ways: first, those issues that are traditional medicolegal or ethical issues across practice areas that have special implications regarding oral surgery in the practice of general dentistry and second, those emerging issues related to technology and to the regulatory environment that, while in some less specific to the oral surgery context, are nonetheless apt because of their changing nature. In the first half of this chapter, we consider those traditional issues with special implications for oral surgery in the general dentistry practice. These include informed consent, standard of care, and scope of practice. The second half of the chapter explores the current regulatory environment, the medicolegal implications of new technologies, and the interplay between technology and compliance. This consists of discussions around opioid analgesic prescribing, HIPAA and HITECH compliance, electronic health records, and

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other related privacy and security issues involving software, hardware, and the emerging Internet of Things.

6.1 Special Implications of Traditional Medicolegal and Ethical Issues

Three specific medicolegal and ethical issues are worthy of discussion in the context of oral surgery performed by the general dentist: informed consent, standard of care, and scope of practice. These three interrelated issues have broad and generalized application within all of healthcare practice, and the special implications discussed here are not exclusive to oral surgery procedures. Rather, they are noteworthy in the oral surgery context because they may have added complexity or may require additional considerations in those instances; none of the implications discussed here would hinder or harm the provider across their practice. It is apt to mention that patient knowledge and expectations have changed in the information age as patients come to providers with more information, whether from mass media, marketing, and/or online resources. These new lenses that patients bring to their interactions with providers impact the medicolegal and ethical landscape of healthcare practice.

6.1.1 Informed Consent

Informed consent is both an ethical and legal construct. With respect to ethics, "informed consent reflects respect for patient autonomy and, as mentioned above, is a process that, from a practical perspective, reduces provider liability. In either case, the essence of informed consent is "a conversation between physician and patient about a proposed treatment, alternative treatments, nontreatment, and the risks and benefits of each of these options" (Whitney et al. 2004). Informed consent is also significantly impacted by the new knowledge and expectations that patients bring to their relationships with providers in the information age. However, the fundamental informed consent process, and it is a process—not a form or a signature, is not altered by patient knowledge or expectations, nor does it vary in premise from one type of procedure to the next.

Broadly, informed consent involves the communication between patients and their care providers about treatments, treatment options, and treatment decisions. The primary goal of the informed consent process is to make sure that patients fully understand the procedures that will be performed (and/or the care that will be provided). A full understanding requires understanding the expected benefits and risks and any alternatives to the proposed procedure that may be available; the opportunity to discuss their treatment choice, to ask questions, and to reflect on the decision; and, finally, to provide a clear indication of their ultimate decision free from coercion or pressure (Mukherjee et al. 2017). All of these elements, together, indicate informed consent.

Despite its critical importance in providing high-quality, safe healthcare that is patient-centered, the informed consent process in practice is very often insufficient. This is a high-risk inadequacy on many levels, as failure to obtain adequate informed consent is not only an ethical conflict because it compromises patient autonomy but it places patient safety at risk and could constitute negligence or even battery from a legal perspective.

6.1.1.1 Fundamental Elements of Informed Consent

Informed consent should include five basic elements: decisional capacity, information, understanding, voluntarism, and a final decision by the patient (Mukherjee et al. 2017).

Decisional Capacity: Patients must be able to participate in all aspects of the informed consent process in a complete and meaningful way. This includes both the legal maturity and cognitive ability necessary to understand the information the dentist provides and to make a reasonable and independent decision based on the way that information interacts with their own values and beliefs. Put simply, a patient must be able to understand, deliberate, and communicate about the issues related to the proposed treatment.

Information: The knowledge a patient needs in order to make an informed decision about the management of their dental problems includes information about the nature of the problems and the proposed treatment by the dentist. The nature of the proposed treatment should include both the benefits of the treatment and the risks associated with it. In addition, patients must have information related to the risks and benefits of alternative treatments, if available, and of nontreatment. One way to ensure that all appropriate information is discussed is the acronym BARN: B—benefits, A—alternatives, R—risks, and N—no treatment.

As mentioned earlier, in the information age, patients will often have conducted their own research prior to a final decision. That research can be both an advantage in helping the patient understand their problem and the treatment options and a challenge for the provider who may need to help a patient make sense of incomplete or inaccurate information that they have found in their own search. In either case, the patient should be heard with respect to their own research and the dentist should take seriously their response to that information.

Understanding: Merely having information is not sufficient for informed consent. Patients must comprehend the information for consent to be valid. Active conversation between the dentist and patient is needed to ensure and assess understanding. This includes clarifying issues for the patient, answering their questions, and verifying, through the conversation, that they have an understanding of the information provided and discussed.

Voluntarism: Ensuring voluntariness protects the participant's right to make his or her own decisions. A consent decision should not be coerced or manipulated either by the dentist or by family members. Nevertheless, if the dentist thinks that the course chosen by the patient will do more harm than good to the patient, the dentist should communicate his or her concerns and reasons in an attempt to

persuade the patient to reconsider. If the dentist knowingly fails to do so, it is a violation of the ethical principle of beneficence.

Final Decision: To complete the act of giving consent, it is essential that the patient make a final decision. While the final decision does not necessarily need to be communicated in writing, it should always be documented in writing by the dentist. With increased risks and complexities, comes an increased advantage to capturing the final decision in writing that is signed by the patient.

6.1.1.2 Additional Aspects of Informed Consent

The fundamental elements of informed consent have nuanced aspects when the process is put into practice and in the application to dental medicine in particular.

Treatment Planning: Dental medicine often carves out two additional elements from the five basic elements of the informed consent process related to treatment planning. With respect to "information," dentists should ensure that the proposed treatment plan is clear to the patient. Regarding the "final decision," the patient must then authorize the treatment plan.

Waiver of Informed Consent: Patients have both the right to be informed prior to consenting to treatment and the right to refuse treatment, with limited exceptions. Two circumstances may arise that place the dentist in a difficult situation with respect to those patient rights.

Rights are inherently waivable—think, for example, of the right to free speech which does not require speech but protects the right to it. Individuals may, then, choose not to exercise a right. If a patient says "I don't need any more information and I don't care what the risks are, Doc…I am going to do whatever you suggest," it places the dentist in a tricky position. While it has been long held that patients may decline the information while retaining the right to decide to undergo treatment (Meisel 1979), it should be carefully documented when a patient does so and it is prudent to inform the patient that they have the right to know the risks, benefits, and alternatives before making a decision.

"Informed Refusal": The other challenge to informed consent arises when a patient decides to refuse treatment while declining to be informed. A theory of "informed refusal" has been articulated in some instances, which would require patients to have the same information required to consent to treatment before declining. However, similarly to declining information and giving consent, one can decline information and decline treatment—for example, "No matter what you say, Doc, I will not have surgery." In such instances, it is still important for the waiver and the refusal to be documented and prudent for the dentist to clearly inform the patient that they have a right to the information before deciding against treatment (Ridley 2001).

It is also worth noting that informed consent, as a process that may span multiple visits, may involve multiple conversations over an extended period of time. This is particularly true as the circumstances and/or treatment options change. Take the extraction of a third molar as an example. A patient may indicate that they will not

consent to the prophylactic removal of the third molar or molars and decline to hear the benefits of such removal. Over time and at subsequent visits, the dentist may revisit the discussion and the patient may decide to hear more information. If the condition of the patient changes over time—such as the emergence of evidence of disease in the third molars—the revisited conversation now becomes obligatory, not optional (Gray et al. 2017). In either case, the continued conversations and the patient's responses should be documented appropriately.

6.1.1.3 Informed Consent and Oral Surgical Procedures

While informed consent always has the same underlying framework and elements, certain aspects of informed consent merit additional discussion in the context of oral surgery procedures, especially when performed by the general dentist.

First, oral surgery procedures likely have some inherent increased risks and complexities that may impact certain aspects of the consent process. Decisional capacity and voluntarism are particularly impacted by the nature of the procedure being proposed. A patient with decreased cognitive ability (e.g., a mildly intellectually disabled patient) may be able to understand and have decisional capacity with respect to tooth cleaning and polishing, but may not have the decisional capacity to provide informed consent to the extraction of multiple teeth. Similarly, issues may arise when the stressors around higher risk procedures create an undue pressure that can undermine the voluntariness of a patient's consent (Roberts 2002).

When engaging in the consent process for more complex or anxiety-inducing procedures—like oral surgical procedures—the dentist must take additional time to ensure that patients are not under duress in making their decision and that they maintain the capacity to decide, despite the complexity of the procedure. In addition, the amount of information necessary for a less routine procedure increases with the complexity. Thus, the information that must be provided for a restorative procedure may be more than needed to gain valid consent for prophylactic care but less than necessary for a surgical extraction or implant.

Coupled with the increased risks of the procedures are increased potential for malpractice claims resulting from adverse procedural outcomes and complications. While informed consent is and should always be equally important from an ethical perspective, when the risk of legal liability increases, the *legal* importance of appropriate and documented informed consent increases, as well.

General dentists benefit from their ongoing relationships with patients when helping a patient navigate the decision-making process, values, and care preferences. In the context of performing a surgical procedure, however, where the risks or complexity are increased, care must be taken not to gloss over or rush through the informed consent process, relying on the inferred consent from the ongoing relationship. The historical treatment patterns, especially with respect to lower risk and less complex treatments, may help the general dentist interpret the patient's questions or reactions but should not impact the nature and extent of the informed consent process for the more complicated surgical procedure on the whole.

6.1.2 Standard of Care and Scope of Practice

Standard of care and scope of practice are inextricably linked, especially at the intersection of the generalist and the specialist. Whether the standard of care, defined as the "duty of a [dentist] to use the care and skill ordinarily used by reputable members of the profession practicing under similar circumstances" (Dym 2012), can be met by the generalist in performing a procedure is one of the primary considerations in determining the appropriate scope of practice for the generalist. Along with informed consent, discussed earlier, standard of care and scope of practice form an interrelated triad of which at least one component provides the basis of the vast majority of malpractice claims.

6.1.2.1 Standard of Care

Perhaps the most significant legal consideration with respect to standard of care when the general dentist practices oral surgery is the consistency with the standard of care for the same procedure performed by the oral surgeon. The standard of care is not simply "doing it the way [you] were taught in dental school, doing it the best [you] can, or doing it the way everyone else is doing it" (Graskemper 2004). The standard of care is also not static. It evolves with new materials, procedures, and legal decisions.

The phrase "reputable members of the profession" that forms the basis of the definition of the standard of care refers to the profession of dental medicine (or even of medicine beyond oral medicine, in some cases related to surgical procedures). That is to say, regardless of whether a procedure is performed by a specialist or a general dentist, the standard of care does not change. Additionally, "reputable members" does not merely mean "everybody else," but rather those professionals who have the most current training and experience, including the understanding and consideration of new materials and treatment modalities available for the instant condition.

It is notable that studies have found higher incidence of postoperative complications in certain procedures where the operator is a general dentist compared with oral surgeons. Moreover, in either the case of the general dentist or the oral surgeons, the extent of experience of the operator was inversely correlated to the incidence of complications—greater experience resulted in fewer incidents (Bui et al. 2003; Sisk et al. 1986).

6.1.2.2 Scope of Practice

Scope of practice can be broken into two distinct aspects: professional scope of practice and legal scope of practice. Professional scope of practice is often referred to as professional competence and in healthcare it is rooted in the way the specific healthcare profession itself defines the type and extent of care that members of that profession are trained to provide. Legal scope of practice emerges from the statutory and regulatory definitions and limitations of the care that may legally be provided by licensed practitioners. The dental practice acts of each state are the basis for the legal scope of practice in each state. Legal scope of practice and professional

competence have significant overlap; however, the legal limitations in the practice acts vary from state to state, and while, for example, dental hygiene programs may instruct hygienists in anesthesia administration, the dental practice acts of many states do not include anesthesia within the scope of the practice of hygienists (Dower et al. 2013).

The professional scope of practice of dentistry has been defined by the American Dental Association as "the evaluation, diagnosis, prevention and/or treatment (nonsurgical, surgical or related procedures) of diseases, disorders and/or conditions of the oral cavity, maxillofacial area and/or the adjacent and associated structures and their impact on the human body; provided by a dentist, within the scope of his/her education, training and experience" (Passi and Bhalla 2012). This broad definition leaves a great deal of space for the general dentist, with the requisite education, training, and experience, to engage in a broad dental practice that includes surgical procedures. Clearly, though, the primary limitation is the sufficiency of the individual dentist's education, training, and experience to perform particular procedures.

Most states do not limit the scope of practice of dental medicine significantly from the definition of professional competency. This makes it incumbent upon the general dentist to appropriately limit the scope of their own practice. The most important consideration is the need for the general dentist to ensure competency in the procedures that are performed in their practice. Therefore, when considering surgery in the general dental office, case selection is of vital importance, continuous professional learning and development with respect to the procedures to be performed is required, and considerations of practical experiences necessary when deciding whether to perform a surgical procedure (Lam 2014). The general dentist performing surgical procedures must be keenly aware of when they have reached the bounds of their skills, training, and abilities and make sure that they refer cases out that exceed those limitations.

Emergence of Mid-level Providers: In recent years, there has been a marked increase in the authorization of mid-level providers in dental medicine practice. Indeed, exploring the expansion of these types of providers in dentistry has support from many deans of US dental schools, and the existence of these providers in other countries has become more widely accepted and valued (Aksu et al. 2013; Koppelman 2017). Whether called advanced dental hygiene practitioners (ADHP), advanced dental therapists (ADT), or other titles created in enabling legislation, like mid-level providers in medicine (advanced practice registered nurses, physician assistants, etc.), mid-level providers have the potential to impact the way dentistry is practiced.

Though the primary aim of the movement for mid-level dental practitioners is to expand access to dental care, particularly in high-need areas, the eventual inclusion of those providers in traditional dental practices may be likely. This is a relevant consideration in the context of the scope of practice of the general dentist as the inclusion of mid-level providers within a general dental practice may provide opportunities for the general dentist to focus on more complicated restorative procedures or oral surgical procedures including extractions or implants (Evans et al. 2007).

This is both an opportunity for the general dentist's scope of practice and a risk. The elements of competency do not change merely because there are now providers who address the lower risk and less complex patients. Dentists should be careful not to assume that the addition of a mid-level provider to their practice necessarily makes them competent to expand their own scope of practice. That said, there is increased potential for the dentist to gain more experience and increase participation in continuing professional development opportunities regarding the performance of more complex procedures and surgeries if they have additional time available where revenue continues to be generated by the mid-level practitioner. Such additional experience and training may facilitate the expanded scope of practice at a competent level by the general dentist.

6.1.2.3 Risk Management

Ensuring a complete informed consent process, practicing at the standard of care, and engaging in the appropriate scope of practice are all essential to an ethical practice of dental medicine and to ensure the highest level of patient care. On an additional practical note, these three concepts are also crucial components of a liability risk reduction strategy.

In some respects that have been discussed, especially regarding standard of care and scope of practice, general dentists may face slightly elevated liability risks when they perform surgical procedures. However, one area where the general dentist often has a distinct advantage is in the doctor-patient relationship. Patients often see an oral surgeon only for the consultation, the procedure, and the follow-up, and the nature of the practice provides little time for relationship and rapport building (Holmes and Udey 2008). The general dentist tends to have a more comprehensive, longer-term relationship with patients than the oral surgeon, and that relationship may, in itself, serve as a mitigating factor in a patient decision to pursue legal action in the face of an adverse outcome. In addition, the persistent relationships that general dentists typically have with patients give them a "prior understanding of a patient's values and preferences" (Moskop 2006) that supports key aspects of the consent process.

Relying on the existing doctor-patient relationship alone to mitigate the risk of liability or to serve as a primary basis for consent is not sufficient. Moreover, to maintain the best doctor-patient relationships and to ensure an overall ethical practice, the general dentist should engage in a comprehensive, procedure-specific informed consent process, adhere to the appropriate standards of care, and ensure the scope of their practice remains consistent with their training, skills, experience level, and abilities.

6.2 The Regulatory Environment, Compliance, and Technology

On the other side of the medicolegal page, dentists must be aware of the regulatory environment that is designed to protect the privacy and safety of patients. There are practice-based compliance issues that arise in that context and there are

also unexpected considerations that emerge from the use of new technologies in the dental practice. Some elements of the regulatory environment relate directly to patient care and safety, such as those involving opioid analgesic prescribing while others involve compliance with standards to protect the privacy of patient information. The regulatory environment is constantly reacting, albeit often slowly, to research, public health issues, and the advent of new treatments and technologies.

Bridging the span between ethical practice issues and the regulatory environment is the prescription of opioid analgesics by dentists. This is of particular interest in this chapter because the highest rates and greatest increases in rates over time of prescribing opioids in dental practice have been following surgical, root canal, and implant procedures (Steinmetz et al. 2017).

The requirements of the HIPAA and the HITECH Act, as well as specific regulatory rules associated with their enactment, create a compliance structure that impacts all healthcare providers and agencies. The provisions of the HITECH Act are integrated into the HIPAA compliance framework. That integration, along with a flow of almost constant technological advances, poses new challenges related to patient privacy and adherence to legal mandates. Some of the technological advances have specific implications with respect to the expansion of oral surgery in the general dentistry practice and some of the advances apply broadly to all dental practice areas.

6.2.1 Opioid Analgesic Prescribing

Dental providers have developed prescribing practices and beliefs around the management of acute dental pain that have unintentionally contributed to the prescription opioid epidemic. This necessitates a reexamination of those reflexive treatment habits and consideration of the evidence from a fresh perspective regarding dental pain management. Specifically, approaches should be adjusted where alternative pain management options exist that may be as or more effective than opioid analgesics, with less potential for misuse. From an ethical perspective, this ensures that dental providers "do no harm in the doctor-patient interaction and at the societal level" (Dionne et al. 2016).

This ethical imperative related to opioid analgesics intersects with the regulatory environment as government agencies at the state and federal levels have attempted to combat the opioid epidemic, as well. Two key statutory and regulatory issues have emerged from those attempts: changes to prescribing processes and dispensing limits as well as increased training for prescribers and consolidated tracking of patient opioid prescriptions.

In 2010, the Drug Enforcement Administration issued an interim final rule that revised existing regulations to "provide practitioners with the option of writing prescriptions for controlled substances electronically. The regulations will also permit pharmacies to receive, dispense, and archive these electronic prescriptions" (Drug Enforcement Administration 2010).

Along with improving care for patients, electronic prescriptions of controlled substances (EPCS) have proven to be effective tools for initiative by public health and law enforcement agencies to address diversion and misuse of opioid analgesics (Gabriel et al. 2016). As a result, many states have made the significant switch to not only permit but require electronic prescribing of controlled substances or opioid analgesics specifically (see Table 6.1 for state policy as of 2017 regarding EPCS).

Furthermore, as of 2017, at least 17 states had enacted laws limiting the duration and/or dosage of opioid prescriptions. Some states have limited initial prescriptions to as few as 3 to 5 days. Federal legislation has also been proposed that similarly limits initial prescriptions of opioids for acute pain management. These limits are evolving and the requirements vary from state to state, creating particular challenges to those providers with patient populations from multiple states.

Electronic prescribing and dosage limits have fed another correlated regulatory response to the opioid epidemic. As of 2016, every state except for Missouri had established prescription monitoring programs (PMPs). Many of these programs have been created with federal grant funding, but PMPs vary by state in the requirements placed on providers. They may range from simply registering with the PMP to mandated training for providers and/or their staff to requiring access to the PMP database when prescribing controlled substances (Deyo et al. 2017). The

Table 6.1 States with existing or pending electronic prescribing requirements (EPCS 2017)

State	Policy	Effective date
Connecticut	All controlled substances must be prescribed electronically	January 1, 2018
Illinois	All medication to be electronically prescribed	January 1, 2022
Maine	All controlled substances must be prescribed electronically	July 1, 2017
Massachusetts	All controlled substances must be prescribed electronically	[a]
Minnesota	All controlled substances must be prescribed electronically	January 1, 2011
New Jersey	All medication to be electronically prescribed	[a]
New York	All medication to be electronically prescribed	March 27, 2016
North Carolina	All controlled substances must be prescribed electronically	July 1, 2018
Oklahoma	Bill consideration, not yet proposed or passed	[b]
Pennsylvania	All controlled substances must be prescribed electronically	[a]
Rhode Island	All controlled substances must be prescribed electronically	January 1, 2020
Virginia	All controlled substances must be prescribed electronically	July 1, 2020

[a]E-prescribing legislation has been drafted and proposed in these states but has not yet passed. Effective dates are anticipated to be 1 or 2 years after passage

[b]E-prescribing legislation has been under consideration but has not yet been drafted or proposed

National Alliance for Model State Drug Laws (http://www.namsdl.org) has compiled information regarding each state's laws and has, historically, linked to specific state statutes and regulations.

Although the evidence is mixed regarding the efficacy of these approaches to the opioid epidemic (Finley et al. 2017), they nonetheless place an onus on providers to be aware of and be compliant with the statutes and regulations of their locales. Given the increased potential for consideration of opioid analgesic prescriptions by general dentists performing oral surgery procedures, it is essential for those providers to remain familiar with the latest statutory and regulatory factors associated with opioids analgesic prescribing.

6.2.2 HIPAA Compliance and Technology

Technology poses several broad (and generally relevant) areas of concern for patient privacy and HIPAA compliance. Public concerns about the disclosure of confidential health information contributed to the structuring of the Health Insurance Portability and Accountability Act (HIPAA) of 1996. Although the original intent of HIPAA was to ensure that employees could continue to receive health insurance if they left or changed jobs, the Act became a vehicle for Congress to address a variety of other healthcare matters ranging from healthcare fraud and abuse to the growing public concern over the confidentiality and security of their health information.

The HIPAA Privacy Rule and the security regulations under HIPAA protect individually identifiable health data, known as "protected health information" (PHI) in any form, written or electronic. All "covered entities" are subject to these provisions. Covered entities include all health plans, healthcare clearinghouses, and healthcare providers who transmit any health information in electronic form in connection with any healthcare transaction. Dentists and dental practices, as covered entities, must protect the confidentiality, integrity, and availability of the PHI that they create, store, maintain, or transmit. With respect to HIPAA compliance, *confidentiality* means ensuring the privacy of the information, *integrity* means ensuring the information is not altered or destroyed improperly, and *availability* means that the information is accessible to and usable by authorized individuals.

Integrity, confidentiality, and availability, as required under HIPAA must be addressed from all of three different perspective: administrative, physical, and technical. Policies must be in place administratively to ensure that PHI is accurately maintained and accessible only to the proper individuals. Physical measures must be practices to prevent the physical theft or loss of devices that contain PHI and other sensitive data. Technical processes must be utilized to protect devices and networks from unauthorized access and breaches (Rinehart-Thompson and Reynolds 2012; Brown 2005; Davis and Having 2006; McGowan et al. 2012). Nearly every function of a dental practice is impacted and covered by these requirements: policies, recordkeeping, technology, and building safety. Under HIPAA, the protection of patient data is a pervasive and comprehensive organizational responsibility.

In addition to the protection of the confidentiality, integrity, and availability of PHI, compliance with HIPAA privacy and security rules requires:

1. Practices to maintain a Notice of Privacy Practices, which is a confidentiality statement posted in a prominent place in their office and, if applicable, on the website of the practice
2. Patients to consent to the release of their health information, as necessary, to conduct the business of the practice
3. Staff to be trained and periodically updated about confidentiality rules and regulations

HIPAA has been effective in raising awareness and sensitivity to patient privacy concerns. Virtually all healthcare organizations and providers have faced the initial compliance responsibilities under HIPAA (Brown 2005; Davis and Having 2006). The challenge that is most pressing now is related to the pervasive use of technology and the constant emergence of new technologies in healthcare practices and the expanding and less "obvious" business associates who interact with covered entities.

Business Associates: Covered entities, like dental practices, have many interactions with other entities, organizations, and/or individuals who they share PHI with for nonclinical functions, like billing and claims processing or information technology services—which we will discuss further. Whether or not these other entities are themselves required to be HIPAA-compliant for their own core business function, as business associates of the dental practice (or other covered entity), they must agree to be compliant with HIPAA on behalf of that practice. In order to comply with these provisions of HIPAA, a practice must enter into a direct "business associate agreement" (BAA) with each entity that creates, receives, maintains, or transmits PHI on their behalf. This means that it is not enough that the entity states or guarantees that they are "HIPAA-compliant." The US Department of Health and Human Services provides detailed guidance on the requirements (Services USDoHH 2017) of and for the direct BAAs that practices must have with those entities.

The HITECH Act: Since HIPAA passed into law in 1996, the United States and the world have seen year-over-year exponential growth in Internet usage and the explosion of the information age. For perspective, according to the US Census, fewer than 18% of US households had Internet access when HIPAA was passed, compared with more than 85% by 2015, and "Google.com" was not even registered as a domain until 1997 (Newburger 2001). As a result, HIPAA did not originally contemplate the emerging health information technology (HIT) opportunities and risks.

The Health Information Technology for Economic and Clinical Health Act of 2009 (HITECH) was a sweeping "commitment to digitizing the U.S. health [care] system" (Blumenthal 2011). The two underlying motivations for passing the HITECH Act were the potential that HIT could improve health and healthcare outcomes and that major systemic inhibitors would likely have impacted the spread of HIT in ways that only government remedies could overcome. Two of the most significant barriers were the economics of digitization and concerns over security

and privacy. HITECH set aside billions of dollars to support movement toward the universal adoption and "meaningful use" of electronic health records (EHRs) and other HIT across the healthcare sector and amended HIPAA to address the management of privacy and security in the digitization of PHI, including increased penalties for violations.

Whether outsourced or internal, HIPAA and the HITECH Act provisions require providers to formally designate a security officer who is responsible for managing systems users and technologies. The security officer also identifies security weaknesses and threats and makes risk assessments related to those threats, ultimately addressing any security concerns of the organization (Office of the National Coordinator for Health Information Technology 2015a).

Audit Trails: The HITECH Act added a requirement to HIPAA for audit trails of electronic information. Regardless of the type of security measures used to protect electronic PHI and other sensitive data, a comprehensive audit trail system must also be in place. Audit trails are defined as "record[s] that show[s] who has accessed a computer system, when it was accessed, and what operations were performed" (Rinehart-Thompson and Reynolds 2012). These trails allow systems activity to be reviewed in the course of a security audit and, in particular, "precisely monitor who had access to patient information," what information was viewed, for how long, and from what computer, among other details.

Cyberattack Threats: Audit trails are a powerful way to detect and respond to the threat of cyberattacks. HIPAA and the integrated HITECH security requirements require covered entities to secure PHI from such threats. Internal or external users can hack, manipulate, or destroy data—including PHI—so all users of technology in a practice must be included in security measures and provided with ongoing educational programs regarding appropriate use and threats. Hacking can best be defended through security measures like firewalls, intrusion detection software, and antivirus software. These measures may protect data integrity and digital threats coming into the system. However, phishing and other schemes are another way that malicious users can attack systems.

Phishing is a "form of fraud in which an attacker masquerades as a reputable entity or person in email or other communication channels… to distribute malicious links or attachments that can perform a variety of functions, including the extraction of log-in credentials or account information from victims" (Rouse 2017). While phishing can move into more technical methods of extracting security-breaching information from victims, they are frequently more direct acts of trickery that cause victims to simply provide the credentials necessary for the attacker to access the secure system.

The best defense against phishing and similar schemes is the education of all employees and secure system users. Users should be educated about how to identify suspicious contacts and never to share their credentials to secure systems with any other user or entity, even if it looks legitimate. If voice calls are received and requests are made for log-in information and/or other usernames or passwords from "technical support" or other official seeming "vendors" or individuals, such information should never be provided. Rather, the contact

information of the caller should be taken and provided to the practice's HIPAA security officer. That individual can then follow up directly with the purported vendor to determine if there is a valid request for system access for an approved reason.

Similarly, links in emails from outside entities or that may even seem to come from internal individuals or requests in such emails should not be responded to. Rather, such requests or suspicious links should be forwarded to the security officer for assessment. Staff should be warned that emails may seem to come from an internal person and may even appear to have internal (or official-looking external—e.g., FBI, IRS, or HHS) logos and email addresses but should still not be responded to.

Smaller, low-profile healthcare providers may believe that they are safe from the threat because cyberattackers will generally target only the largest organizations. However, every day, there are cyberattacks in the forms of hacking and phishing that specifically target small- and mid-sized organizations. Smaller organizations have been targeted—and successfully attacked—for the very reason that they are less likely to be fully or effectively protecting themselves (Office of the National Coordinator for Health Information Technology 2015b).

6.2.2.1 Electronic Health Records

According to the American Dental Association, most dental practices are not obligated, by law, to adopt an EHR. A small number of states have added dentists to their EHR mandates (beginning with Minnesota in 2015), and while HITECH mandated the adoption of EHR by virtually all medical practices, only those dentists who are Medicare-eligible are compelled by the federal law to shift to EHRs. Voluntary adoption, however, can improve quality and patient safety by building in protocols and reminders as well as enhancing the quality of documentation and the accuracy of recordkeeping; reducing paperwork and paper storage issues; improving office efficiency with respect to scheduling, billing, and reimbursement; and addressing the e-prescribing options and/or requirements discussed earlier (Foisey 2016).

Voluntary adoption of an EHR by a dental practice would still trigger the privacy, security, and compliance requirements associated with the implementation of an EHR by those providers otherwise mandated under HITECH (Fernández-Alemán et al. 2013). These compliance matters are not significantly different from the protection and securing of any forms of electronic PHI, including, for example, stand-alone billing systems. The voluntary adoption of an EHR by dentists also has patient information security advantages.

One benefit to the adoption of an EHR is the inclusion of secure online patient communication options. The current environment of online accessibility for consumers broadly has led patients to develop expectations of online communications with healthcare providers. As explained in the next section of this chapter, email and text are not generally secure mechanisms to communicate with patients, particularly when communicating about PHI. The communication modules of EHR systems offer a secure alternative.

The "carrot" contained in the HITECH Act to promote adoption of the EHR is a financial incentive related to Medicare reimbursements. In order to qualify, providers must not only adopt an EHR but also demonstrate "meaningful use" of the EHR. Essentially, meaningful use means that the EHR is used to improve the delivery of care. The most consequential opportunity for meaningful use is the inclusion of clinical decision support systems (CDSS). CDSSs can provide general references regarding a condition or, potentially, specific suggestions that take into account a patient's individual clinical data. This includes the integration of evidence-based decisional factors (Menachemi and Collum 2011; Berner 2009).

Such a system, integrated with the EHR, has the potential to ensure that the appropriate standard of care is met, as discussed earlier in this chapter. Moreover, individualized information that connects a specific patient's clinical data to the research-based treatment guidelines that is readily available within the CDSS that is integrated into the EHR can also support the informed consent process and the adequacy and accuracy of treatment information provided to the patient.

6.2.2.2 Electronic and Mobile Communication, the "Cloud," and Compliance

The ubiquity and relative convenience of electronic communication has led to an increasing number of patients to expect to be able to communicate with their providers using electronic communication methods. Deciding what and how to securely and competently integrate electronic communications into the doctor-patient relationship is a more complicated decision than it may seem on its face. Furthermore, both electronic communication and mass data storage now take place, at least in part, in an increasingly virtual space—where physical servers are not located on-site for organizations. More and more data and applications are hosted in the "Cloud" which raises privacy, security, and compliance issues in its own way. Indeed, many EHRs utilize Cloud-based applications and data storage. This increased reliance on virtual environments has challenges but also affords the potential for enhanced data integrity and comprehensive, failure-resistant data backup solutions.

Email: In any discussion about communication with patients and patient privacy, it is essential to clarify that the obligations are not bilateral. Rather, providers and their associates are required to ensure privacy and confidentiality in their communications with patients, but patients may communicate however they wish and through whatever channels they wish. It is *never* a HIPAA violation when a patient communicates with a provider about her or his own care—regardless of whether it is in the grocery store, on Facebook, or through telephone, email, or text message. It is the providers' initiation of communication and responses to patients that must comply with ethical and regulatory standards and the handling of any information *received* from the patient that is also protected—once it has been received by the provider.

The HIPAA Security Rule requires that when a provider sends PHI to a patient, it is sent through a secure method. The provider must have a reasonable belief that it will be delivered to the intended recipient. With increasing demands for online

access and near real-time communications from patients, providers must be careful to use communications mechanisms that allow for the appropriate security rule safeguards. This can include things like an email system that encrypts messages or requires patient log-in, such as the patient portal integrated into an EHR.

In order to comply with HIPAA regarding email communication with patients, three elements must be in place. First, there must be strong security. This includes secure email sending that is encrypted when PHI is included, the automatic scanning of outbound emails for sensitive data, and appropriate email use policies. Second, the HIPAA Omnibus Final Rule released March 18, 2013, requires that patients consent to communications via email after being provided with information about the risks related to sending PHI through email prior. Finally, there must be a business associate agreement with any third-party email provider (e.g., Gmail, Microsoft, Yahoo, or any Internet hosting company used) (Menachemi et al. 2011; Murray et al. 2011). To be clear, this means that a provider may not simply start using a Gmail email address to communicate with patients via email. While Gmail offers secure email options that meet HIPAA standards, and even after patient consent, a BAA is still required to be specifically signed by Google for your own practice prior to using a Gmail account for patient communication.

Text Messaging: Similar to email communication consideration is text messaging. Texting and emailing, because of the expanded use of multifunctional mobile devices, are extremely commonplace. Text messaging, like all communication technologies, needs to be managed appropriately with assurances of both security and privacy of the information transmitted and stored.

One of the considerations with respect to text messages is that they may reside on mobile devices indefinitely and, due to theft, loss, or device exchange, the information can be exposed to unauthorized third parties at various points in the lifecycle of a device. Depending on the security measures set up on the mobile device, the text messages may be accessible without any level of authentication. This means that, for example, if a secure passcode is not set up, anyone who has access to the device may have access to all of the text messages that are on the device at that time.

Another complication of text messaging is the HIPAA privacy rule provision that gives individuals the right to access and amend PHI about themselves that is maintained in a "designated record set." The designated record set includes PHI "used, in whole or in part, by or for the covered entity to make decisions about individuals" (HIPAA 2018). This means that if a dental assistant in the office sends the dentist a text message that Ms. Smith is still experiencing pain the day after a procedure and asking whether to refill Ms. Smith's prescription, for example, that text message may be subject to the right of access and amendment. If the practice cannot later provide Ms. Smith with access to the text message, there is a risk of noncompliance with the privacy rule.

Security controls that may mitigate the risks of noncompliance associated with texting include administrative policies prohibiting texting of PHI or placing limits on the type of information that may be shared via text message (e.g., information identifying a patient), training on appropriate and approved use of work-related

texting, employing mobile device security measures (as described later in this section), implementing policies that require annotation of the patient record with any PHI that is received via text and used to make a decision about a patient, or using alternative technology, such as a vendor-supplied secure messaging applications.

One interesting and important difference between text messaging and email or other online methods of communication is the way that the US Department of Health and Human Services has classified telecommunications providers, because telecommunications providers are "entities acting only as conduits of ePHI and that do not access the information other than on a random or infrequent basis as necessary for the performance of the transportation service do not qualify as business associates" and, thus, do not require a business associate agreement with the covered entity to be HIPAA-compliant (Greene 2012; Office for Civil Rights 2006).

While both text messaging and email may be convenient forms of communication with or regarding patients, it is imperative to avoid online or electronic communication unless the communication method meets, or is exempt from, the HIPAA Security Rule.

Mobile Devices: With the increased power and presence of mobile devices for computing purposes, including and beyond the messaging and email use discussed earlier, providers' and other staff have an increasing likelihood of accessing, maintaining, transmitting, or receiving PHI on business-issued or personal mobile devices. Precautions must be taken to secure those devices, which are easily lost or stolen, leaving the potential for exposures of PHI and breaches of patient privacy requirements. The Centers for Medicare and Medicaid Services have provided a list of 11 steps that can be taken to secure health information on mobile devices (see Fig. 6.1).

The "Cloud": In its earliest iterations, email servers and other networking servers were local to organizations. That is to say, the hardware and storage devices were physically located and under the control of the organization itself. However, for many reasons, electronic communications, data storage, and even many software applications now reside on virtual storage solutions that have come to be known, collectively, as the "Cloud." Cloud-based storage solutions include tools like Dropbox and Google Drive, and Cloud-based applications can range from standard office software like the Microsoft Office 365 suite or Google Apps to billing software up to a Cloud-based EHR.

All of the same security and privacy requirements apply to Cloud-based tools as have been discussed with respect to other local technology and resources. It is critical to note that any Cloud-based service provider used by a dental practice that has a product or tool that will have secure information or PHI within that resource must have a business associate agreement with between the practice and the Cloud-based service provider.

When using Cloud-based tools to support patient care in any way, dental practices must guarantee the security of patient data on the Cloud. This including ensuring that the Cloud platform has the needed security mechanisms in place. In addition, security in the transmission of data between the Cloud and devices that are used to

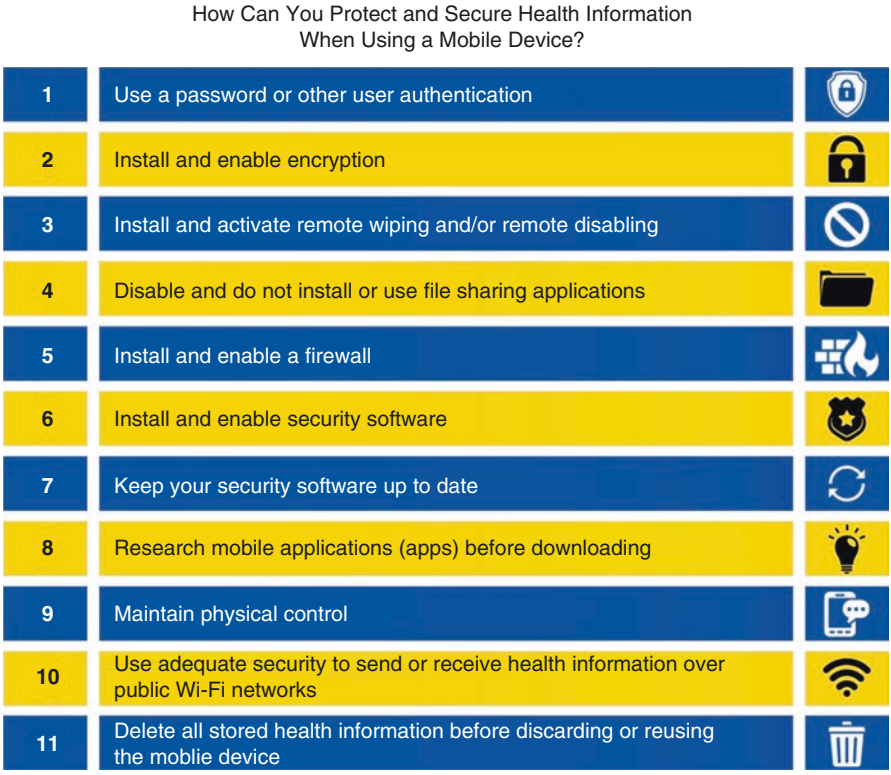

Fig. 6.1 Centers for Medicare and Medicaid Services recommendations for protecting and securing mobile devices (Medical Learning Network 2017)

access the cloud must be maintained, including appropriate network security protocols that protect against external attacks on the data (Rodrigues et al. 2013; Zhang and Liu 2010). Practices should be very selective when choosing Cloud services and have assurances that the Cloud service provider understands the sensitivity of patient data and is experienced with PHI security standards.

6.2.2.3 Technology Security and Embedded PHI

Technical issues raise some persistent HIPAA concerns in both the hardware and software spheres related to issues including security patches, upgrades, and the maintenance or expiration of support services. With respect to both software and hardware, network and Internet connectivity have created a constantly evolving threat to security ranging from vulnerability to viruses, malware, and attacks to the compromising of network systems and services. Protection from and mitigation of these threats require both diligence and state-of-the-art information and hardware security practices. Inadequate security may result in compromised confidentiality, data integrity, and data availability resulting from unauthorized, often malicious access.

Digital Images: One of the most common digital technologies in dental offices are digital imaging devices. From digital radiography to intraoral cameras, digital images abound in dental practices. For storage and management purposes, patient identification data is often included in the metadata embedded in the images. Metadata is data about other data, and images commonly have various metadata tags with the latent image information (Yee et al. 2003). Among the data that may be stored along with digital images in a dental context are patient names, billing identification information, or patient/medical record numbers. All of these can make digital images, on their own, constitute PHI, even if the image does not visibly identify the patient, either by printed name or by photographic recognition. Therefore, digital images taken, received, stored, or used in the treatment of patients should generally be considered PHI and treated with the appropriate security and privacy precautions as other PHI would be.

Clinical Devices: There are a variety of new and emerging technologies that may be utilized by any dental practice and especially when performing oral surgery in the general dentist's office. The American College of Prosthodontists has issued a position statement that describes the use of "Advanced Digital Technologies in Dentistry" with respect to digital diagnostics, design, and manufacturing. They discuss the use of medical and dental digital imaging, including computed tomography (CT), cone-beam CT (CBCT), and magnetic resonance imaging (MRI), to "develop implant planning, Orthognathic surgical planning, orthodontic planning and design of guides, maxillofacial prosthetic devices, and single and multiple tooth restorations, and dentures" (American College of Prosthodontics 2014).

The pervasion of digital dental device research is opening opportunities for "all aspects of production of dental prostheses and include customized implants, full denture construction, and orthodontic appliances. In fact anything that you might expect a dental laboratory to produce can be done digitally and potentially more consistently, quicker and at a reduced cost" (van Noort 2012). The equipment that will be used for this production will inevitably be highly connected and integrated with both the Internet and the other technology in dental offices. This means that all of the existing and emerging technologies in the dental office must be considered in the protection of private patient information and also in ensuring network and device security from breaches and attacks.

Digital Copiers and Nonclinical Devices: One of the most common examples of network-enabled nonclinical devices are the digital copiers in many dental offices. The Federal Trade Commission has described digital copiers as "today's generation of networked multifunction devices" that copy, print, scan, email, and fax. If a dental office uses digital copiers and/or similar devices, they must include those devices in their information security plans. These devices use hard drives and other memory storage components to manage jobs and increase production speeds. Most of these devices are Internet enabled and/or integrated and often unprotected. They can, therefore, become targets for information attacks.

Security of Internet-Enabled "Things": If a practice uses an Internet-enabled devices, whether clinical or nonclinical, ranging from digital copiers to radiography equipment, from lasers to 3D printers, and anything in between, it is likely that these

devices to create, receive, maintain, or transmit PHI, those devices are subject to the same HIPAA security standards and requirements as any other device in the office.

The Federal Trade Commission recommends several steps to ensure the security of digital copiers and similar devices (Commission FT 2017). These steps may also be applied when considering a privacy and security plan for other Internet-enabled clinical or nonclinical devices:

1. The same individuals in a practice who have expertise and responsibility for securing computers and servers should be responsible for securing data and network interactivity for all Internet-enabled devices.
2. All mechanisms of device connectivity should be secured appropriately, including Wi-Fi that will need to be secured like any other Wi-Fi capable devices in the practice's network.
3. All devices should be configured to comply with the practice's PHI security and privacy policies.
4. Understand and utilize data security features available either as standard equipment or as optional add-ons for connected devices. These include features like encryption and overwriting, as well as hardware passcode protection.
5. If a device is removed from an office for maintenance, treat the device the same as any other transportation of PHI, such as a laptop computer with PHI being taken out of the office.
6. Have a plan for the secure and appropriate disposal of accumulated data on devices over time; in particular, understand the lease or purchase contract provisions for ownership of hard drives and disposal of data at the end of life of the device or component.
7. Be aware that, especially in the case of leased devices, vendors may be business associates under HIPAA and require a BAA for compliance.

The Internet of Things: The US National Intelligence Council has defined the Internet of Things (IoT) as "the general idea of things, especially everyday objects, that are readable, recognizable, locatable, addressable, and controllable via the Internet - whether via RFID, wireless LAN, wide-area network, or other means" (Swan 2012). While the most familiar Internet-connected devices are computers or obviously computer-based, such as laptops, servers, smartphones, and tablets, the IoT concept encompasses far more technology-embedded tools. Even stand-alone devices often have network connectivity, and there are an increasing number of healthcare applications of sensor-based technology that shares data from wearable, ingested, installed, or injected miniature microprocessors. These "things" collect and often transmit data that could be classified as PHI and certainly will be classified as such if the devices are increasingly used to help inform treatment and treatment decisions.

Internet-enabled devices and the IoT have an almost unlimited potential to impact the future of healthcare quality and practice. However, as these technologies become more ubiquitous, it may be easier to overlook them as potential threats to patient privacy and health information security. Such technology should not be

avoided solely because of the risks, but appropriate attention should be paid to the way technology is used and secured so as to maximize the benefit to health outcomes and mitigate the risks to the PHI of patients (Swan 2012; Peppet 2014).

6.3 Closing Remarks

The medicolegal issues discussed in this chapter share a core common characteristic, to best serve the interests of patients. Whether through traditional ethical and legal practice issues, such as informed consent, standard of care, and scope of practice or through the attention to patient privacy rights in general administrative practices and use of technology, the center of these issues is and should be patients. At the same time, that attention to these important issues supports a patient-centered approach to practice, such attention has the dual benefit of reducing risks of liability for care-related outcomes and statutory and regulatory compliance violations.

It is important to note that the medicolegal issues that face dentists—and all healthcare providers—often have common characteristics that foster the types of suggestions and considerations raised by this chapter; however, laws and regulations vary from state to state and local counsel should always be sought for their familiarity with malpractice laws and the legal landscape of the particular jurisdiction. This chapter does not purport to establish, impact, or effect standards of care, nor is this chapter intended to serve as a substitute for competent legal advice on any specific issue.

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Part II

Principles of Exodontia

Local Anesthetics in Dentistry

7

Christy Lottinger

"It is, of course, a trifle; but there is nothing more important as trifles."

—The Man with the Twisted Lip

Abstract

Since the advent of their use over a hundred years ago, local anesthetics have continued to shape the field of dentistry and its specialties by providing the means with which to accomplish a multitude of procedures in an office setting without the need for a general anesthetic. In oral and maxillofacial surgery, local anesthetics have the added benefit of providing hemostasis to the surgical field, resulting in increased visualization and attenuation of blood loss. In addition, long-acting local anesthetics have become increasingly popular for the control of postoperative pain, mitigating the need for the prescription of narcotic pain medication. A variety of agents, both for topical use and for injection, are available on the market in the United States. While the mechanism of action of these local anesthetic agents is similar, each drug offers its own unique characteristics, allowing the practitioner to tailor his or her selection of local anesthetic to the needs of the patient and the demands of the procedure. The aim of this chapter will be to introduce the basic pharmacology of local anesthetic agents and to familiarize the reader with the variety of drugs currently available on the market, their unique properties, and potential risks and complications associated with their use.

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7.1 Introduction

The use of local anesthetic agents is so intimately tied to the field of dentistry that it is difficult to imagine a modern practice without them. With some exception, dentistry as a whole relies heavily on the ability to perform minimally to moderately invasive procedures on conscious patients, and it is because of this practice model that it has been so important to develop agents that are capable of controlling painful stimuli. Prior to the development of local anesthetic agents, painful procedures would require the use of general anesthetic agents, most often ether, which was developed in 1846 by a dentist by the name of W.T.G. Morton who first publicly demonstrated its effectiveness by performing a tooth extraction of a patient under its influence (Calatayud and Gonzalez 2003). However, general anesthesia carries inherent risks to the patient and can prove to be impractical, particularly in an outpatient setting.

It was not until the late 1800s when surgeons began to use cocaine as a topical analgesic for surgery and dentists began using subcutaneous injection of cocaine-containing solutions with a hypodermic needle for tooth extraction. However, the unwanted side effects of injected cocaine caused dentists to adhere solely to using cocaine as a topical anesthetic. Later, with the addition of epinephrine to cocaine-containing solutions, and the concept of nerve blockade, introduced by William Halsted and William Hall, the injection of smaller amounts of local anesthetic at distal sites was able to provide longer-lasting local anesthesia with fewer unwanted side effects. Soon thereafter, the invention of a synthetic analog of cocaine, procaine, was introduced onto the market as "Novocaine." Novocaine had fewer unwanted side effects compared to cocaine, but it was a vasodilator as opposed to a vasoconstrictor, so it spread easily away from the site of administration. The agent was subsequently combined in solution with vasoconstrictor, which counteracted its vasodilating properties, and enjoyed revolutionary success in the world of both medicine and dentistry (Calatayud and Gonzalez 2003; Nathan et al. 2016).

Further advances over the past several decades have been made in both the development of dental syringes and cartridges as well as in the development of new and different local anesthetic agents (Nathan et al. 2016). Today, the ability to provide temporary sensation loss intraoperatively without the need for general anesthetic agents provides a safe and comfortable working environment enjoyed by dentists and dental specialists everywhere. Local anesthetics are frequently used in dentistry and medicine not only as primary surgical anesthesia via infiltration or nerve blockade but combined with general anesthetics and as agents for the control of postoperative pain (Ganzberg and Kramer 2010). This chapter focuses on the basic pharmacology of local anesthetic agents, the specific drugs and their availability in dental cartridges in the United States, their selection and proper administration, as well as potential complications of their use.

7.2 Pharmacology of Local Anesthesia

7.2.1 Neurophysiology

Information throughout the body is carried by nerve fibers from one region to another in the form of electrical action potentials, which are propagated along the cell membranes of neuronal axons via transient depolarizations. These depolarizations affect the permeability of neurons to sodium ions by producing conformational changes in membrane proteins that serve as ion channels. Specifically, excitation along a nerve will disrupt the electrochemical gradient, allowing an influx of Na+ ions across the cell membrane, which is essentially impermeable to sodium ions at rest. The influx of sodium will continue until a firing threshold is reached, at which point further rapid sodium ion influx results in initiation of an impulse, or action potential. This depolarization process takes only about 0.3 ms. Afterward, the neuron undergoes a process of repolarization, whereby the cell membrane's permeability to sodium ions, and thus the resting membrane potential, is once again restored (Malamed 2013a).

Local anesthetics work by reversibly blocking ion channels along the nerve fiber, which lowers the rate of depolarization and results in failure to produce an action potential along the nerve. They bind to specific sites within sodium channels to prevent the conformational change that would allow the passage of sodium necessary to produce an action potential. When a critical length of a nerve fiber is exposed to local anesthetic, the result is conduction blockade. Myelination of a nerve fiber or an increase in the diameter of a fiber produces a greater intermodal distance, thereby increasing the critical length and decreasing the nerve fiber's sensitivity to the local anesthetic agent. It is for this reason that small, unmyelinated fibers such as those that transmit pain signals are more easily blocked by local anesthetics than large, myelinated fibers such as those of motor neurons. Because local anesthesia diffuses through a nerve bundle from the outer mantle of the axon to the inner core, the structures innervated by the outer axons will display a loss of sensation first, followed by the structures innervated by the core. This is why in the case of the inferior alveolar nerve block, loss of sensation proceeds from proximal to distal, with the lip being the last to be anesthetized. Recovery also occurs proximal to distal, with the lip being the last to regain sensation as well (Giovanitti et al. 2013).

7.2.2 Pharmacology of Clinical Agents

7.2.2.1 Local Anesthetics

Most local anesthetics used in dentistry are tertiary amines. Injected local anesthetics possess a lipophilic aromatic ring connected to a hydrophilic amino group by an intermediate hydrocarbon chain. They are classified according to their intermediate chain into ester and amide groupings. Ester-linked local anesthetics such as procaine are easily hydrolyzed in aqueous solution, whereas amide-linked local anesthetics are hydrolyzed much more slowly (Becker and Reed 2006).

Local anesthetics are available for clinical use as acid salts. After injection into the tissues, the acidic solution is buffered by the body and dissociates into an uncharged base and a cation. The degree of ionization after injection determines the anesthetic's rate of onset, as it is the uncharged base form that is able to diffuse across the nerve membrane to block an action potential. The amount of base form present after injection is dependent on the p*K*a of the local anesthetic and the pH of the tissue, with lower p*K*a values resulting in faster onset. presence of inflammation or INFECTION in the tissue results in a relative abundance of H+ molecules, which causes more of the local anesthetic to be present in its cationic form. As this form cannot readily diffuse through the nerve sheath, the onset of local anesthesia will be delayed. Once inside the nerve fiber, the drug once again is able to dissociate back to its cationic form, and it is this form that performs the sodium ion channel binding that is necessary for conduction blockade (Calatayud and Gonzalez 2003).

Duration of action of local anesthetic agents relies on their protein-binding capabilities, as sodium ion channels and binding sites are primarily protein. In addition, protein-bound local anesthetic molecules serve as a reservoir for the drug that can be made available as it is moved from the active site by uptake from local vasculature. The potency of a local anesthetic agent is dependent on its lipid solubility, which is determined by its aromatic ring. Drugs with greater lipid affinity will demonstrate greater potency (Giovanitti et al. 2013; Becker and Reed 2006).

The biotransformation of amide local anesthetics occurs primarily in the liver and therefore may be impaired in patients with severe liver dysfunction. By contrast, the biotransformation of esters occurs in the plasma by pseudocholinesterase. Therefore, patients with pseudocholinesterase deficiency will be at an increased risk for toxic effects from ester local anesthetics. However, duration of action is largely unaffected even when biotransformation is slowed, as it relies more on the redistribution effect of the drug from the site of injection into the bloodstream (Haas 2002). Articaine, although classified as an amide, does possess an ester side chain and therefore undergoes biotransformation both in the liver and by plasma esterases.

7.2.2.2 Vasoconstrictor

It is the absorption of the local anesthetic into the vasculature that removes it from the injection site and precipitates a return of clinical sensation. Of note, all clinically effective local anesthetics with the exception of cocaine work as vasodilators, which speeds this redistribution effect. At the outset of the use of local anesthesia for the performance of surgical procedures, it was suggested that a tourniquet be applied to delay the absorption of the anesthetic agent and to prolong its effect (Giovanitti et al. 2013). Today, that effect is achieved by the addition of vasoconstrictor to constrict blood vessels, which slows redistribution and prolongs anesthesia. As a result, the blood concentration of these drugs is lowered, effectively reducing their systemic toxicity, and their effects are prolonged. Vasoconstrictors also aid in providing hemostasis at the surgical site, reducing the loss of blood during surgical procedures and increasing the visibility of the surgical field.

In dental cartridges, the vasoconstrictors that are available for use in conjunction with local anesthetics are epinephrine and levonordefrin. Both these agents have similar effects both locally and systemically; however, levonordefrin is approximately 15% times less potent than epinephrine (Malamed 2013b). Their desired effect is agonism of alpha adrenergic receptors in small arterioles and capillaries, causing blood vessel constriction and consequently a reduction in local blood flow. However, they will be ultimately absorbed from the site of injection and can exert their effects on both alpha and beta agonists throughout the body. The use of vasoconstrictors in patients with cardiovascular disease remains controversial. Some investigators maintain that the risk of the use of vasoconstrictors is very small, given their seemingly minimal effects on the cardiovascular system (Cawson et al. 1983). However, there has been evidence that vasoconstrictors can produce a significant effect on stroke volume, heart rate, and both systolic and diastolic blood pressures in the same fashion that strenuous exercise might (Haas 2002; Dionne et al. 1984). Physiologic responses may include an increase in heart rate, stroke volume, blood pressure, ischemic changes, and incidence of dysrhythmias (Brown and Rhodus 2005; Goldstein et al. 1986; Mochizuki et al. 1989; Hughes et al. 1966; Ryder 1970; Hasse et al. 1986; Vanderheyden et al. 1989). However, there is incomplete data to suggest what the maximum dosage of vasoconstrictor should be in patients with cardiovascular disease (Niwa et al. 2001). While Malamed (2013c) has proposed a maximum dosage of 40 μg of epinephrine in these patients, Little (2013) has proposed no more than "one or two carpules" or 36 μg maximum dose of epinephrine if using local anesthetic solutions with 1:100,000 parts of epinephrine. Additional studies are probably needed to more clearly elucidate these guidelines. It is, however, generally accepted that small doses of vasopressor-containing local anesthetics are well tolerated in patients with cardiovascular disease (Niwa et al. 2001; Malamed 2013c; Davenport et al. 1990).

7.2.2.3 Other Dental Cartridge Components

Local anesthetic agents containing vasoconstrictors also contain an antioxidant, usually sodium bisulfite, to prolong their shelf lives. Although rare, allergy to sodium bisulfite is possible, and therefore the use of local anesthetic solutions containing sodium bisulfite is contraindicated in patients with a true sulfite allergy (not to be confused with allergy to sulfonamides or "sulfa drugs" (Haas 2002)). The standard dental cartridge will also contain distilled water for volume and sodium chloride to achieve tonicity, neither of which should be of any risk to patient (Malamed 2013d).

7.3 Topical Anesthetics

In dentistry, topical anesthetics are commonly used to improve patient comfort with injection of local anesthesia; however, they may also be used in place of injected local anesthetics to relieve discomfort from oral mucosal lesions such as aphthous ulcers or for certain dental procedures such as gingivectomy, extraction of exfoliating

deciduous teeth, placement of rubber dam clamp, or scaling and root planning. For a topical anesthetic to be effective, it must be active when applied to the mucosa, which can be achieved by both ester- and amid-type local anesthetics. Some local anesthetic agents, such as mepivacaine, articaine, and procaine, are not effective for use as topical agents, as they would require unacceptably high doses to produce topical anesthesia (Malamed 2013e; Meechan 2000). Topical anesthetics are transferred through the mucous membrane by diffusion over a period of 30 s to 2.5 min depending on site of administration, and they penetrate to a depth of 2–3 mm (Meechan 2000; Golan et al. 2012). Because their action requires diffusion across this distance, they typically require higher concentrations to achieve clinical effect than injected anesthetic agents. Additionally, they may not contain vasoconstrictors and may undergo rapid vascular uptake. Therefore, care must be taken to avoid over administration resulting in local and systemic toxicity, particularly when used in conjunction with injected local agents.

Several studies have attempted to determine whether or not the application of topical anesthetic is effective at alleviating the discomfort of local anesthetic injection. Results are equivocal but appear to vary based on site of administration and whether or not needle penetration was accompanied by the injection of local anesthetic (De Freiras et al. 2015; Nakanishi et al. 1996; Alqareer et al. 2006; Rosivack et al. 1990; Vickers and Punnia-Moorthy 1992a; Gill and Orr 1979; Keller 1985; Martin et al. 1994). Effectiveness of topical anesthesia is undoubtedly affected by proper administration. When topical anesthetic is being administered prior to injection of local anesthesia, it should be applied in small quantity to dried mucosa only at the site of needle penetration. The topical should remain in contact with the mucosa for at least 2 min to allow sufficient time for it to diffuse across the mucous membrane, thus providing anesthesia to a depth of 2–3 mm and improving pain on injection (Malamed 2013e; Meechan 2000).

The two most commonly used topical anesthetics in dentistry, lidocaine and benzocaine, are not water soluble and therefore poorly absorbed into circulation, which reduces the likelihood of toxicity (Golan et al. 2012). However, compound agents, which employ a combination of topical anesthetic agents with or without vasoactive agents, have been implicated as potentially harmful if used without caution due to their low therapeutic index, variations in composition, and difficult dosing (Kravitz 2007).

7.3.1 Benzocaine

Benzocaine is one of the most widely used topical anesthetic agents in dentistry and is available most commonly as either a spray or a gel, although gel patches, ointments, and solutions of benzocaine have also been developed. It is frequently used as either a single agent or in concert with other topical anesthetics and is available in concentrations of 10–20%. Benzocaine is an ester local anesthetic that is mostly insoluble in water and poorly absorbed into the systemic vasculature, making systemic toxicity possible but unlikely at clinically relevant levels. However,

methemoglobinemia with topical application of benzocaine has been documented, with the elderly and neonates being especially susceptible. Therefore, unmetered spray devices should be used with caution intraorally, if at all, with careful monitoring of the patient (Malamed 2013e; Kravitz 2007; Guerriero 1997; Aronson 2016). Few reports of allergic reaction have also been reported with topical use of benzocaine, with incidence of contact dermatitis being about 2% in the North American literature (Marks et al. 2000).

7.3.2 Lidocaine

Lidocaine is commonly used for topical application in both dentistry and medicine and is available in many different forms, from sprays and eye drops to gels, ointments, and patches. Lidocaine is also available in viscous solution at concentrations of 0.5%, 1%, and 2%, which are commonly used in preparations of "magic mouthwash" for symptom relief from conditions such as radiation mucositis and aphthous ulcers (Boyce et al. 2016). As a single agent ointment, lidocaine is available in either a 2% water-soluble form or a 5% base form and is commonly used by pediatric dentists in lieu of injected local anesthetic for simple procedures such as exfoliation of primary teeth. Systemic absorption is greater with the water-soluble form, and care must be taken to avoid overdose, particularly in the pediatric population (Malamed 2013e). Lidocaine is an amide, and therefore risk of allergy is very low; however, the prevalence of contact allergy to lidocaine in North America has been reported as 0.7% (Mackley et al. 2003).

7.3.3 Tetracaine Hydrochloride

Tetracaine is a long-acting ester that can be applied topically for local anesthesia. It is supplied in several forms and can be used as a topical agent on mucosal membranes such as is common for dental procedures or on the skin, for instance, to ameliorate the pain of insertion of an intravenous catheter. It is commonly encountered in dentistry compounded with other agents, such as in TAC 20 percent Alternate, which is a compound of 20% lidocaine, 4% tetracaine, and 2% phenylephrine. A similar tetracaine-containing compound originally formulated for use in soft tissue laser surgery is Profound, which contains a mixture of 10% lidocaine, 10% prilocaine, and 4% tetracaine (Kravitz 2007). It has also been developed as a nasal spray in 3% concentration compounded with oxymetazoline for the achievement of anesthesia of maxillary teeth (Malamed 2013e; Hersh et al. 2016). Tetracaine is a highly potent, water-soluble ester with a slow onset of action given relatively high p*K*a compared to many other local anesthetics (Covino 1971). It is rapidly absorbed through the mucosa and has a potential for systemic toxicity; therefore, it may not be an appropriate agent for use over large areas.

7.3.4 EMLA

Another commonly used compound topical anesthetic is EMLA (Eutectic Mixture of Local Anesthetics) cream, which is an emulsion of lidocaine and prilocaine both in concentrations of 2.5% in the form of a eutectic oil, which enhances its ability to penetrate intact skin (Fiala et al. 2016). EMLA is effective and popular for use prior to venipuncture particularly in pediatric patients but is additionally employed as a topical anesthetic agent in a variety of minor soft tissue procedures. To achieve desired results, EMLA cream should be applied to the desired site and covered with an occlusive dressing for at least 60 min, although maximum effect occurs at 2–3 h (Rogers and Ostrow 2004). Superficial dermal anesthesia lasts approximately 1 h after removal of the cream (Malamed 2013e). EMLA appears to be a potent topical anesthetic when used on oral mucosa as well, although this use remains "off-label," as the manufacturer guidelines state that EMLA is indicated for intact skin and genital mucous membranes only (Vickers and Punnia-Moorthy 1992b; Bernardi et al. 1999; Munshi et al. 2001; AstraZeneca 2013).

The use of compound topical anesthetics in general may pose a significant risk of toxicity due to their varying composition, difficult dosing, and low therapeutic index. Therefore, caution should be exercised in their use, particularly when used in conjunction with injected local anesthetic (Kravitz 2007).

7.4 Injected Local Anesthetics

7.4.1 Effectiveness and Proper Administration

A number of local anesthetic agents with varying onset, duration of action, and maximum dose are available in dental cartridges either with or without the addition of a vasoconstrictor. Therefore, the choice of anesthetic will depend upon the demands of the patient and procedure with focused attention on efficacy and safety. Currently, the anesthetic agents available in North America are lidocaine, mepivacaine, bupivacaine, articaine, and prilocaine. These are all amide-type local anesthetics that are often offered with epinephrine in concentrations of either 1:50,000, 1:100,000, or 1:200,000. Selection of a particular anesthetic is therefore important, as there are a variety of options with clinically relevant differences.

The practitioner must always remember that the time of onset and duration of a drug's anesthetic action can be affected by many factors, such as accuracy and method of administration, individual patient response, anatomic variations, and tissue conditions. Therefore, these values are reported as approximations. The practitioner must also take into account the maximum allowable dose of the anesthetic agent, which is a weight-based calculation and therefore of particular concern to clinicians who provide care to small children or frail, elderly patients. Biotransformation and distribution of local anesthetics may also be affected by liver function, plasma protein binding, and blood volume. Therefore, maximum dosages should be decreased in the medically compromised, debilitated, or elderly patient as

well as patients with significant liver dysfunction. There is no clear formula for this dosage decrease, however, and it must be determined on an individual basis. Another confounding variable often encountered in determining the maximum allowable dosage of anesthetic is the use of two or more local anesthetic agents in the same patient. When this situation is encountered, the maximum allowable dosage of anesthetic can best be determined by ensuring that the total dose of each agent not exceed the lowest maximum doses for the individual agents. Of course, using the lowest dose necessary to achieve clinical success is of paramount importance to limit the risk of side effects and toxicity (Malamed 2013f).

7.4.2 Procaine

Procaine is the first synthetic anesthetic agent, introduced in 1904 and marketed under the trade name of Novocaine. It is an ester local anesthetic that is no longer available in North America but is worth mentioning due to its historical significance and impact on the field of dentistry. Due to its high p*K*a and potent vasodilating properties, procaine has a low potency, slow onset, and short duration of action. Additionally, because procaine is an ester-type local anesthetic agent and is metabolized to para-aminobenzoic acid, it has a higher allergic potential than the amide anesthetics. Procaine has now been replaced by newer local anesthetic agents with more desirable properties and fewer potential side effects (Haas 2002).

7.4.3 Lidocaine

Lidocaine is the most widely used local anesthetic in both dentistry and medicine and the first amide local anesthetic to be marketed to clinicians as an alternative to procaine in 1943. Lidocaine has been extensively studied and is regarded as safe, reliable, and effective. As such, it remains the standard against which other local anesthetics are measured. Lidocaine is currently available in North America in two preparations, 2% with 1:100,000 epinephrine and 2% with 1:50,000 epinephrine. The 1:50,000 preparation has been shown to be of use in circumstances that warrant more significant hemostasis, such as surgical procedures, as it provides a greater attenuation of blood loss than the 1:100,000 epinephrine preparation (Buckley et al. 1984; Shorogui et al. 2008). Onset, duration of action, and maximum recommended dosages for each of the two preparations are the same. When used for local infiltration, onset of anesthesia is less than 2 min. Pulpal anesthesia can be expected for at least 1 h, and soft tissue anesthesia for approximately 2.5 h. When administered for nerve blockade, onset averages between 2 and 4 min, and pulpal and soft tissue anesthesia is extended to 90 min and approximately 3 h, respectively (Dentsply 2011). Although the American Academy of Pediatric Dentistry still recommends a maximum dosage of lidocaine with epinephrine of 4.4 mg/kg in the pediatric patient, the FDA lists a maximum dosage of 7.0 mg/kg for both adult and pediatric patients, not to exceed a maximum total dose of 500 mg (AAPD 2015).

7.4.4 Mepivacaine

Mepivacaine, which is pharmacologically similar to lidocaine, was introduced into dental cartridges in 1960 as a 2% solution containing levonordefrin. The following year, a 3% solution was introduced without the addition of vasoconstrictor (Su et al. 2014). Because of mepivacaine's less potent vasodilating properties compared to lidocaine, it does not rely as heavily on the addition of vasoconstrictor in order to provide clinically acceptable duration of anesthesia. Therefore, mepivacaine 3% without vasoconstrictor is still on the market and is used frequently in patient populations where the practitioner may wish to limit the use of vasoconstrictor. However, studies have shown that 3% mepivacaine has an inferior success rate in terms of duration and depth of anesthesia compared to lidocaine with epinephrine, whereas mepivacaine performs similarly to lidocaine when each local anesthetic is combined with vasoconstrictor (Su et al. 2014). Therefore, 3% mepivacaine plain may best be reserved for procedures that are short in duration and do not require profound pulpal anesthesia. In addition to 3% plain solutions, mepivacaine is currently available as a 2% solution with the addition of either 1:50,000 epinephrine, 1:100,000 epinephrine, or 1:20,000 levonordefrin. There is no significant difference in depth or duration of anesthesia among the different concentrations or type of vasoconstrictor. The maximum recommended dose of mepivacaine 2% with vasoconstrictor and mepivacaine 3% without vasoconstrictor is 6.6 mg/kg, with an absolute maximum dosage of 400 mg (Malamed and Yagiela 1998).

7.4.5 Bupivacaine

Bupivacaine is an amide local anesthetic agent similar to lidocaine but with a slower onset time (6–10 min) and a prolonged duration of action. It may be the anesthetic of choice for lengthy dental procedures and/or for controlling postoperative pain, as pulpal anesthesia can last anywhere from 90 to 180 min and soft tissue anesthesia from 4 to 9 h. As such, bupivacaine is not recommended in young children or in the developmentally delayed, as unintentional self-mutilation due to prolonged soft tissue anesthesia is a concern. It is routinely used, however, for postoperative pain control and if used properly can reduce or even eliminate the need for postoperative opioid analgesics, particularly if supplemented with nonsteroidal anti-inflammatory drugs. Bupivacaine is available in dental cartridges in a 0.5% solution with 1:200,000 epinephrine, and its maximum recommended dosage by the FDA is 90 g in a healthy adult patient, which is unique in that this recommended maximum dosage is not weight-based (Hospira, Inc. 2017). Of note, bupivacaine has been associated with particularly severe reactions upon accidental overdose. This is believed to be due to its increased cardiotoxicity compared to other local anesthetics due to several factors including a negative chronotropic and ionotropic effects on the heart, a decrease in coronary blood flow, potential disruption in conduction through the heart, and an inhibition of cardiovascular control at the level of the brainstem. The reason for its negative cardiac effects may be due to its increased lipid solubility

and thus ability to penetrate cell membranes (Tanz et al. 1984; Pitkanen et al. 1992; Bourne et al. 2010).

7.4.6 Articaine

Articaine has enjoyed profound popularity in the United States only recently compared to other countries such as Germany and Canada, as it has only been approved for use in the United States since 2000. Articaine is similar in structure to the other amide local anesthetics on the market except that it is the only agent with a thiophene rather than a benzene ring, which increases its liposolubility and makes it more effective at crossing lipid barriers. Articaine is also unique in that it contains an ester group, which causes it to be metabolized both in the liver and in the blood by plasma esterases. Due to its ability to diffuse quickly through both hard and soft tissues, articaine has a short onset of action (1–9 min) and reaches peak blood levels in as little as 25 min (Ogle and Mahjoubi 2011). It has also been suggested to have superior anesthetic effect compared to lidocaine on buccal infiltration, both in the maxilla and mandible (Malamed et al. 2000; Katyal 2010; Shurtz et al. 2015); however, 2% lidocaine and 4% articaine may not be significantly different in terms of onset, duration, and quality of anesthesia when used for local infiltration for minor dental procedures in the maxilla (Vahatalo et al. 1993). Adding to its attractive features, there is evidence to support that maxillary buccal infiltration with 4% articaine may be capable of achieving palatal anesthesia as well, obviating the need for additional palatal injections, which are notoriously painful (Al-Mahalawy et al. 2018).

Several studies have been conducted on the safety and efficacy of articaine as compared to lidocaine, and caution has been suggested in the use of articaine with nerve blockade owing to a possible increased risk in paresthesia compared to lidocaine. An epidemiological study by Haas and Lennon in Ontario over a 20-year period reported a 2.5-fold increased risk in paresthesia with the use of 4% articaine compared to 2% lidocaine (Haas and Lennon 1995). To further this point, data from the FDA Adverse Event Reporting System over a 10-year period was published by Garisto and Gaffen (2010), implicating articaine with significantly higher risk of paresthesia than all other available local anesthetics with exception of 4% prilocaine, thus proposing that the more concentrated formulation may contribute to neurotoxicity when used for nerve blockade. In contrast, a 2001 study by Malamed comparing the use of 4% articaine with 1:100,000 epinephrine and 2% lidocaine with 1:100,000 epinephrine in 1325 subjects failed to show a significantly higher rate of paresthesia or other clinical complications with the use of articaine (Malamed et al. 2001). However, as suggested by Hillerup et al. in a 2011 epidemiological review of neurosensory deficits associated with local anesthetic injection compared to market share, the incidence of neurosensory disturbance with local anesthetic injection is uncommon enough to render inconclusive results from prospective trials even with 1300+ participants. In this review, the authors calculated a 3.1–8.6-fold increase in risk of neurosensory deficit with the injection of 4% articaine relative to

its market share (Hillerup et al. 2011). Therefore, while the use of 4% articaine for nerve blockade has not been eradicated, it is suggested that clinicians consider avoiding its use for nerve blockade when there are viable alternatives. This caution may also be prudently applied to 4% prilocaine for similar reasons.

7.4.7 Prilocaine

Prilocaine is another amide-type local anesthetic that is available in dental cartridges. While biotransformation of all amides occurs in the liver, prilocaine is unique in that metabolism also takes place in the kidney and plasma. Of note, prilocaine has been implicated in the development of acquired methemoglobinemia through a metabolite (orthotoluidine) that inhibits the methemoglobin reductase pathways. Peak levels of methemoglobin occur 3–4 h after administration and may manifest as weakness, tachycardia, respiratory distress, nausea, and vomiting. At further increased blood concentrations of methemoglobin, lethargy and stupor can occur, and levels above 70% are often fatal if untreated. A cyanotic patient that is unresponsive to administration of supplemental oxygen as well as a chocolate-brown appearance of the blood indicates that a patient is suffering from methemoglobinemia, and this should be treated with administration of 1% methylene blue (1.5 mg/kg). The practitioner should remember that a patient with methemoglobinemia may have normal partial pressures of oxygen and that oxygen saturation as measured by pulse oximetry is falsely elevated. Though methemoglobinemia is unlikely to develop at or below the manufacturer's guidelines for maximum dosage of prilocaine with or without epinephrine (8.0 mg/kg up to 600 mg), it is relatively contraindicated in patients with a history of congenital methemoglobinemia (Kreutz and Kinni 1983; Rehman 2001).

Because prilocaine is metabolized in multiple sites, plasma levels decrease more rapidly than lidocaine and are therefore considered to produce less systemic toxicity. Prilocaine is available in dental cartridges as a 4% concentration both without epinephrine and as a solution with 1:200,000 epinephrine. The non-vasoconstrictor containing solution is popular among practitioners wishing to limit the dosage of epinephrine, as in the treatment of patients with severe cardiovascular disease.

7.5 Complications

The statistics regarding incidence of complications from administration of local anesthesia for dental procedures are not well reported on but may be anywhere from 4% to 26% and are generally transient and relatively minor (Daublander et al. 1997; Kaufman et al. 2000; Moore and Hersh 2010). A 1997 study by Daublander et al. of 2731 patients evaluated by questionnaire after receiving dental anesthesia reports only a 4.5% incidence of complication, 0.07% of which were severe adverse events (Daublander et al. 1997). It can be reasonably assumed from the prolific use of local anesthetic agents in the field of dentistry and oral surgery that they are safe, effective,

and reliable. However, the injection or administration of any drug is not without risk, and the prudent dental practitioner should be well aware of the potential adverse events as well as the appropriate strategies for their management.

7.5.1 Local Complications

7.5.1.1 Paresthesia

The most common cause of paresthesia associated with the administration of local anesthesia is with a mandibular nerve block. The incidence of trigeminal nerve injury varies wildly in the literature, although it is probably between 1:20,000 and 1:785,000 (Moore and Haas 2010). It is also believed that all but 10–15% of these patients recover full sensation over the course of a few days up to several months (Moon et al. 2012). Paresthesia may be caused from mechanical injury from the needle, pressure from edema or hematoma, or from neurotoxicity of the local anesthetic agent. As discussed previously, there may be an association with certain local anesthetic agents and higher incidence. When paresthesia does occur, a neurosensory exam should be performed and repeated at each follow-up in order to document the extent and degree of injury. Steroids and NSAIDs may be useful in treating acute nerve injury by alleviating edema around the affected nerve but do little to improve persistent paresthesia beyond 10 days after injury. Painful dysesthesias that do not resolve within 1–2 weeks after injury may be treated with tricyclic antidepressants or gabapentin, but these medications are for symptom relief only (Moon et al. 2012).

7.5.1.2 Prolonged Anesthesia and Soft Tissue Injury

Particularly in children and in the mentally disabled, prolonged soft tissue anesthesia can result in inadvertent biting of the tongue, lips, or cheek, resulting in minor to potentially severe soft tissue damage in the form of laceration, ulceration, and/or contusion. Even in the normally mentating adult, self-inflicted trauma is a complication of dental treatment under local anesthesia if care is not taken to prevent it. These injuries occur in as many as 18% of children and are more common in young children, although children 12 years and older are still at a risk of about 7% (College et al. 2000).

The treatment for soft tissue as a result of inadvertent self-mutilation is generally aimed at treating and protecting the affected soft tissue until sensation is restored. Largely, the focus is on prevention. Many practitioners, particularly as it relates to the pediatric population, argue against the use of bilateral mandibular block anesthesia as a prevention strategy for managing soft tissue injuries; however, the rate of injury has not been shown to significantly differ between patients receiving unilateral versus bilateral blocks (College et al. 2000).

Another prevention strategy to reduce the frequency of soft tissue injury after local anesthesia is the selective use of short-acting local anesthetic agents such as plain mepivacaine. Even so, soft tissue anesthesia can last several hours, leading dental practitioners to seek other options (Chi et al. 2008). Since its FDA approval

in 2008, phentolamine mesylate (OraVerse), a nonselective competitive antagonist of alpha adrenergic receptors, has been used to reverse the effect of conduction blockade and return sensation to anesthetized soft tissue. Phentolamine mesylate acts as a potent vasodilator, which enhances the clearance of local anesthesia from the site of delivery and results in a recovery of normal sensation in about 50–60% of the normal recovery time (Tavares et al. 2008; Hersh et al. 2008). OraVerse is available in standard dental cartridges as a solution with 0.4 mg phentolamine mesylate. Its recommended dosage is not weight-based; rather it is recommended to administer the same number of cartridges of OraVerse as were administered for local anesthesia, with a total dosage of 0.2 mg (1/2 carpule) maximum in children weighing between 15 and 30 kg. It is not recommended for use in children under the age of 3 or weighing less than 15 kg (OraVerse 2016).

7.5.1.3 Hematoma

Injection into an area of high vascularity can result in hematoma formation due to inadvertent damage to a nearby vessel with the needle. Most often, this occurs during injection of local anesthetic in the posterior maxillary region, as for a posterior superior alveolar nerve block, and is likely due to injury of the pterygoid plexus of veins, although injury to the posterior superior alveolar artery or its gingival branch is also possible. Hematoma formation can also be caused by inferior alveolar nerve block if the needle is directed too high (Blanton and Jeske 2003). Hematoma formation can occur rapidly after vessel injury and will result in cheek swelling on the affected side followed by several days of ecchymosis as the hematoma resolves. Although bleeding is generally self-limiting, the goals of initial treatment are to achieve hemostasis with pressure and minimize inflammation in the area by application of an ice pack. The patient should be reevaluated in 24–48 h to assess for recurrent bleeding or signs of secondary infection. Hematomas generally resolve on their own in 1–2 weeks, although the healing process is often accompanied by trismus and/or ecchymosis. The frequency of hematoma formation after injection is higher with maxillary posterior injections, but the overall incidence is around 0.1% (Kuster and Udin 1984).

7.5.1.4 Trismus

Trismus is an uncommon complication of local anesthetic injection, but it has been known to be associated with inferior alveolar nerve blocks and posterior maxillary injections. The likely etiology is intramuscular edema and hemorrhage, both of which are worsened by multiple needle passes (Stone and Kaban 1979). Hematoma and needle-track infection from contaminated needles can also cause postinjection trismus. Acute pain and inflammation are accompanied by muscle spasm, resulting in limitation in mandibular range of motion. Treatment is aimed at addressing pain and inflammation and improving range of motion, often with NSAIDs, moist heat, and physiotherapy. Movement of the jaw prevents fibrosis, which can lead to long-term hypomobility. If infection is suspected, antibiotics should be initiated early.

7.5.1.5 Ocular Complications

Diffusion of local anesthetic agents through myofascial spaces or inadvertent intravascular injection has the potential to directly affect both the motor and autonomic neurons that supply the eye, resulting in various ophthalmologic consequences. These are rare but may present as blurry vision, temporary blindness, mydriasis, ptosis, diplopia, or ophthalmoplegia. These symptoms generally occur immediately after administration of local anesthesia and are self-limiting, although visual impairment may be permanent as much as 8% of the time (Alamanos et al. 2016). Ocular complications are best prevented by aspiration prior to injection of local anesthetic and proper injection technique. If visual disturbances develop after injection, the patient should be monitored and reassessed frequently for resolution of symptoms. If symptoms do not resolve within 6 h, referral to an ophthalmologist is warranted to assess for damage to the eye and associated structures (Boynes and Echeverria 2010).

7.5.1.6 Palsy of CN VII

Palsy of the facial nerve is possible with injection of local anesthetic and most often presents immediately but can present in a delayed fashion, typically within hours to days. The common etiology is inadvertent administration into the parotid gland, as from a mandibular nerve block where the practitioner has injected too posteriorly (Cummings et al. 2011). Additional anesthetic techniques that may inadvertently anesthetize the facial nerve are auriculotemporal nerve block or intra-articular injection of local anesthetic into the temporomandibular joint space.

On clinical presentation, patients will display unilateral facial weakness on the side of injection. This can include lagophthalmos of the eye on the affected side, asymmetrical smile, and/or an inability to raise the eyebrow. Immediate palsy of the facial nerve after administration of local anesthesia is a result of direct blockade of neural conduction and should resolve within a few hours, depending on the duration of action of the local anesthetic agent. Delayed-type palsy, however, may take anywhere from 24 h to several months to fully resolve, and the etiology is not well understood. Akin to Bell's palsy, the standard treatment is systemic steroid therapy as well as proper protection and lubrication of the eye in the case of lagophthalmos (Tzermpos et al. 2012). It has been proposed that a possible etiology for delayed facial nerve palsy after local anesthesia injection is reactivation of latent herpes simplex virus. Therefore, some practitioners also elect to prescribe an antiviral medication such as acyclovir, although this remains controversial (Chevalier et al. 2010).

7.5.2 Systemic Complications

7.5.2.1 Overdose

In dentistry, the incidence of local anesthetic overdose is not well known, but severe consequences are very rare. However, the signs and symptoms of toxicity must be diligently surveilled for, particularly in young children with low body mass and in

the elderly or medically compromised patient, whom may have delayed absorption, metabolism, and excretion as well as impaired plasma protein binding. Dysfunction of the cardiovascular, hepatic, and renal systems may all increase the incidence of toxicity in different ways. Even pregnancy may predispose the patient to toxicity at lower doses, given the reduction in protein binding and more rapid absorption from higher cardiac output (Byrne and Engelbrecht 2013). The maximum dosages of local anesthetic agents provided by the manufacturer in accordance with the FDA and ADA are generally weight-based and formulated for the "average" patient. These suggested dosages do not take more specific patient considerations into account; therefore, some patients may experience signs of local anesthetic systemic toxicity at lower doses than the proposed maximum dose. Overdose of local anesthesia may occur even when local anesthesia is properly administered in appropriate amounts, but it is more likely to occur with intra-arterial injection or with dosages exceeding the recommended maximum.

In the early stage of local anesthetic toxicity, the patient may complain of tinnitus, light-headedness, and circumoral tingling. Initial cardiovascular and central nervous system response to local anesthetic toxicity is excitatory, as inhibitory neurons within the central nervous system are targeted and blocked by the systemic absorption of the drug. The signs that may be encountered in this excitatory phase are tremors, shivers, twitching, and even convulsions. Hypertension and tachycardia may also be evident, and the patient may become unusually talkative, apprehensive, agitated, or disoriented. What follows is a generalized depression phase characterized by myocardial depression, ectopic cardiac rhythms, bradycardia, and hypotension. Decreased cardiac output is accompanied by central nervous system depression resulting in drowsiness and loss of consciousness (Moore and Hersh 2010). Respiratory and circulatory collapse are the end points of severe local anesthetic overdose and present a dire situation for the patient.

Management of local anesthetic overdose will depend on the severity of the reaction and is aimed at providing support to the patient until symptoms subside or help arrives. The practitioner should administer supplemental oxygen to the patient and monitor their vital signs carefully while continuing to assess the patient's airway, breathing, and circulation. Tonic-clonic convulsions are common with overdose. If present, the patient should be placed in a supine position and protected from injuring themselves. The administration of an anticonvulsant, such as midazolam or diazepam, may be required in cases where convulsions are prolonged but are not often necessary (Cummings et al. 2011). The emergency response team should be notified early, and the principles of basic life support should be adhered to until help arrives. Maintenance of a patent airway and adequate ventilation is paramount to successful patient recovery, and if properly managed, the patient generally suffers no long-term sequelae (Malamed 2013g).

7.5.2.2 Methemoglobinemia

Methemoglobinemia is a condition that occurs when iron atoms contained within hemoglobin are oxidized from their normal ferrous form to a nonfunctional ferric form that has a much higher affinity for bound oxygen and therefore impaired

ability to release oxygen to and remove carbon dioxide from peripheral tissues (Hall et al. 2004). In dentistry, the most common causes of acquired methemoglobinemia are application of topical anesthetics such as benzocaine and the injection of prilocaine, in which peak levels of methemoglobin occur 3–4 h after administration (Rehman 2001). The degree of cyanosis is affected by the fraction of hemoglobin molecules oxidized, with signs and symptoms apparent at a methemoglobin level of 15–20%. Mental changes such as headache, fatigue, and syncope may be noted at levels of 20–30%, and physiologic signs of tachypnea, tachycardia, dysrhythmia, and seizure may be evident at concentrations above 30%. At further increased blood concentrations of methemoglobin, lethargy and stupor can occur, and levels above 70% are often fatal if untreated (Trapp and Will 2010).

A diagnosis of methemoglobinemia should be considered in a cyanotic patient that is unresponsive to administration of supplemental oxygen with unexplained decreased SpO2 despite adequate ventilation. Another hallmark feature is a chocolate-brown appearance of the arterial blood. Upon diagnosis or high suspicion, immediate treatment should be instituted in the form of 1% methylene blue 1–2 mg/kg administered over a period of 5–10 min, which can be redosed after 1 h up to a maximum of 7 mg/kg. In patients with NADPH and/or G6PD deficiencies, methylene blue is ineffective for treatment of methemoglobinemia, and alternate strategies for treatment include hyperbaric oxygen, charcoal, transfusions, or hemodialysis (Hall et al. 2004).

The practitioner should remember that a patient suffering from methemoglobinemia may display falsely elevated SpO2 readings on pulse oximetry, as pulse oximeters misinterpret fractional arterial oxygen saturation at high levels of methemoglobin. SpO2 readings will be expected to fall with rising levels of methemoglobin but only to a plateau of approximately 85%. They therefore should not be relied upon to estimate the level of methemoglobin in patients with methemoglobinemia (Barker et al. 1989).

7.5.2.3 Allergy

True allergy to local anesthetic is estimated to account for only 1% of all adverse reactions during dental anesthesia, and 80–90% of these cases are allergic contact dermatitis. Most patient-reported history of allergy to local anesthetic are actually adverse events not related to allergy and can be elucidated from a thorough medical and dental history. In patients who do report true allergy to local anesthetic agents, intracutaneous testing has been suggested as a strategy to identify safe agents that can be used in their treatment. However, intracutaneous testing has been shown to be of no value in this circumstance due to its propensity toward both false-negative and false-positive results (Tomoyasu et al. 2011). Instead, the challenge test, whereby a small amount of local anesthetic is deposited into the mucosa as the patient is monitored for adverse effects, is thought to be the best strategy to determine if an allergic response is present (Berkun et al. 2003). Challenge testing carries a risk of anaphylaxis, however, and therefore should be undergone with caution, in a setting with a proper emergency response team, and with continuous monitoring. For patients with true allergy to local anesthetics, 1% diphenhydramine has been

used as an alternative to more traditional local anesthetic agents with reportedly good success and no cross-reactivity (Pavlidakey et al. 2009).

Patients have been told they are "allergic to dental anesthetics" when instead they exhibited signs and symptoms of epinephrine sensitivity. Thus a careful history must be taken when a patient reports a local anesthesia allergy.

7.6 Summary

Local anesthetic agents represent a class of drugs that are capable of providing safe and reliable loss of sensation and control of painful stimuli, allowing for patient comfort during dental and surgical procedures without the need for general anesthesia. A variety of local anesthetic agents are available for use in multidose vials or, as is more common in dentistry, dental cartridges. While all local anesthetic agents exert their effects similarly, they each display their own unique characteristics and are therefore selected with care and special attention to the needs of the patient and the procedure. Complications associated with the administration of dental anesthesia are uncommon and almost always self-limiting, but untoward events can occur in relation to their use. As such, judicious and cautious use of any drug is the standard of care in both medicine and dentistry.

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Uncomplicated Exodontia

8

Roger S. Badwal and Andrew Emery

"Mediocrity knows nothing higher than itself: but talent instantly recognizes genius."
Sherlock Holmes in—The Valley of Fear

Abstract

Although the mission of dentistry is to save teeth, dental practitioners must be prepared to extract non-restorable dentition effectively when the need arises. This chapter will detail the equipment and techniques employed to perform simple dental extractions.

8.1 Introduction

The practice (or rather learned proficiency) of extracting teeth (aka exodontia) is a part of medicine that dates back thousands of years. Although other areas of dentistry have evolved considerably over time, the basic tenets of tooth extraction have remained relatively stable. The idea is to free the tooth from its attachments within the alveolar socket and remove it from the jaw while preserving as much bone as possible. Depending on the location and anatomy of the tooth, different instruments are more useful and desirable. In addition to performing the procedure itself, there are a number of ancillary pre-op and post-op requisites that must be done, which are discussed in this chapter.

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8.2 Preoperative Issues

Arguably the most important step of any procedure, and especially for one that is irreversible such as a dental extraction, is assuring the patient is adequately informed and the provider is suitably prepared. To do this, the correct diagnosis must be made based on collected diagnostic information, full disclosure must be provided to the patient regarding treatment options and risks/rewards, and the provider must document consent as provided by the patient, both verbally and written.

Correct Records: Preventing mistakes in dentistry starts with having the right records. Prior to extracting a tooth or performing any procedure, the dental provider must first confirm that they have the correct patient. Items used for confirming the correct patient include but are not limited to patient name, date of birth, phone number, address, and any previous patient photos on file. Medical record numbers are also helpful as an additional measure of confirmation. Additionally, emergency contact information can also be an additional security check in confirming the correct patient is being selected (Charangowda 2010).

The next step is to verify the procedure planned. This is frequently done by reviewing treatment notes from previous visits, comments from presurgical consults, and radiographs and can be further verified by conducting a brief oral exam to confirm the previous diagnostic impression. If there is a discrepancy with the patient's presentation and previous notes, adequate patient records should be taken, including a full extraoral exam, intraoral exam, radiographs, and any other records deemed necessary for each case. Part of verifying the procedure is assuring that the operator is on the correct side of the mouth and addressing the tooth of interest. Measures to reduce wrong-sided surgery include marking the correct side of the patient (e.g., on the cheek) in accordance with patient records, with a witness auditing the process to catch any potential mistakes. The correct side can also be initially confirmed by asking the patient to point to the tooth they believe they are having extracted or area of pain/concern, but it is ultimately up to the provider to use their own discretion to determine where the surgery is to be performed.

A time tested and universal methodology for preventing surgical mistakes is to take a few moments before a procedure to conduct a "time out" (Lee 2010). A "time out" involves a member of the surgical team verbally reviewing the patient's identity and surgical plan with all participants listening to screen for discrepancies and confirm the correct information for patient and procedure about to begin.

Diagnosis Based on Objective Criteria: Evidence-based decision-making is an important part of every procedure. It is not enough to merely suggest a treatment or procedure, but instead one must arrive at a decision systemically and objectively. In fact, every treatment should be tied to a proper diagnosis. To do this, it is important to use preset criteria or guidelines for determining what the diagnosis is and thus what the recommended course of treatment should be given to that diagnosis.

There are several factors or checkpoints to consider prior to extracting a tooth. Often the first step is to take a good history, which is often gleaned by asking the right questions. For example, start by determining if the tooth is painful or not. If the tooth is painful, is pain spontaneous or is the pain elicited with certain stimuli? Has

the patient noted any drainage or signs of swelling? These questions can give the clinician an idea of which type of tooth pathology the patient is presenting with.

Once a thorough history is acquired, the next step is often a clinical exam. To do this well, the provider will examine both extraorally and intraorally, making note of any pain on palpation or percussion, swellings, asymmetries, or marked erythema. The tooth itself is assessed for periodontal health via periodontal probing, assessment of mobility, and assessment of structural soundness. Specifically, one should determine the likelihood of extraction forces breaking the crown and need for more advanced surgical techniques for removal of the remaining roots. If the tooth is decayed or has been treated endodontically leading to a higher risk of crown fracture, the provider should consider the need for a surgical approach to gain better access, typically by making an incision and reflecting the soft tissue. For more information on surgical approaches to extractions, see Chap. 9 on complicated exodontia.

Following a clinical exam, radiographic assessment should be done to correlate with clinical findings. Radiographs should clearly demonstrate the tooth in question, particularly in relation to important nearby anatomy. Examples of important anatomic considerations are the shape of the roots, proximity to anatomic structures such as the maxillary sinuses and inferior alveolar nerve canal, and the quality or quantity of surrounding bone. Reviewing older radiographs and comparing to more recent ones is also valuable in creating a timeline for the tooth. It is also necessary to plan ways for replacing teeth prior to their removal in order to prepare for any socket preservation or immediate implant placement, which would be required at the time of extraction. For more information on implant treatment planning and preprosthetic considerations, see Chap. 21 on dental implants.

Once data is collected, the clinician will then take a systematic and evidenced-based approach to planning treatment. There are many reasons to extract teeth, including the following (Hupp et al. 2008):

- Teeth are diseased:
  - Caries, particularly those that extend through a significant portion of the crown.
  - Non-vital teeth.
  - Vertical root fracture or cracked tooth.
  - Periodontal compromise.
  - Treatment plan necessitates extraction (i.e., in preparation for complete denture or partial denture).
  - Pericoronitis or teeth erupting such that it compromises the health of other teeth (e.g., that which is commonly seen with erupting third molars and their effect on second molars).
  - Teeth associated with other pathology such as cysts and cancer, along fracture lines (see Chap. 9 on Complicated Exodontia for more information on advanced surgical techniques).
  - Teeth associated with fractures or part of planned resections are consequently also frequently extracted.
- Elective reasons
  - Nonsurgical orthodontic treatment for arch length discrepancies

- Impacted teeth in anticipation of future complications with that tooth or adjacent teeth
- Supernumerary teeth (e.g., mesiodens)
- Financial reasons

There are many stories of patients being treated with root canal therapy for pain associated with undiagnosed trigeminal neuralgia. There are also cases of teeth being extracted unnecessarily with radiographic suspicion of periapical abscess, but actual presence of focal or periapical cement-osseous dysplasia. Unfortunately, many pathological conditions can present similarly but often require vastly different treatment plans. As such, it is paramount to take an objective and scientific approach to working up teeth in question.

In the end, a risk-benefit conversation must be had with the patient regarding extracting a tooth and whether doing so maximizes patient benefit. Since patients have different values, this decision cannot be made without discussing with the patient the prognosis of taking out a tooth or leaving it in and the prognosis of treatment options (e.g., implant with crown vs. root canal therapy with post, core, and crown). Although the literature is refute with articles comparing root canal therapy and implant longevity, more high-quality research is necessary to make definitive distinctions or more clearly define the best way to select treatment options depending on how the case presents.

Informed Consent: Informed consent for tooth extractions typically involves a review of the risk and rewards of different treatment options, including no treatment. Most notably is the risk of simple exodontia on adjacent teeth and nearby skeletal anatomy, such as nerves and maxillary sinuses. The patient should also be informed about post-op risks and expectations, including swelling, bleeding, bruising, infection, dry socket, potential paresthesia, etc. The patient should consent both verbally and on paper to provide adequate documentation of this discussion, which may be required if a complication did occur and the patient wished to seek retaliation through the court. For more information on informed consent, see Chap. 6 (Medical-Legal).

8.3 Operative Considerations

8.3.1 Adequate Visualization

Light: Proper visualization is not possible without an adequate light source. Whether you use a headlamp, dental loupe light, or dental chair light, it is important to see where you are working and that instruments are functioning. Discriminating between bone and tooth is not always as obvious by feel as it is by visualization. Thus, an adequate light source is especially important for helping the operator accurately perform dental extractions.

Suction: There are several different types of suction available for keeping the operative field dry. The Yankauer suction is a large bore suction that is especially useful for high-volume suction, particularly when using copious irrigation. By contrast, the surgical suction has a smaller diameter tip, which may be more

desirable for suctioning up a piece of tooth or bone, but not aspirating it into the suction. The narrow tip of the surgical suction also has the benefit of fitting into smaller spaces, such as alveolar sockets.

8.3.2 Protect Patient

- Eye protection (e.g., glasses, towel head wrap, etc.)
- Pharyngeal curtain (Fig. 8.1)
- Bite block or mouth prop (Fig. 8.1)

Available Instruments: Dental surgery has come a long way since the advent of the dental pelican and other now outdated dental instruments. However, many of the functions have been preserved with increased ergonomics and instrument variety.

8.3.2.1 Tray Setups

A tray setup for a simple extraction can vary but frequently involves several of the most commonly used instruments. For example, Fig. 8.2 shows a common tray

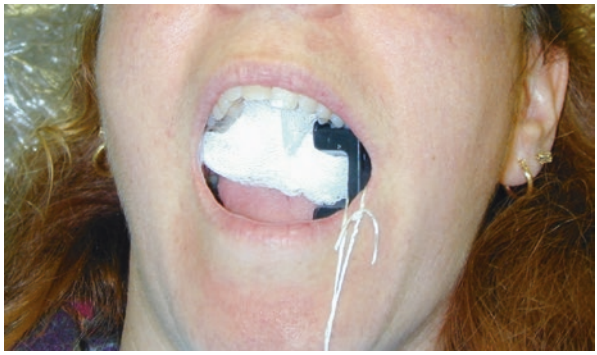

Fig. 8.1 Patient with bite block and pharyngeal curtain in place

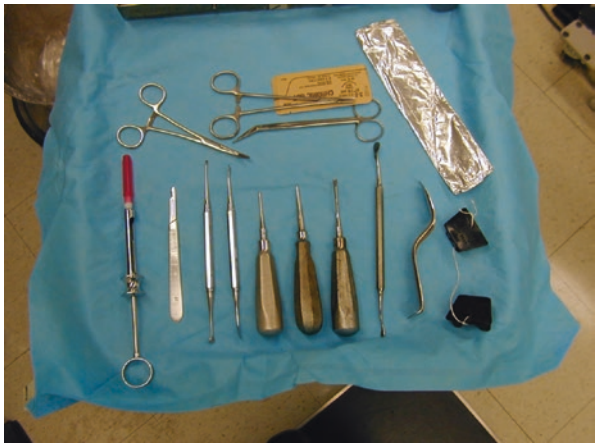

Fig. 8.2 Tray setup for simple extraction

setup with a local anesthetic syringe and needle, scalpel and blade, Molt curette, periosteal elevator, small straight elevator, large straight elevator, offset elevator, bone file, Minnesota retractor, bite block, aluminum foil used as a sterile barrier for light handles, hemostat, needle holders, suture scissors, and a suture. This setup allows for most dental extractions to be carried out effectively. Depending on the tooth being extracted, different forceps can also be added to the tray to aid in tooth removal.

8.3.2.2 Types of Forceps

Dental forceps are multipronged instruments used to grasp teeth. There are many different iterations of dental forceps that are designed for different functions. The following section will describe the most commonly used dental forceps and explain how form dictates function.

The basic anatomy of dental forceps consists of a handle, hinge, and beak. The handle is used to provide the operator with an adequate grip and control over the instrument. Depending on the instrument and location of use, the handle can be gripped differently (e.g., overhand vs. underhand) to provide the operator better ergonomics and improved leverage. The hinge, located where the handle transitions to the beak, allows for pivoting and instrument function. The beaks are designed to grab and hold onto the tooth. Specifically, the beaks are designed to adapt to the root form, not the crown. Maxillary forceps are designed with the beaks parallel to the handle, while mandibular beaks are perpendicular to the handle. To optimally use forceps, it is important to also have proper patient positioning where the maxilla is perpendicular to the floor when extracting maxillary teeth and the mandible is parallel to the floor when extracting mandibular teeth.

One of the most common dental forceps is the **No. 150 forceps**, which is seen in Fig. 8.3. These forceps, also known as universal, are used for extracting maxillary teeth, particularly maxillary anteriors and premolars. The beak tip is well suited for single rooted teeth. The beaks notably have no serrations and are rounded at the tip.

The analogous instrument to the No. 150 forceps used for the mandible is the **No. 151 forceps** (Fig. 8.4). These forceps, also called universal, are best used for mandibular anterior and premolar teeth. The difference between the No. 150 and No. 151 is that the beak of the No.151 is bent to accommodate the perpendicular position of the mandibular teeth to the floor and forceps handle.

Mandibular molars, which are positioned posteriorly in the mouth, are often more easily extracted with the **No. 17 forceps** (Fig. 8.5). These forceps have pointed tips that are able to better engage the buccal and lingual furcations. The bent beak,

Fig. 8.3 No. 150 forceps

Fig. 8.4 No. 151 forceps

Fig. 8.5 No. 17 forceps

Fig. 8.6 Cowhorn forceps

similar to the No. 151, allows for better operator positioning for a more comfortable and effective extraction technique.

Similar to the No. 151 and No. 17 forceps, the **Cowhorn forceps**—aka No. 87—(Fig. 8.6) are also useful for extracting mandibular molars. Like other forceps used for lower molars, the beaks are bent in relation to the plane of the handle. These forceps are designed with sharp beaks that when closed are squeezed into the furcation leading to elevation of the tooth out of the socket. Notably, these forceps create a lot of force and can impose a lot of damage if not used with caution. If enough force is applied or the teeth are fragile, the tooth may fracture, often buccal-lingually. This amount of potential force, however, may be advantageous for teeth better suited for extraction in pieces as the forceps may split the tooth.

One of the most popular instruments for extracting anterior teeth is the **English Style 74N** forceps (Fig. 8.7). These forceps have beaks positioned at a 90-degree angle to the long axis of the instrument. Like other forceps designed for taking out anterior teeth, the beaks are narrow (as designed by the "N") which helps grip smaller diameter teeth. The beaks are also serrated for improved grip of teeth.

Similar to the English Style 74N forceps is the **English Style 13 forceps** (Fig. 8.8)**.** These forceps are designed for extracting anterior teeth but have larger beaks. Like the English Style 74N, they also have serrated beaks for improved grip (Fig. 8.9).

Fig. 8.7 English Style 74N

Fig. 8.8 English Style 13

Fig. 8.9 English Style 74N (left) vs. 13 (right)

A newer type of dental forceps is the **physics forceps** (Fig. 8.10). These forceps were originally introduced by Dr. Richard Golden in 2004 as a way to extract teeth more "atraumatically" than traditional forceps. They are designed with one beak that has a blunt plastic guard and the other beak that is sharp and hook shaped. The blunt plastic guard is used to brace against the alveolar process, while the sharp beak engages the tooth or tooth root and directs extraction forces vertically, instead of horizontally as often occurs with traditional extraction forceps. Conventional forceps function as two first-class levels that are connected by a hinge, which acts as a fulcrum to magnify and transfer the forces exerted on the handles to the beaks and ultimately to the tooth. By contrast, the physics forceps work as one first-class lever, in much the same way that an elevator is inserted between tooth and a bony margin and rotated works, but work on a larger scale. One study by El-Kenawy and Ahmed reported statistical significance for a sample size of 200 patients in favor of the physics forceps extracting teeth with fewer crown and root fractures than conventional forceps. Although the design of physics forceps prevents universal

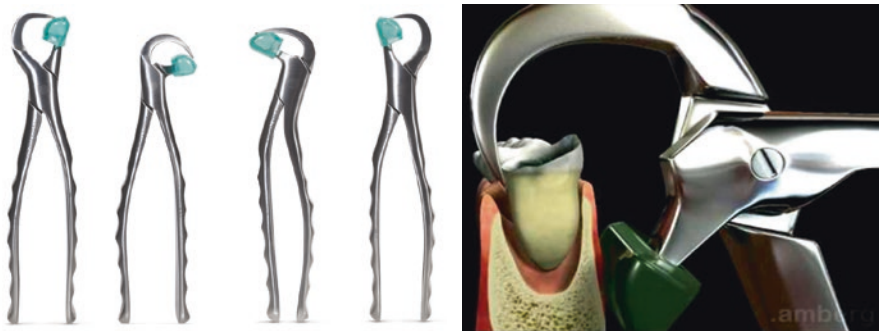

Fig. 8.10 Physics forceps (WAMkey n.d.)

Fig. 8.11 Rongeurs

application to all extraction scenarios, it appears to have support for its use in many simple extraction cases and may be a nice complement to oral surgery armamentarium (El-Kenawy and Ahmed 2015).

Another type of forceps that is used frequently for removing bone and occasionally soft tissue are **rongeurs** (Fig. 8.11). These forceps are easily manipulated with one hand due to the spring mechanism between the forceps handles. They are typically designed with either side cutting only or side and end cutting functions (aka Blumenthal rongeurs). They are often used to trim sharp pieces of bone or remove interradicular bone. However, they are not designed to remove teeth and should never be used for that purpose.

8.3.2.3 Types of Elevators

One of the most commonly used instruments for extracting teeth are dental elevators. They are designed with a handle that connects to a blade via a shank. Despite the variety of blade and shank designs, they all function to help luxate teeth by transferring rotational forces from the operator to the tooth.

One of the most commonly used elevators is the **small straight elevator**, aka 301 (Fig. 8.12). This instrument is often inserted between tooth root and bone, and rotational forces are delivered to the instrument to engage the tooth resulting in coronal forces that help elevate the tooth out.

Similar to the small straight elevator is the straight elevator, aka 34S (Figs. 8.13 and 8.14). The main difference between the two instruments is that the blade size of the 34S is larger. It is common to begin elevating with the 301 followed by the larger 34S.

Another useful elevator, particularly for posterior teeth like upper molars, is the **offset 92 elevator** (Fig. 8.15). This elevator has a bent shank that offsets the blade from the plane of the handle. This allows for the blade to gain access to the tooth without being impeded by the cheek. The blade of the offset 92 elevator is not as concave as the 34S allowing for a broader contact with tooth surface. Also, the blade of this elevator is serrated, which aids in gripping teeth during elevation.

A visually distinct set of elevators that are often used to remove broken roots in sockets are the **Cryer elevators** (Figs. 8.16 and 8.17). The east is the elevator that has a blade pointing to the right or east when the instrument is laid on the ground

Fig. 8.12 Small straight elevator (301)

Fig. 8.13 Straight elevator (34S)

Fig. 8.14 301 elevator (top) vs. 34S elevator (bottom)

Fig. 8.15 Offset 92 elevator

Fig. 8.16 Picture on left has the above Cryer elevator (east) and below elevator (west). The picture on the right is a close-up of the east elevator

Fig. 8.17 Cryer elevator (west)

Fig. 8.18 Crane pick elevator

edge with the handle positioned superiorly. Both cryers have triangular-shaped blades that curve and can be placed within sockets to engage more mesial or distal tooth roots or fragments.

Similar to the east, the west Cryer elevator has a blade that points to the left or west when the instrument is placed on its ground edge, and the handle is positioned superiorly.

The **Crane pick elevator** (Fig. 8.18) is used to remove broken root fragments in the tooth socket. The blade is bent and pointed, which can often be utilized by inserting it into a hole drilled into the root or tooth surface.

8.3.2.4 Miscellaneous Instruments

In addition to elevators and forceps, there is also an assortment of ancillary instruments that are used in oral surgery. One of these instruments is the **hemostat** (Fig. 8.19). These are narrow, curved-beak forceps that have horizontal serrations and used to grip bone and tooth fragments or remove loose soft tissue. The design of the beaks is such that they are not intended for use to grasp suture needles and should not be used for suturing. That function should be reserved for needle holders. Other functions of hemostats include controlling bleeding by clamping blood vessels. The handles are designed with two finger holds that are often occupied by the thumb and ring finger, with the operator's index finger resting along the handle length and pointing toward the beaks. Finally, the handles have a locking mechanism that helps to retain the closed position of the instrument without the operator needing to maintain force to keep the beaks closed.

Often confused with hemostats (Fig. 8.19) by the unfamiliar operator are **needle holders** (Fig. 8.20). These instruments are designed with shorter beaks than hemostats, and also have locking handles, but have a crossed-hatch serration pattern that aids in gripping suture needles in any orientation.

Suture scissors, aka Dean scissors (Fig. 8.21), are also important for cutting excess suture material or removing non-resorbable sutures after soft tissue has approximated. They are uniquely designed with bent, short beaks and long handles to allow for adequate reach of the instrument in small spaces far back in the mouth. The short beaks are also designed to avoid damaging surrounding structures since they open and function in the isolated area of interest only. Although they may work for cutting tissue, they are not designed to do so.

Fig. 8.19 Hemostat

Fig. 8.20 Needle driver

Fig. 8.21 Suture scissors

Fig. 8.22 Tissue forceps

Fig. 8.23 Bone file

Fig. 8.24 Molt curette (straight)

Along with needle holders and suture scissors are the **tissue forceps** (Fig. 8.22). These are either called the Adson forceps (when short) or Stillies forceps (when long). These forceps have teeth on one end and are used to grasp soft tissue for suturing or dissecting. Since the metal teeth are sharp, they can crush or tear tissue easily so caution should be exercised while using them.

Another instrument that is used for smoothing out sharp bony spicules is the **bone file** (Fig. 8.23). This instrument has two ends, one large and one small, and has sharp horizontal serrations that are angled to cut or remove small amounts of bone with pulling strokes. Pushing the instrument leads to crushing or burnishing bone, which is not suggested.

One instrument that is often used to remove soft tissue from bony surfaces is the **Molt curette**, aka straight curette (Fig. 8.24). This curette has a straight handle with

straight shanks and small and large spoon-shaped blades at each end. This instrument often helps to remove soft tissue from bony surfaces like granulation tissue from a socket or granulomas and small cysts from periapical lesions. The curettes can be used in a pulling motion for scooping or often in a pushing motion for blunt dissection, such as cyst enucleation.

Another type of dental curette that is used during the extraction process of teeth is the **periapical curette** (Fig. 8.25). This doubled-ended curette has bends in the shank at both ends that aid in reaching all aspects of teeth. For example, they are often used to reach tooth sockets to remove granulation tissue or to relieve soft tissue around teeth, particularly molars.

A **scalpel** is an essential part of any extraction setup (Fig. 8.26). It consists of a handle and a scalpel blade. To attach the blade to the handle, it is often recommended to grasp the scalpel blade with a hemostat and line up the oblique lower border of the blade with that of the handle. Blades are straight with a curvature, which helps them to cut when held in different orientations. It is suggested to cut with the belly of the blade or the bend in the curve. Scalpel blades are disposable and should be thrown out after each procedure, but the handles are reused after an autoclave cycle.

A frequent favorite for any dental extraction is the very versatile **number 9 periosteal elevator** (Fig. 8.27). This straight double-ended instrument has one small end that is more pointed and one larger end that is more rounded. This instrument is best known for its utility in elevating soft tissue off the bone, especially during the initial phase of dental extraction. The smaller end is frequently used first followed by the rounded end.

An instrument uniquely special to oral surgery is the **Minnesota retractor** (Fig. 8.28). This offset retractor has one end with an acute turn that is best fitted for hooking on to the operator's thumb with the other end that is straighter and more round that is well suited for retracting soft tissue, especially flaps. The offset allows the instrument to reach farther back into the patient's mouth with less impedance by

Fig. 8.25 Periapical curette

Fig. 8.26 Scalpel and scalpel blade

Fig. 8.27 Number 9 periosteal elevator

Fig. 8.28 Minnesota retractor

Fig. 8.29 Weider retractor

the tongue than if it were straight. It is particularly helpful during third molar extractions. It can also be used to protect tissues from cutting instruments like drills or chisels.

Another common retractor in oral surgery is the **Weider retractor**, aka sweetheart retractor (Fig. 8.29). This retractor has a heart-shaped end that is useful for retracting the patient's tongue when working near it. The serrations are used to more aptly grip and engage retracting tissues such as the tongue. The other end has a curvature that helps the operator hold it with minimal hand skills since it can merely hook around a finger or hand. It is important to not push this instrument too far into the patient's mouth as doing so may trigger a gag reflex.

The **mouth mirror** is an absolute necessity, especially when working on posterior maxillary teeth (Fig. 8.30). The instrument consists of a handle into which

Fig. 8.30 Mouth mirror

Fig. 8.31 Aspirating syringe

Fig. 8.32 Irrigation tip

screws a small round mirror that can be replaced when scratched or damaged. The mirror also doubles as a retraction tool for the cheek or soft tissue.

Another very important instrument that is key to nearly every procedure in oral surgery is the **aspirating syringe** (Fig. 8.31). This instrument consists of a chamber into which local anesthetic carpules are loaded. There is a threaded end to the chamber onto which screws the anesthetic needle via a plastic hub. After the carpule is loaded, the metal harpoon on the end of the handle is pushed into the silicone plunger of a local anesthetic carpule and confirmed to be adequately engaged prior to use. This allows the operator to aspirate during local anesthetic injection.

To aid in visualization and remove debris during extraction, the operator must have adequate irrigation. **Irrigation tips** (Fig. 8.32) are attached to plastic syringes and often used to direct sterile saline into a socket to remove debris. This larger bore tip allows for enough water or sterile saline to be dispersed to provide proper irrigation for cleaning out a socket or lubricating a dental drill.

Fig. 8.33 Suction

Fig. 8.34 SteriGage

Another instrument that cannot be spared during dental procedures is **suction** (Fig. 8.33), particularly surgical suction when extracting teeth. This instrument has a long bent metal tube with a depression halfway down that allows air in unless covered. When using it, the operator can put his or her finger over the opening on the body of the suction to increase suction forces, while not doing so will result in weaker suction, which may be better at certain times, such as when suctioning around soft tissue. Also, the smaller diameter of the suction allows for it to suck up small pieces of tooth or bone or soft tissue, which is useful when using hemostats or another instrument for picking up pieces proves more difficult.

Lastly, any operator should be familiar with the **SteriGage** indication strip (Fig. 8.34), which is found in each cassette. As pictured, a SteriGage that has undergone a proper autoclave cycle will result in the black indicating strip extending into the accept end. If it does not, then the autoclave cycle was not successful, and the instruments were not properly sterilized.

8.3.3 Proper Use of Elevator and Forceps

Exodontia is a deliberate and controlled process of loosening a tooth from its alveolar socket and removing it from the mouth with as little collateral damage or bone removal as possible. There are many instruments for this process that are often used in a typical sequence.

After confirming the records are correct, including the patient, tooth, and procedure, the first step is to anesthetize the patient properly (see Chap. 7 for more information). Before doing so, first make sure the patient is wearing appropriate protective eyewear on to prevent iatrogenic trauma to their eyes. After local anesthesia is achieved, the patient's throat should be protected with pharyngeal curtain, often done so by opening up a 4 × 4 piece of gauze. If working on the patient's lower jaw, this is also a good time to insert a rubber bite block on the opposite half of the

mouth in order to protect the patient's temporomandibular joint and reduce fatigue from staying open for a while.

At this point, a number 9 periosteal elevator or double-ended periapical curette may be used to release the attached gingiva and mucosa from around the tooth. Once the tooth is successfully freed from soft tissue, an elevator is usually inserted perpendicular to the facial side of the tooth, between tooth and alveolar process, with the concave face toward the tooth. The elevator should be held with the operator's index finger along the length of the shank and blade. Caution should be taken to make sure the elevator is between tooth and bone, not between teeth. Once in place and a purchase is found, the elevators are turned either clockwise or counterclockwise, which helps to break PDL fibers and luxate the tooth.

Finally, once luxation has been achieved and the tooth has gained mobility, or elevating is no longer effective, the correct forceps, which depends on the tooth being extracted, can be selected and used. The forceps' beaks are placed parallel to the tooth, one beak at a time (i.e., typically palatally or lingually first then followed by buccally). The first direction of force is apical in an attempt to seat the forceps as apically on a tooth as possible, which provides counter pressure and helps expand the alveolar process. Slow and steady buccal or lingual pressure is applied followed by similar pressure in the opposite direction. A controlled amount of force should be used in order to feel and respond to tactile feedback from the tooth or alveolus and avoid sequelae of uncontrolled forced such as fractured teeth, fractured alveolar bone, or instrument slipping causing collateral trauma. A slow figure-8 motion can also be used to help break more PDL fibers and better luxate the tooth. Anterior teeth that are single rooted and often conical and straight are often successfully luxated with rotational forces using forceps. However, caution should be exercised to avoid applying excessive rotational forces to teeth with roots that are possibly dilacerated (as may be radiographically evident) or multi-rooted as that may lead to unfavorable fracturing of tooth roots. As a result, providers would be left with a more difficult extraction as they attempt to remove a piece of tooth that has poorer access, visibility, and leverage points.

Once the tooth is extracted, it should be inspected thoroughly for any signs of root fracture that may indicate part of the root was left behind. For more information on management of root tips, see Chap. 11 on surgical complications.

8.3.4 Postextraction Toilette

A rather historical and often overlooked step of exodontia is postextraction **curettage** of the alveolar socket (Fig. 8.35). Many surgeons instinctively or reflexively perform curettage, but recent literature and old principles challenge that practice. Is curettage always necessary?

A study from 2014 by Wahl et al. found that postextraction curettage carries a number of inherent risks but few benefits (Wahl et al. 2014). They report that complete radiographic healing occurs without postextraction curettage in teeth with periapical radiolucencies. An interesting point raised by the study was that periapical

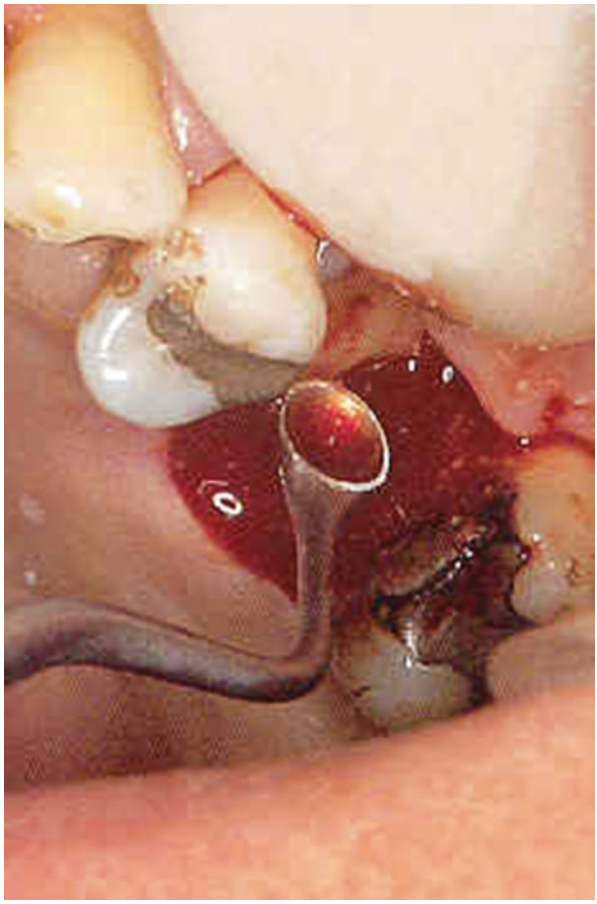

Fig. 8.35 Surgical "toilette" or result of socket curettage following tooth extraction

lesions of endodontic teeth heal well after root canal therapy, suggesting that the same should happen for periapical lesions following tooth extraction. Given the risks of perforating through sinus walls, injuring nerves, excessive bone removal, and increased postoperative pain, curettage should be done much more selectively. Although little literature exists on the exact indications for postextraction curettage, doing so is generally recommended when there is loose soft granulation tissue along socket walls and when easily accessed apically, but excessive pressure or force should not be exerted to avoid the previously mentioned risks.

In addition to curettaging after tooth extraction, the alveolar socket is often **irrigated** with sterile normal saline. This is typically done to wash out debris and bacteria. As stated by Dr. Sherry Rogers, a medical doctor specializing in environmental medicine, "The solution to pollution is dilution." That being said, irrigating a socket often helps to dilute out unwanted pollutants in the socket. However, this postextraction curettage routine has been reconsidered by some. One study by Tolstunov found that the rate of alveolar osteitis in patients undergoing mandibular third molar

removals was less when the socket was not irrigated (Tolstunov 2012). The study found that it was easier for younger patients to reform blood clots following socket lavage than older patients. Although the literature is light on the benefits and risks of socket irrigation and the study presented focused specifically on mandibular third molars, postextraction irrigation should be considered more on a case-by-case basis. In particular, it is important to consider the patient's age and health, tooth being extracted, and difficulty of extraction when deciding whether to irrigate or not.

After the tooth is removed, it is important to control bleeding which is most often done by having the patient bite on moist gauze. Biting on moist gauze helps to prevent the blood clot from being removed when the gauze is taken out or changed, and the pressure the gauze provides helps achieve adequate hemostasis. Patients should typically bite down for about 20–30 min, with more or less time depending on extent of bleeding. The operator may also wish to straddle the alveolar ridge around the edentulous tooth socket with their thumb and index fingers and apply compressive forces to push the expanded alveolar socket walls back in and facilitate quick wound closure.

Special Considerations: Patients on anticoagulants or with conditions that prolong bleeding time or coagulation may benefit from having Gelfoam, surgical, or another resorbable hemostatic agent in the socket to reduce prolonged bleeding risk. After the socket is filled or packed with these agents, a figure-8 suture is typically used to help re-approximate soft tissue and retain the Gelfoam or other hemostatic agent.

8.4 Post-Op

Oral Hygiene: There are a number of postoperative hygiene recommendations to follow after tooth extractions. Patients are encouraged to avoid any motion that creates suction such as sucking (e.g., using a straw, spitting, smoking, or using alcohol). Also, patients should brush their teeth gently avoiding the extraction socket so as to avoid disrupting the blood clot or granulation tissue. Lukewarm salt water rinses are also helpful to facilitate healing and can be done several times a day during the healing phase. However, caution should be taken to not spit, but rather let the salt water passively empty from one's mouth.

Diet: After extraction, patients should have a soft diet (e.g., yogurt, soup, etc.). Patients should drink lots of fluids, especially water, and avoid very hot or cold foods and liquids. Also, it is best to avoid carbonated beverages and alcohol.

Analgesics: For more information, refer to Chap. 12 (Acute Pain Management).

8.5 Summary

Simple exodontia is fundamental to dentistry and one of the longest practiced procedures of the profession. Over the years, a lot of progress has been made to improve patient outcomes, but there is still a lack of evidenced-based support for much of the

clinical decisions that are made. It is important to always take a logical, stepwise approach to dentistry, especially dental extractions, with justification for each step from diagnosis to decision to irrigate or curette alveolar sockets. As more time and research is invested in understanding the benefits or consequences of different treatment options, more evidence will be available to justify treatment recommendations and will better direct dental practitioners in decision-making.

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Complicated Exodontia

9

Stuart Lieblich

"The plot thickens."

—A Study in Scarlet

Abstract

Planning for the extraction of teeth involves not only preparing the appropriate dental treatment plan for the patient but an appreciation of what potentially makes a case more complicated. Anticipating that a procedure may be more complicated than usual often is achieved via experience. The general dental practitioner that may be comfortable with some aspects of exodontia still may need to understand when a case may need to be referred to a specialist. This chapter will present some aspects of extractions as well as patient issues that may indicate that the procedure may be more complicated or present unusual circumstances.

9.1 Assessment

The initial aspect of planning for surgery is to determine if the patient is an appropriate candidate. Certainly emergency procedures may dictate that cases need to be done more urgently, but in general extractions can usually be deferred until the patient's health status is optimized. The intake of the patient needs to include certain aspects of their medical history and vital signs (Table 9.1). The surgeon must determine if the patient can safely undergo the surgical procedure. Most practitioners will primarily be treating with local anesthetics, but even these medications can cause an adverse outcome if the patient is not in optimal health.

One important screening tool is the patient's ability to undergo some basic levels of physical activity. Simple questions such as what tasks they can accomplish such

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Table 9.1 Basic patient evaluation for extractions

• Vital signs
– Blood pressure
– Heart rate and rhythm
• Medical history
– Comorbid diseases?
– How have you been feeling lately?
– Which medications do they take?
• Can they go up a flight of steps? (METs >4)
• Can they take deep breath and hold it for 5–10 s?
• Can they extend head/open mouth wide?

as walking upstairs, playing tennis, etc. gives an indication of the patient's metabolic equivalents (METs). METs are scaled from 1 (just sitting in a chair) to 10 (able to play single's tennis for an hour). A patient that can walk up a flight of stairs has some basic level of cardiac and respiratory reserve that should be an acceptable risk for treatment in an office setting with local anesthesia (Eagle et al. 1996).

Some of the patient evaluation issues will alert the practitioner to a situation that complicates extraction. For example, the use of anticoagulant medications can create postoperative bleeding issues. In general, the risk of a stroke with stopping these medications is greater than the potential for postoperative bleeding, and typically these medications are continued. Although there is no absolute maximal INR that is thought to be safe, values of 3.5 or less are usually not associated with significant postoperative hemorrhage. Concerns may be greater for patients under dual anticoagulant therapy than just a single agent (Lillis et al. 2011; Lu et al. 2016). It is interesting that periodontally involved teeth are often associated with more bleeding in patients taking anticoagulants. Also the ability to control any postoperative bleeding will depend on the anatomical site involved. For example, simple intraoral oozing is more easily observed and treated than occult bleeding into the maxillary sinus or the floor of the mouth.

The use of intrasocket hemostatic agents is indicated for use in these patients along with suture closure. Other local measures that can be used are tranexamic acid rinses. Cessation of anticoagulant medications should not be done without consultation with the prescribing physician. Other coagulopathies such as von Willebrand's disease or the various presentations of hemophilia necessitate collaboration between the dentist and the hematologist. Patients need to be advised of the likelihood of significant ecchymosis forming following even a relatively simple extraction (Fig. 9.1a, b).

Other medication issues are the use of the medications known to be associated with MRONJ (medication-related osteonecrosis of the jaws). There are no specific guidelines in these cases other than to try to avoid extractions if at all possible with endodontic treatment and root retention. With the use of the oral bisphosphonates, some have recommended a 3-month drug holiday prior to extractions (Ruggiero et al. 2009). There is little evidence to support this, and current recommendations for patients that have been taking oral bisphosphonates or an anti-resorptive such as denosumab for less than 2 years can have invasive oral surgery and continue their medications (Ruggiero et al. 2014). If they have been on these medications for

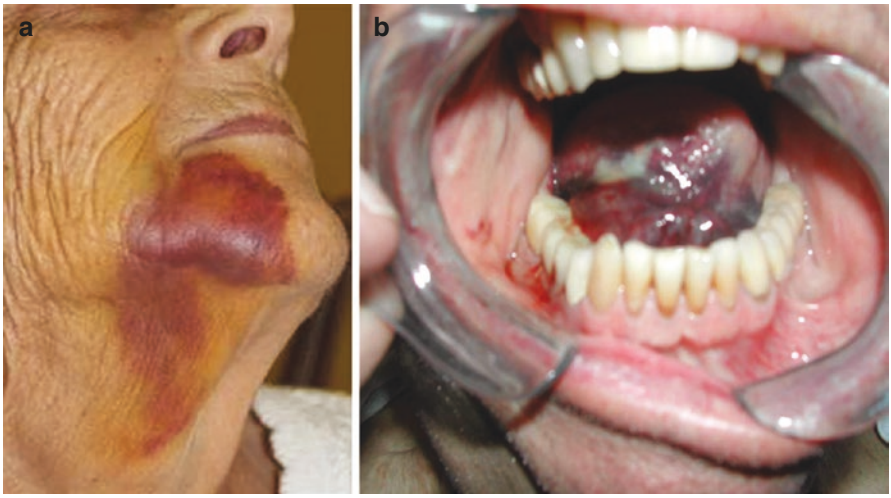


Fig. 9.1 (**a**) Ecchymosis following simple extraction in a patient taking warfarin. (**b**) Severe floor of mouth ecchymosis that can become life-threatening due to impingement of the airway

greater than 4 years, there may be some theoretical advantage to a 2-month drug holiday (Damm and Jones 2013).

However, if active infection is present with fistula formation, extractions may be necessary. Although there is no evidence that antibiotics are indicated, in these cases the preoperative administration is often considered. The term "atraumatic" extraction is often used in these cases, although this is a goal in every patient population.

In evaluating the patient for extraction, access to the tooth planned for extraction must also be considered. A limited range of opening can severely hinder the dentist's vision to the region as well as the ability to place necessary instrumentation. The surgeon should evaluate the access especially in posterior areas of the mouth along with malaligned adjacent teeth that can hinder visualization or placement of necessary instrumentation. Other anatomical barriers can be tipped adjacent teeth which hinder access. Adjacent prosthetic restorations that may be failing (Figs. 9.2 and 9.3) can easily be dislodged during the extraction of the planned tooth creating secondary damage and/or be aspirated by the patient.

The availability of three-dimensional imaging, e.g., cone beam CT (CBCT) scans, will often provide additional information regarding the location of the teeth to be extracted and the proximity to other roots, nerves, and the sinus cavity. Although not typically indicated for most extractions, the dentist should consider if the information provided by the CBCT will aide in the extraction or reduce the risk to the patients. A principle of ALARA (as low as reasonably acceptable) should be followed in order to determine if the additional radiation exposure to the patient could improve the outcome. Figure 9.4 shows an impacted mandibular canine that on the panoramic image cannot be determined if it is on the buccal or lingual aspect. Using a CBCT to evaluate the tooth in all three dimensions, the surgeon can localize the tooth to the buccal aspects as well as determine the proximity to the incisor roots in this region.

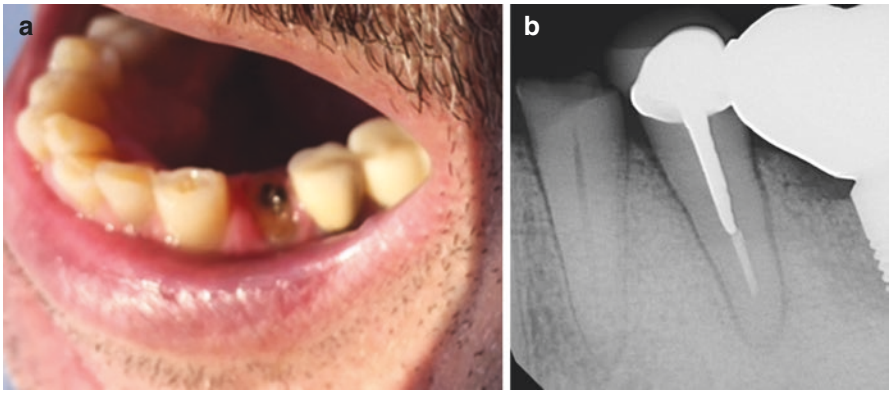
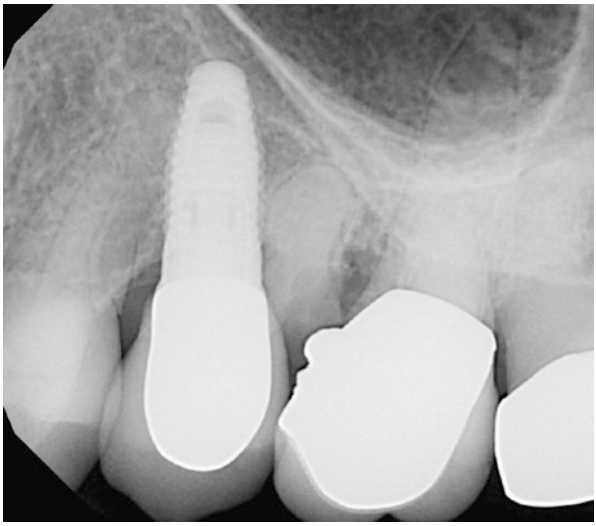


Fig. 9.2 Clinical and radiograph of a failing bicuspid indicated for extraction. Although there is only a single conical root, the proximity to other potentially failing and overhanging prosthesis complicates this case

Fig. 9.3 The presence of this dental implant in contact with the failing molar makes extraction more difficult. The risk of creating a bone defect on the distal aspect of the implant might indicate a need for grafting of the molar extraction site, along with attempts at primary closure



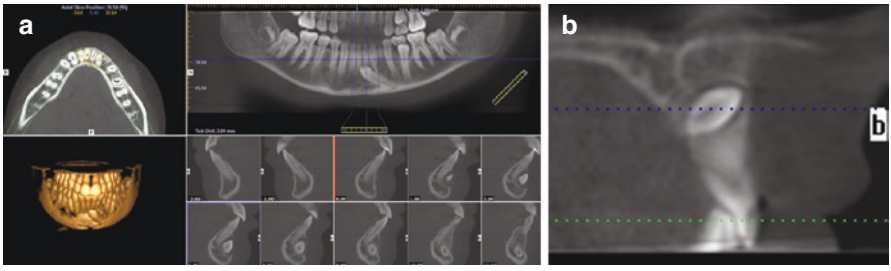


Fig. 9.4 A cone beam CT provides important three-dimensional information in more complicated extraction cases. (**a**) Mandibular impacted canine showing buccal position. (**b**) Maxillary supernumerary tooth demonstrating palatal position and proximity to the central incisor root

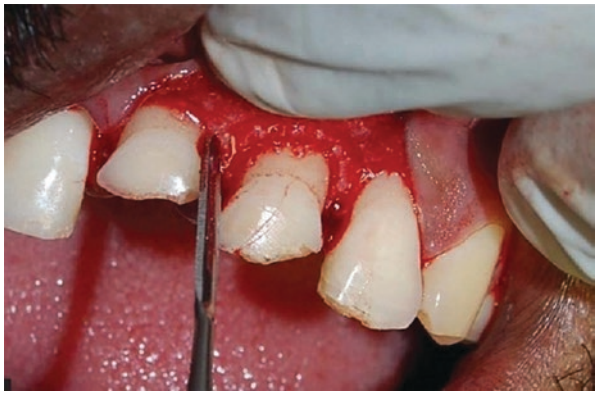


Fig. 9.5 Use of a periotome type of elevator to preserve bone around the site anticipated for subsequent dental implant placement

9.2 Anatomical Issues

Complicated extractions are often described as requiring more bone removal. An example is the disto-angular or full bony impacted lower third molar. These teeth typically require substantial bone removal. The additional time and bone removal associated with these cases can lead to an increased rate of postoperative discomfort and swelling as well as a higher rate of infection. The rate of infection is noted to be increased with the complexity of the extraction and most likely the time necessary to extract the tooth (Piecuch et al. 1995). Although in general antibiotics are not indicated for routine extractions, if a complex extraction is anticipated, a consideration for prophylactic antibiotics (i.e., administered prior to surgery) can be entertained. Intraoral surgery is considered "clean-contaminated" surgery in most cases, yet as noted routine antibiotics are not proven to be effective (Krishnan et al. 2017).

Cases where it is anticipated that a dental implant will secondarily be placed into the site may entail other considerations. Careful sectioning of the teeth with maintenance of the buccal plate and interradicular bone (in multirooted teeth) may provide more predictable sites for the upcoming implant placement. Even with conical-shaped anterior maxillary teeth, a more precise extraction technique should be considered to avoid creating a postsurgical defect. The use of fine elevators, known as periotomes (Fig. 9.5), can be used to expand the sockets and typically preserve the surrounding boney socket. The dentist may also consider planning to graft the sockets to preserve the local anatomy.

9.3 Maxillary Issues

The maxillary sinus can complicate extractions due to risk of bone fractures creating an oral-antral communication (Fig. 9.6). When the maxillary molar is lone standing or there is significant pneumatization of the sinus, there is a significant risk of associated bone fracture. If expected the tooth should be sectioned and removed as individual roots. During an extraction palpation of the alveolar crest will often indicate if

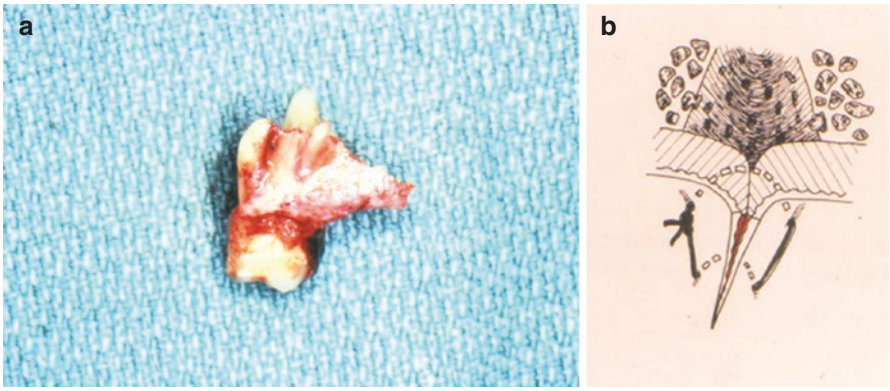


Fig. 9.6 (**a**) Extraction of a maxillary first molar that created oral-antral communication. (**b**) Horizontal mattress suture to attempt primary closure between the oral cavity and the maxillary sinus

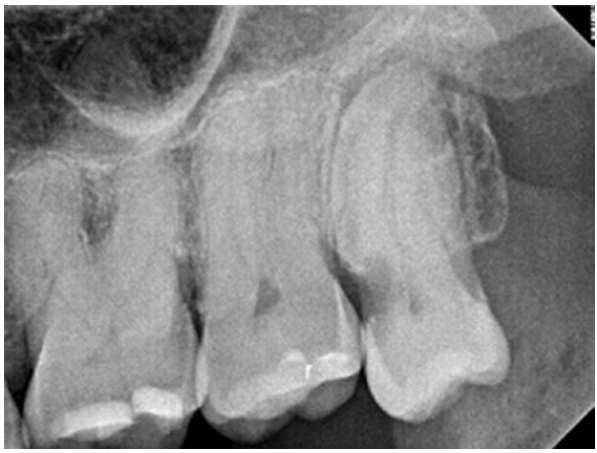


Fig. 9.7 Significant tuberosity bone on the distal of the third molar can complicate extraction due to potential fracture of the bone

a fracture is occurring. Once noted, care should be taken to dissect the mucoperiosteum off the bone to maintain a maximal amount of tissue for primary closure.

It is not important to reestablish a bony separation from the oral cavity to the maxillary antrum. Soft tissue should be adequate once the tooth is removed as long as the mucosa is not torn and carefully dissected from the bone. A horizontal mattress suture is used to attempt a "water-tight" closure. Patients are instructed to not blow their nose for 2 weeks to avoid causing a dehiscence in the incision and a secondary oral-antral communication. If primary closure cannot be achieved, most small communications (less than 5 mm) will spontaneously close.

Other often overlooked anatomic issues are the maxillary tuberosity. The presence of a significant tuberosity is subject to fracture during the extraction. The cleavage plane can extend up the lateral aspect of the maxilla to the infratemporal space (Fig. 9.7). When this situation is recognized, preoperative sectioning of the

tooth and slow, careful expansion of the socket is indicated. If a significant fracture occurs, cessation of the procedure and stabilization of the tooth to the adjacent tooth until the fracture heals (4–6 weeks) are indicated.

9.4 Mandibular Extraction

The increased density of mandibular bone and the issues associated with the course of the inferior alveolar nerve can create issues unique to this area of the oral cavity. Proximity of the apical regions of mandibular molars with the inferior alveolar nerve may dictate that a coronectomy procedure would provide a better outcome by reducing risk of damage to the neurovascular bundle (Fig. 9.8).

The dense bone of the mandible and often multirooted molar teeth can present a challenge to even the most experienced surgeon. As noted in Fig. 9.9, the mandibular third molars are anticipated to be a relatively complicated extraction. The surgeon will often need to remove a significant amount of bone as well as section these teeth to enable removal. Late infections and even fractures of the mandible can occur due to excessive forces during the extraction or overheating the bone during surgery. Consistent irrigation with the use of sterile solutions is indicated throughout cutting the bone and teeth.

It is important to be aware of the risks of subcutaneous/submucosal emphysema (Miller and Lieblich 2012) with the use of conventional dental handpieces. The air and air/water spray can dissect under raised flaps creating substantial tissue emphysema (Fig. 9.10). Most surgical handpieces are a combination of rear exhaust along with the use of nitrogen gas. If nitrogen gets under the tissues, it is rapidly absorbed due to its solubility. In contrast forced air continues to dissect under the tissue planes and may not be recognized by the practitioner or initially felt by the patient due to local or general anesthesia. In severe cases the air has dissected into the periorbital regions causing visual changes as well as inferiorly creating acute airway compromise.

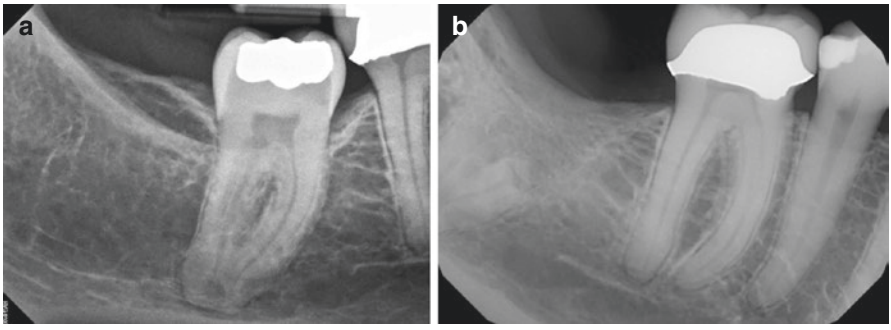


Fig. 9.8 Deeply impacted lower second molar with radiographic evidence of contact with the inferior alveolar nerve. (**a**) Preoperative view. (**b**) Coronectomy procedure with intentional retention of the roots to reduce risk of nerve injury

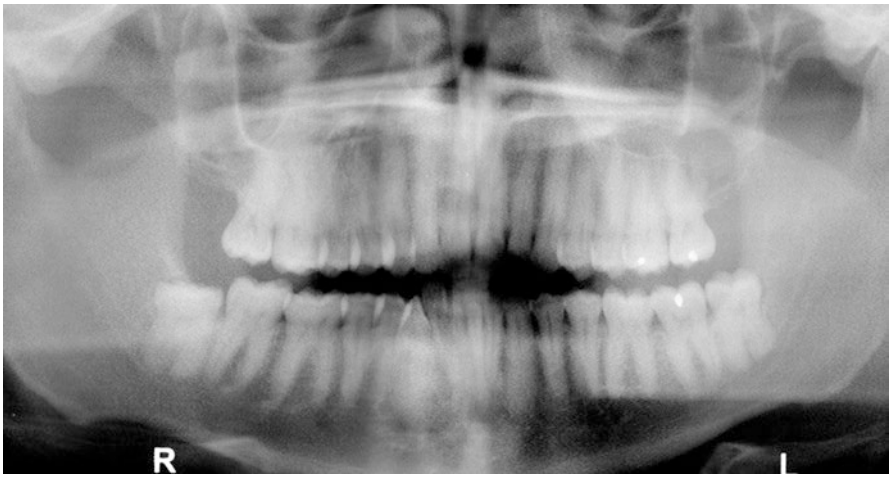


Fig. 9.9 The posterior ramus of the mandible provides an anatomic hinderance to the extraction of these lower third molars

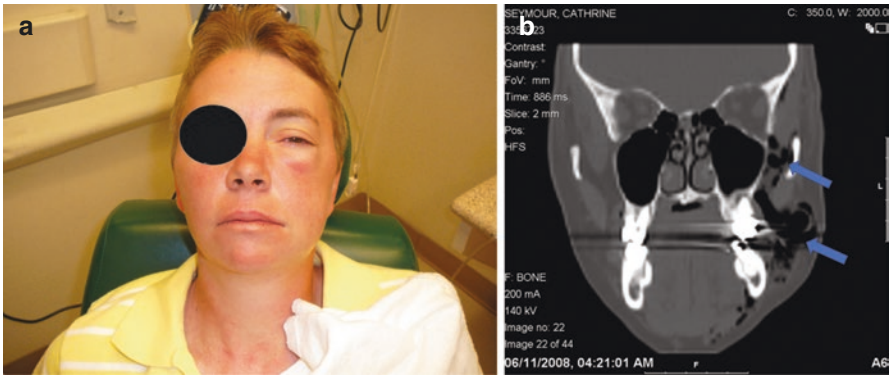


Fig. 9.10 (**a**) Facial swelling immediately following extractions with the use of a conventional dental handpiece with air/water spray being used. (**b**) The CAT scan shows extensive free air (arrows) in the submucosal tissues that has dissected to the orbital region causing visual defects

9.5 Conclusion

The extraction of teeth can range from relatively simple to extremely complex. It's incumbent upon the dentist to start with a careful evaluation of the patient to assure they are physically able to withstand the procedure. Although complicated extractions cannot always be predicted in advance, there are certain anatomic factors that can indicate the surgery may be more complicated. Preparing the patient for the complexity as well as an honest assessment of the practitioner's experience with these cases may help determine which cases can be treated or which ones need to be referred.

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Unerupted and Impacted Teeth: A Guide for Assessment and Treatment

10

Leon A. Assael

"How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth."

—The Sign of the Four

Abstract

This chapter provides a comprehensive review of patient assessment and treatment recommendations for patients with unerupted and/or impacted teeth. Risk assessment for treatment options is provided.

10.1 Introduction

Among the normal developmental and pathologic conditions of note in dental practice is the presence of unerupted teeth. While the most common unerupted tooth is the mandibular third molar at all stages of life, mandibular canines are next in frequency of impaction. However, every deciduous and permanent tooth has been noted to be unerupted sometimes with associated pathology and sometimes without any discernable health consequence. Supernumerary teeth also are noted to be impacted, about 70% of which are mesiodens in the anterior maxilla in the incisive foramen region (McBean and Miloro 2018). The comprehensive oral health assessment of the patient always must consider unerupted teeth and their potential health consequences.

Seventy-nine percent of all young adults have four third molars present, while only 12% have no impacted third molars (Hugoson and Kugelberg 1988). In addition to third molars, every deciduous and permanent tooth has been noted to exhibit delayed eruption or impaction due to associated pathology and sometimes with important adverse health consequences. These adverse consequences of impaction

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may be local, causing damage to vital structures or system, due to the effects of inflammation or neoplasm. Thus, the comprehensive oral health assessment of the patient always must consider unerupted teeth and their potential health consequences. Patients depend upon their general dentist for assessment of their personal oral health, which includes assessment of pathology and prognostic assessment. If the dentist determines the removal of an impacted tooth is required, does the patient with an unerupted tooth require referral to a surgeon or will the dentists carry out the procedure themselves? An understanding of difficulty assessment and relative risk of morbidity assessment is needed to determine that plan. Can the plan for a patient's impacted teeth also be based upon all determinants of health: concomitant oral health status, systemic health, and the social determinants of health? The general dentist, with their long-term relationship with the patient, may be in the best position to bring the presence of impacted teeth into the context of what is of greatest benefit to the patient. Thus, the need for detailed knowledge of impacted teeth is critical to optimal general dental practice.

10.2 Assessment of Unerupted and Impacted Teeth

The role of the general dentist as the leader of the oral health-care team is essential in the assessment and considerations for management of impacted teeth. Patients will expect their family dentist to be able to advise on the presence of impacted teeth as well as their need for either observation or removal.

Physical examination involves the counting of each tooth and determination of the status of missing teeth, including all 20 deciduous and all 32 permanent teeth. Palpation of the jaws and dental arches will determine areas of hard or soft tissue swelling that might represent the presence of unerupted or impacted teeth. Displacement of erupted teeth, translocation of erupted teeth, and crowding of erupted teeth are associated with concomitant impacted teeth. Inflammation including redness, tenderness, swelling, or warmth may represent infection associated with an impacted tooth. Soft displacement of the tissues during palpation, termed ballotability, is a sign associated with impacted teeth. In the case of third molars, partial eruption may result in pericoronitis and infection of the pericoronal tissues characterized by pain, trismus, fetor, and purulent discharge. Due to the ectopic position of some impacted teeth, they may not be visible on routine intraoral radiographs, so determination of their status will help determine the need for further imaging evaluations.

Imaging: Utilization of comprehensive imaging of the dental patient now includes the assessment of dental growth and development and pathology of the jaws for every patient. Due to contemporary imaging techniques, with the common use of the panoramic radiograph in general practice, and more recently with cone beam CT scan, every general dentist should have access to comprehensive imaging assessment of impacted and unerupted teeth, and their associated pathology, during the course of growth and development as well as throughout life. The use of full mouth series, periapical radiographs, does not adequately detect or evaluate

impacted teeth and is a known risk for false-negative findings as a diagnostic tool for this purpose. Full mouth series will result in false negatives when determining the presence or characteristics of impacted teeth. Panoramic radiographs are adequate to identify essentially all impacted teeth as well as their location and associated pathology for purposes of surgical decision regarding the need for removal and as a guide to removal method in most cases (Figs. 10.1 and 10.2). Cone beam CT provides a comprehensive three-dimensional evaluation of the impacted tooth and is a consistently useful guide as to best methods for removal with minimized surgical trauma and risks to vital anatomic structures including the inferior alveolar nerve.

Evidence-based assessment: Patients depend upon the general dentists for their assessment which includes assessment of pathology and prognostic assessment. Simply stated, does the patient with an unerupted tooth require its removal? In a

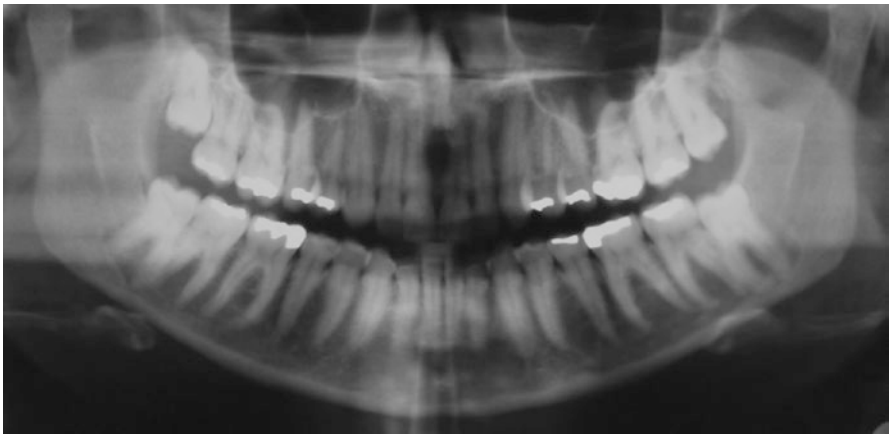

Fig. 10.1 Panoramic radiograph reveals impacted tooth #1, impacted #17 with hypercementosis, Pell and Gregory type 2B and impacted #32, also with hypercementosis and Pell and Gregory type 1A

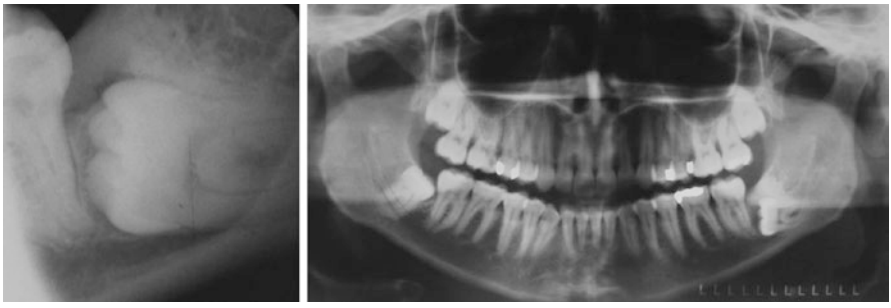

Fig. 10.2 This periapical radiograph does not adequately evaluate the relationship of this impacted tooth to the inferior alveolar nerve or the associated osseous pathology demonstrated in the panorex

practical sense, referral to a surgeon usually indicates a plan to remove the tooth. Although an assessment by the specialist can be requested, a bias toward tooth removal will be commonly made by the specialist as their life experience, seeing the complications of retention of impacted teeth, and practice model may be a guide toward treatment. Surgeons who reject a dentist's plan for the removal of an impacted tooth usually do so for assessment of medical comorbidities or assessment of increased risk of surgically related complication such as nerve injury or damage to adjacent teeth. Despite a predilection toward removal of impacted teeth, not all impacted teeth need to be removed. Decision to remove an impacted tooth needs to be made on sound diagnostic criteria and indications for care. Fortunately, there is a broad scientific body of knowledge regarding the indications for care in the management of impacted teeth that can guide the general dentist toward knowing which cases should be referred and how patients should be informed of risks and benefits of unerupted teeth. These decision points may be delineated according to the following criteria:

1. Is the tooth simply unerupted, or is it impacted?
2. Is the tooth ankylosed during growth, or are there other etiopathologic reasons for failure of eruption?
3. Does the tooth demonstrate a threat to periodontal health of adjacent teeth?
4. Is the tooth carious, is the distal of the second molar carious, or has it undergone internal resorption?
5. Is an abnormal pericoronal or periradicular radiolucency present?
6. Are there signs of acute or chronic infection?
7. Does the patient exhibit pain associated with the impacted tooth?
8. Is the tooth contributing to a malocclusion or skeletal facial deformity?
9. Does the tooth impinge on vital structures?
10. Does the impacted tooth have an effect on systemic health?
11. Does the patient have a syndromic or developmental problem associated with unerupted teeth?
12. Does the unerupted tooth represent a potential important functional component of the masticatory system?

10.2.1 Is the Tooth Simply Unerupted, or Is It Impacted?

Teeth that are unerupted during normal growth and development are not impacted. There are predictors of impaction that might indicate future impaction. For example, Ricketts arcial growth analysis of mandibular vertical and horizontal ramus growth demonstrated that persistence of the third molar in the vertical ramus might be a strong predictor of impaction (Ricketts 1972). His demonstration of the downward and forward growth of the mandible showed that lower mandibular plane angles and longer horizontal ramus length resulted in less impaction of third molars. Third molars that remain above the occlusal plane in the vertical ramus by age 12 nearly always remain impacted, while those unerupted teeth in the horizontal ramus nearly always erupt. On the other hand, Kugelberg's work demonstrated that the period

between ages 20 and 30 surprisingly resulted in eruption of nearly half of teeth that would have been presumed to be impacted in a longitudinal third molar observation study (Kugelberg et al. 1991). The 60% of third molars that were mesial or vertically impacted at age 20 and followed without extraction had an overall impaction rate of 32% at age 30. Thus, with 100% of third molars impacted at age 15 and observed, just a third of retained third molars remained unerupted at age 30.

Nonetheless, many unerupted teeth are removed in midteens/late teens, though they are not yet determined to be impacted, but justifiable removal may be carried out for orthodontic purposes, to prevent later greater risk of inferior alveolar nerve injury, or because of the decreased risk of complications in removal in younger patients.

In 1933, Pell and Gregory attempted to define third molar impaction based upon a classification system describing the length of the dentoalveolar process and the location of the vertical ramus, whereby inadequate arch length produced impaction (Pell and Gregory 1933). Teeth entirely in the horizontal ramus are Class 1, those less than half in the vertical ramus are Class 2, and those in with a majority in the vertical ramus are Class 3. The subclassification is type A for at the occlusal plane, type B for a tooth above the cementoenamel junction (CEJ) of the second molar, and type C for a tooth apical to the CEJ of the second molar (Fig. 10.1). Anatomically, a Class 1A tooth would have the greatest ease of removal with the lowest morbidity, and a Class 3C would have the highest difficulty and risk for morbidity. This classification system has now been adapted for assessment with cone beam CT (Maglione et al. 2015). For impacted premolars, loss of arch length due to pediatric caries is the most common reason for impaction.

As a practical matter, impaction is a diagnosis made on the basis of the preponderance of evidence in a clinical situation. Is there an anatomic obstruction to eruption? Is there adequate arch length to permit eruption into a functional aspect of the dentoalveolar process?

10.2.2 Is the Tooth Ankylosed During Growth, or Are There Other Etiopathologic Reasons for Failure of Eruption?

Deciduous molars and permanent first and second molars in the mandible are the most commonly ankylosed teeth causing failure of eruption as well as diminished vertical growth of the dentoalveolar process in the affected region (Fig. 10.3a). Ankylotic failure of eruption is often identified by the progressive impaction of the tooth over time, by dilacerations of the root, and by the absence of a portion of the periodontal ligament with associate direct alveolar bone contact with the tooth (Fig. 10.3b). Unerupted maxillary canines that do not respond to exposure and orthodontic traction can be noted to be ankylosed (Plaisance et al. 2017).

10.2.3 Does the Tooth Demonstrate a Threat to Periodontal Health of Adjacent Teeth?

Analysis of the regional and general periodontal health of patients with impacted third molars has been an object of assessment in multiple longitudinal third molar

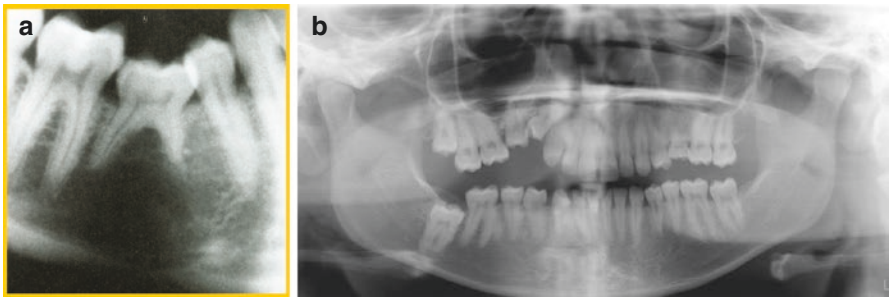

Fig. 10.3 (**a**) Impaction of a deciduous second molar due to ankylosis. (**b**) Impaction with ankylosis is noted for teeth numbers #4, 5, and 31. Note progressive impaction of these teeth due to ankyloses in the dental arch during vertical development of the jaws

studies. Increased pocket depth, increased levels of inflammatory mediators, and increased gingival index have been noted in the second and first molar and to a lesser extent in the entire quadrant where a partially erupted third molar is present in the mandible. Substantial periodontal pathology has been observed in patients with asymptomatic impacted third molars, and that pathology has been noted to be progressive (Blakey et al. 2002). The microorganisms in the gingival crevicular fluid of impacted third molars have been noted to express orange and red organisms according to Socransky's criteria, meaning that they are those organisms associated with progressive bone loss (Socransky and Haffajee 2002). The prevalence of those organisms in impacted third molars has demonstrated colonization by invading neutrophils resulting in chronic inflammation and bone loss due to periodontal pathogens. This can also be measured by levels of inflammatory mediators, cytokines in the pericoronal tissues. White demonstrated elevated levels of IL-1B and PGE2, two cytokines associated with periodontal bone loss in partial bony impactions (White et al. 2002). Additional longitudinal studies on impacted third molar retention show a greater risk of periodontal bone loss progressive over time in the quadrant where the partially erupted impacted third molar remains, at least for mandibular teeth. Kugelberg et al. noted that extraction of the third molar during the course of impaction prior to the age of 25 results in recovery of pocket depth and bone loss, while removal later in life does not accrue that benefit. (Kugelberg et al. 1991). Early removal of mesioangular impacted third molars had beneficial effects on pocket depth and periodontal health (Fig. 10.4).

10.2.4 Is the Tooth Carious, Is the Distal of the Second Molar Carious, or Has It Undergone Internal/External Resorption?

During development, impacted third molars do not gain the functional anatomic resistance to caries equivalent to other teeth. This is due to the variable deep pits and fissures in the crown and decreased extent of enamel development. The result is a

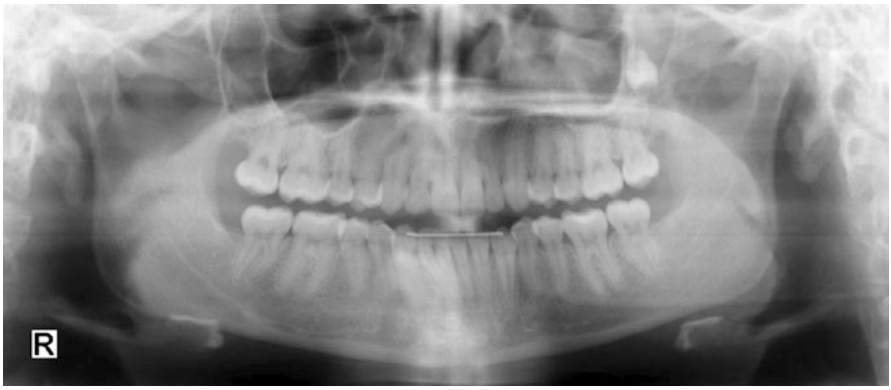

Fig. 10.4 Normal osseous recovery after removal of third molars for orthodontic purposes

high caries rate in erupted and partially erupted third molars noted to be high in White's studies with a progressive extension of caries in observational studies. Erupted third molars have a higher risk of cervical caries in the older patient as well. Resorption of the cervical portion or roots of adjacent teeth is associated with impaction as well as internal and external resorption of the impacted tooth. In young adults, the risk of caries on the distal of the second molar more than doubles if a partial bony impacted third molar is present (Assael 2002). This may result in pulpal necrosis of the impacted or adjacent teeth with subsequent symptoms. Resorption of the impacted tooth is also associated with the neurovascular bundle in the mandible and may also be associated with narrowing of the neurovascular bundle.

10.2.5 Is an Abnormal Pericoronal or Periradicular Radiolucency Present?

All impacted teeth will exhibit a pericoronal radiolucency. This represents the coronal dental follicle which envelops the enamel of the unerupted tooth. The epithelial attachment of this follicle should be at the cervical margin of the tooth in the unerupted state such that the developing periodontal ligament has a direct interface with adjacent alveolar bone. When the unerupted tooth is in a pathologic state, inflammation and epithelial migration of the pericoronal cap cause expansion of the pericoronal radiolucency to both enlarge its pericoronal components and to encompass a portion of, or all of, the root of the impacted tooth. This process results in a dentigerous cyst, which will undergo osmotic expansion until it is disrupted by eruption of the tooth or surgical decompression or removal. When pericoronal expansion occurs in an erupting tooth, it is termed an eruption cyst which once broken will through gingival apoptosis allow the eruption of the tooth and development of the gingival crevicular epithelium.

Other pathologic conditions also can produce periradicular radiolucency. These include most commonly keratocystic odontogenic tumor (aka odontogenic keratocyst)

or other odontogenic tumors such as ameloblastoma. Adenomatoid odontogenic tumor is also noted to occur nearly exclusively in association with impacted maxillary canines (Al-Shimari et al. 2017).

The prevalence of pericoronal pathology should encourage the submission of all such tissue removed during the course of impaction removal to the pathologist, but this is by no means a routine standard of practice. The overall risk of pathology has been evaluated associated with the submission of otherwise normal pericoronal tissue to oral pathology services where all removed soft tissue is submitted. A study of 2646 such specimens reveals that 67% were non-pathologic, while 28% represented dentigerous cysts and 3% keratocysts, and the remaining were various other tumors most notably 13 ameloblastomas and 6 carcinomas (Curran et al. 2002). Overall in just under 1 in 20 cases, the pathologic diagnosis resulted in a need for subsequent clinical action due to the risk of progressive disease.

10.2.6 Are There Signs of Acute or Chronic Infection?

Anamnestic assessment (patient history) should assess a recent history of signs of infection.

In addition to physical evaluation noted above, objective findings of the clinical examination should be recorded, including range of motion, swelling, pain, fever, and fetor. In the adolescent and young adult, tonsillitis with beta-hemolytic strep is also associated with pericoronal inflammation in third molars. Radiographic signs of chronic infection such as mottling of bone or focal bone loss should be noted.

10.2.7 Does the Patient Exhibit Pain Associated with the Impacted Tooth?

Pain associated with impacted teeth is one of the frequent reasons for their removal. In the ramus of the mandible, myofascial pain is often noted in chronic impaction. Bone pain is noted as well, but the reasons for this when no infection is present have not been discerned. Of note as a possible cause is the increased levels of osteolytic cytokines associated with impacted teeth including proinflammatory cytokines that could even in the absence of infection elicit pain. While this pain commonly associated with eruption (aka teething) is a temporary phenomenon that ceases with the eruption of the tooth, patients with impacted teeth may suffer from periodic exacerbations of bone pain associated with the impaction.

10.2.8 Is the Tooth Contributing to a Malocclusion or Skeletal Facial Deformity?

The role of impacted teeth as etiologic in malocclusion is, after numerous studies, remains unclear. Lower incisor crowding and maxillary crowding are associated with the presence of impacted teeth especially mesioangular impacted teeth

(Beeman 1999). This association has caused orthodontics for decades to recommend the removal of impacted third molars especially when young adults are going into retention therapy after full-banded orthodontics. There is however scant evidence that this association is one of the causes and effects. There are some interesting studies in this regard.

Early studies indicated the reasons for incisor crowding after orthodontics to be non-impaction related. An Iowa study of models with a split-mouth design took post-retention orthodontic patients and removed third molars unilaterally. Less crowing was noted on the extracted side. Attempts to use pressure transducers after extraction actually showed lower interdental forces on the non-extraction side. The effect of impacted teeth on occlusion is multifactorial and has not been categorized sufficiently to be a guide to treatment decisions. Impacted mandibular third molars are associated with more mesial angulation of mandibular first and second molars and more incisor crowding assessed with contemporary imaging methods (Hasegawa et al. 2013).

10.2.9 Does the Tooth Impinge on Vital Structures?

Impingement on adjacent teeth is associated with external root resorption and periodontal bone loss. The lingual nerve is impinged upon by lingually inclined and vertical/distoangular impactions of the mandible third molars. Chronic pericoronitis of these teeth is associated with adherence of the lingual nerve to the follicle markedly increasing the risk of lingual nerve injury at the time of removal. Determination of the risk of inferior alveolar nerve injury is dependent upon the factors indicating direct impingement. These have been noted radiographically by Rood and others to include loss of the white line of the inferior alveolar canal, narrowing of the inferior alveolar canal, darkening of the root of the impacted tooth as seen on panorex, and deflection of the root. Periapical film is inadequate to evaluate this risk (Fig. 10.2). While the background risk of inferior alveolar nerve injury is noted to be about 1%, multiple positive radiographic features noted here increase the risk to as high as 24%. Thus, radiographic and clinical assessment of the risk of nerve injury will guide a decision to carry out elective removal of impacted mandibular third molars.

Impacted canines occur far more frequently in the maxilla where damage to the lateral incisor and less so to the central incisor can result in the loss of these teeth. Such teeth are variously observed, exposed and orthodontically erupted, or removed. The relationship of the impaction on vital structures including teeth and the floor of the nose can guide treatment decisions.

10.2.10 Does the Presence of an Impacted Toot Have an Effect on Systemic Health?

If inflammatory mediators are present producing local inflammation and immune response, does this have an impact on systemic health. Such impacts have been

studied for untreated periodontal disease and caries in populations such as those with atherosclerotic disease and pregnant patients with remarkable associations noted. Moss reported on the systemic impact of impacted third molars with periodontal pathology (Moss et al. 2006). This study found that third molars with greater than 4 mm of pocket depth had association with more negative health outcomes including gestational age less than 37 weeks and elevated serum levels of C-reactive protein during the study. It should be noted that this was an observational study in which the association does not demonstrate cause and effect; however levels of these inflammatory mediators drop after the removal of such impacted teeth including in the adjacent second molar. The recommendation is that for systemic purposes early third molar removal is recommended when pocket depth is greater than 4 mm.

10.2.11 Does the Patient Have a Syndromic or Developmental Problem Associated with Unerupted Teeth?

Cleidocranial dysplasia is associated with impacted and supernumerary teeth, often with major failure of eruption and not functional dentition. Other syndromes are associated with failure of eruption or delayed eruption. Multiple unerupted or supernumerary teeth should initiate a genetic consultation to determine whether there is an inherited underlying cause.

10.2.12 Does the Unerupted Tooth Represent a Potential Important Functional Component of the Masticatory System?

Unerupted teeth can be successfully brought into good function in the oral cavity by surgical exposure, assisted eruption, and uprighting. This is commonly done for canines and mesioangular molars (Magkavali-Trikka et al. 2018). Erupted teeth can also be removed to facilitate the eruption of delayed teeth. This is especially the case for first bicuspids associated with impacted second bicuspids and blocked-out canines. Loss of first molars during growth due to caries will often permit the facilitated eruption of third molars in order to achieve a two molar occlusion in the affected quadrant. In the past this was sometimes done with third molar to first molar transplant, but more contemporary therapy allows for the mesial orthodontic movement of the second and third molar. The removal of impacted third molars or other impacted teeth may be deferred when the adjacent teeth in function exhibit advanced caries (or rarely early aggressive periodontal disease). Even the late loss of a first or second molar due to caries can permit the subsequent assisted or spontaneous eruption of the impacted third molar.

10.3 Risk Assessment in Third Molar Removal

A fundamental question in risk assessment is "Should asymptomatic third molars be removed?" This question relates to risk since it is clear if there was no morbidity, risk, or mortality associated with the removal of asymptomatic nonfunctioning impacted teeth, then they should all be removed. However notable risk for temporary disability, permanent injury, and even death can result from this surgical intervention. Thus, indications for care must take into account a demonstrated benefit that outweighs these real if rare substantial complications.

What is the risk of surgical catastrophe after third molar removal? Every experienced surgeon has seen hospitalization for bleeding or infection after impacted tooth removal, and many have seen severe systemic complications including death associated with anesthesia and surgery for removal of third molars. Risk of death during ambulatory anesthesia for oral surgery has been variously reported in ranges from 3 in 5,000,000 to as high as 1 in 50,000 cases. Hospitalization from bleeding occurs in about 1 in 10,000 cases and permanent lingual or inferior alveolar nerve injury in about 1% of cases.

10.3.1 Indications for Third Molar Removal

When all the indications for removal are assessed, the evaluation of third molars has driven most health systems toward removal either electively or as a result of pathology. Indeed, even in societies where elective third molar removal is not usual as in Norway, 85% of elder patients have no third molars present (Hugoson and Kugelberg). Reasons for removal most commonly include pericoronal inflammation, periodontitis, caries, jaw pathology, and for preprosthetic reasons.

All surgical procedures must include a statement of the indications for care. While at minimum, this includes a diagnostic code, a narrative indicating the pertinent findings from assessment as noted in the previous assessment is needed to justify what will be a substantial surgical procedure, the removal of an impacted tooth. An evidence-based assessment of the benefits of removal that are more influential in guiding treatment than acceptable risk should be noted. This is an individualized process that should respect the individual needs and desires of the patient and patient autonomy.

10.3.1.1 Findings and Indications for Care

Example 1: This 22-year-old male presents because of mesioangular impaction of a left mandibular third molar associated with inadequate arch length, chronic pericoronal inflammation, and 6 mm. pocket depth on distobuccal of the mandibular second molar.

Example 2: This 40-year-old clarinet player presents for assessment of a full bony impacted mandibular third molar with a 3 mm pericoronal radiolucency. Rood classification indicated deflection of the root and narrowing of the inferior alveolar

canal. Treatment plan is to inform the patient of symptoms to be on alert for and to return in 1 year for examination and radiographs part of routine dental follow-up. No extraction indicated at this time.

Indications for third molar removal have been assessed by consensus and evidence and vary among health systems. In Europe impacted teeth are retained if they are fully impacted with no oral cavity communication and no associated osseous pathology. If erupted they are retained if gingival tissue is keratinized and pocket depths are less than 4 mm with no bleeding or drainage on probing and no caries (Wower and Nielsen 1989).

As a practical matter, those factors that affect the clinical decision to remove an impacted tooth include the presence of symptoms, age of the patient, health status of the patient, concomitant risk factor assessment, pocket depth, presence of inflammatory signs, proximity of vital structures, and presence of additional pathology.

10.3.2 Evidence-Based Assessment of Surgical Technique and Perioperative Care

A Cochrane review of surgical techniques for removal of mandibular wisdom teeth was performed in 2014 which demonstrated a cacophony of methods for removal (Coulthard et al. 2014). This review of 35 trials indicated a high risk of bias due to the observes and the preferred methods of the operators. Triangular and envelope flaps were compared; irrigation methods, technique of bone removal, use of retractors closure technique, and use of surgical drains and coronectomy were compared. No conclusions would be made that would support in changing preferred practice of the operating surgeon with regard to comparative techniques.

Decision points in the operative technique for removal of impacted teeth include:

1. Adjunctive medical management: steroids, analgesics, antibiotics
2. Access incisions
3. Ostectomy and osteotomy
4. Sectioning of the tooth
5. Preservation of vital structures
6. Management of the osseous defect
7. Closure
8. Postoperative instructions

10.4 Adjunctive Medical Management: Steroids, Analgesics, and Antibiotics

Steroids are a class of anti-inflammatory drugs based upon the steroid ring of cortisol, a hormone that modulates inflammation by decreasing movement of fluid into the extracellular space, thereby decreasing edema, and inhibiting the

migration through chemotaxis of inflammatory cells, thus reducing the effects of inflammatory mediators in the surgical site. In the removal of impacted teeth, they are demonstrated to reduce trismus, swelling, and pain in the immediate postoperative days.

Analgesics: Postoperative opioids have been the bulwark of pain management following impacted tooth removal for decades. Recent attention to the adverse effects of these drugs have included an understanding that prescription opioids, especially in the young adults, carry substantial risk of subsequent abuse and potential addiction risk. In addition, recent analgesic studies demonstrate that nonsteroidal anti-inflammatory drugs, most prototypically ibuprofen, demonstrate equivalent or even superior analgesic effect, especially when used preemptively, as a preoperative dose of 400–600 mg of ibuprofen followed by scheduled postoperative dosing. Effectively addressing postoperative patient has the additional advantages of supporting adequate postoperative oral intake and return to activities of daily living, both of which are associated with more rapid recovery from surgical interventions.

Recently nonsteroidal anti-inflammatory drugs have been injected into the surgical site concurrent with impacted tooth removal with good effect (Gorecki et al. 2018). The use of rescue medication increased by 16 h for the highest dose of submucosal diclofenac.

Antibiotics: While antibiotics are commonly prescribed in conjunction with impacted tooth removal, no standardized approach to this has reached the practicing community. Antibiotics are given preoperatively or during the procedure or postoperatively or not at all. Morrow examined whether postoperative antibiotic use had an impact on inflammatory complications through a practice-based research model. Inflammatory complications were low in both groups 4.3% in the antibiotic group and 7.5% in the no antibiotic group, a 40% drop in risk (Morrow et al. 2018). Contemporary assessment of antibiotic use associated with removal of teeth indicates it is overused and not in an evidence-based fashion (Kim et al. 2018). Evidence-based interventions have substantially reduced the utilization and improved the quality of utilization of antibiotics in association with impaction surgery, while the use of antibiotics remains well established (Piecuch et al. 1995).

10.5 Access Incisions

Access incisions for removal of impacted teeth must address the need to preserve or reconstruct adequate attached gingival tissue abutting the surgical site and for the adjacent teeth (Fig. 10.5). There is no single correct flap designed for any given surgical situation, and planning should involve a balance between the need for complete access to the surgical site and the need to preserve critical components of soft tissue associated with osseous defects and the dentition. Indeed, studies comparing flap designs have not demonstrated appreciable differences at 90 days after exodontia, though releasing incisions have been associated with higher initial

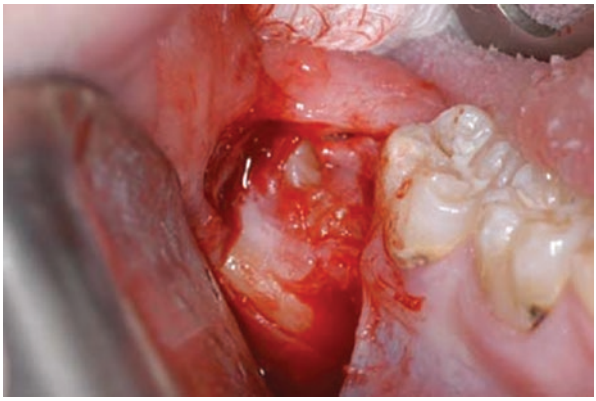

Fig. 10.5 Triangular flap (with anterior release) for removal of mandibular third molar

symptoms and swelling (Ottria et al. 2017). Gingival margin incisions have the advantage of permitting replacement without the risk of vertical defect, while releasing incisions can give more substantial access to the surgical site for ostectomy and tooth sectioning. For third molars, releasing incisions are always performed lateral posteriorly, but if the flap is released anteriorly as well, it is referred to as a triangular flap. Triangular flaps can offer greater visibility of deep impactions but, due to incising of the buccinator muscle, result in greater buccal swelling and trismus.

10.6 Ostectomy and Osteotomy

Cutting of bone (osteotomy) and removal of bone (ostectomy) are performed in order to gain access to the impacted tooth for removal. Small areas of very thick bone, such as on the external oblique ridge of the mandible, normally undergo ostectomy, wherein the cut bone is removed, while areas where a thin bone layer may be covering the impacted tooth as in the maxilla for an impacted third molar or canine can undergo osteotomy with osteoperiosteal flap, preserving the thin layer of buccal bone attached to the overlying periosteum. Bone that is removed in association with impacted teeth should remove cortical bone in direct apposition to the periodontal ligament or crypt of the impacted tooth of a sufficient thickness to permit placement of an elevator. Too aggressive removal of bone may result in an excessive loss of anatomic integrity of the bone and increase the risk of fracture of the jaw during elevation of the tooth (Fig. 10.6).

Due to the risk of tissue emphysema or venous air embolism, routine high-speed dental handpieces are not suitable for removal of bone or sectioning impacted teeth. Such air embolisms have been demonstrated to be a fatal outcome of their misuse of the handpiece in the dental operatory. A designated surgical handpiece such as the Hall air drill does not permit the anterior escape of air that can result in air embolism or tissue emphysema.

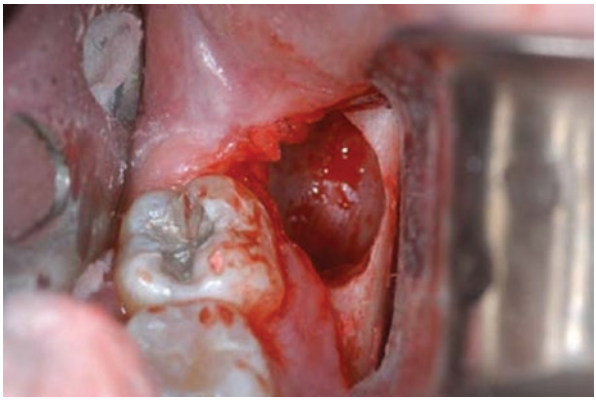

Fig. 10.6 Appropriate defect associated with removal of mandibular third molar

10.7 Sectioning of the Tooth

Impacted teeth may be sectioned prior to removal for several purposes: to provide removal of the tooth through a more limited osteotomy access, to allow the manipulation of curved roots separately to permit a pathway for removal, and to protect vital structures such as the inferior alveolar nerve from the pressure of luxation. Teeth are sectioned in two basic fashions, to separate the crown from the roots or to separate roots from one another. Maxillary third molars are very rarely sectioned due to the softness of maxillary bone the path of removal along a distobuccal track. Maxillary canines often benefit from sectioning the crown from the root to facilitate removal in a dentoalveolar site of crowding, especially adjacent to the maxillary lateral incisor. Mesioangular third molars are routinely sectioned vertical separating the mesial from the distal crown and root, while vertical and distoangular impacted third molars in the mandible generally have the crown sectioned from the root followed by crown delivery and root delivery in one or two root segments.

10.8 Preservation of Vital Structures

For maxillary impacted teeth, violation of the maxillary sinus with disruption of the Schneiderian membrane can result in sinusitis or an oral antral fistula. During removal of mandibular third molars, a lateral posterior flap design must be used to protect the lingual nerve which is coursing just directly distal to the second molar and on the lingual crest of the mandible. Some surgeons advocate the retraction of lingual tissues to prevent lingual nerve severing, while others prefer to not manipulate lingual tissues due to the risk of traction nerve injury of the lingual nerve. Removal of the roots of impacted teeth should be done with judicious force understanding the risk to the inferior alveolar nerve and toward displacement of roots beyond the boundary of the mandible, especially into the submandibular space.

10.9 Management of the Osseous Defect

Removal of impacted teeth necessarily results in a substantial osseous defect in a region where regeneration is often needed to regain osseous strength and to restore periodontal health. Various bone preservation and guided tissue regeneration techniques have come into common use to regain healthy bone and soft tissue. These have included the use of platelet-rich plasma, cadaver bone, bone substitutes, bone morphogenic proteins, and other bone-promoting substances among others. Membranes have also been used to enhance gingival epithelial reattachment. While all of these are reports, study of the impaction site in healing without these methods indicates that they are not routinely desirable or necessary where normal health can be anticipated. Such normal healing can be anticipated in patients under the age of 25, with no medical comorbidities and no preexisting pathology such as greater than 4 mm. pocket or coexisting osseous pathology.

10.10 Closure

Primary closure of surgical sites after odontectomy can result in increased swelling due to contained hematoma and greater postoperative edema due to fluid retention. On that basis, adaptation of critical portion of the wound such as gingival attachment at ling angles is performed while permitting partially open socket to permit the egress of blood and extracellular fluid. As a technique for this in mandibular third molar removal, a single suture to adapt the distal buccal line angle of the second molar is often performed after envelope flap with distal release. Drains may be used after deep impaction, and these have shown some benefit but require greater maintenance and follow-up which has limited their routine use (Fig. 10.7).

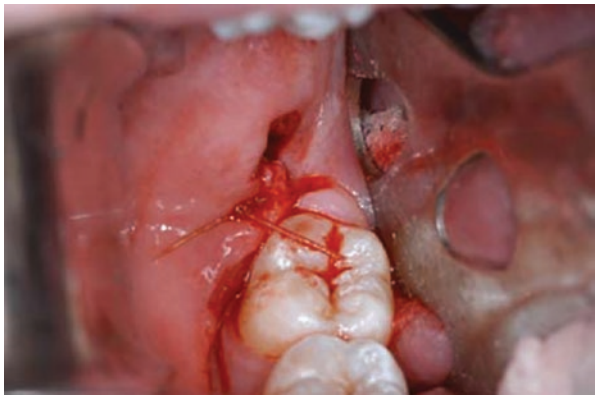

Fig. 10.7 Single suture on distobuccal line angle of second molar to close third molar site

10.11 Postoperative Instructions

Postoperative instructions after impaction surgery include the following domains:

Activity: Can the patient drive, operate machinery, and make decisions?

Diet: What food and liquids and in what quantity should be consumed?

Medications: Does the patient understand their analgesic use and other medications that may have been prescribed?

Medical comorbidities: Does the patient know how to manage systemic diseases and associated medications during the postoperative period?

Precautions: Does the patient know what to expect regarding swelling, bleeding, and pain, and do they know self-care plans regarding packs, ice, and analgesia?

Contact: Do they have 24/7 contact information to get help or answer queries?

10.12 Complications of Care

10.12.1 Methods to Mitigate and Treat the Risks of Third Molar Removal

The overall risk of complications after removal of impacted third molars is substantial. Ons sing;e-center reported a complication rate of 17% with dry sockets accounting for the majority of cases. Interestingly, since most surgeons are right-handed, the incidence of complications is higher on the left (contralateral side) of the operating surgeon, indicating a potential iatrogenic aspect of surgical complications (Schwartz-Arad et al. 2017).

10.12.2 Dry Socket

Dry socket is an acute localized osteitis of the extraction site in which the initial clot fails to organize and undergo fibrinogenesis, leaving bacterially contaminated exposed bone with associated fetor and pain. It is never a simple dry socket when pus is present or when it is associated with regional cellulitis. Dry socket is not an infection, and it does not respond to antibiotics; however if an infection is misdiagnosed as a dry socket, it may progress dangerously if treated with packing rather than drainage.

Essential ways to differentiate dry socket from postoperative infection include the following, increased redness, tenderness/pain, temperature, and swelling (rubor, dolor, calor, tumor), which are more indicative of postoperative infection than dry socket. Laboratory values may be useful in which a leukocytosis with a shift to the left is noted on CBC with infection and not with dry socket and increase in systemic temperature is noted in infection but not dry socket.

Dry socket has been associated with various factors that could cause the failure in the formation and retention of fibrin in the extraction site. Some of these include cigarette smoking, use of birth control pills, menses stage, presence of pathogenic bacteria, and food impaction.

Prevention has been promoted through the use of topical antibiotics, prophylactic systemic antibiotics, copious saline irrigation, and chlorhexidine irrigation and the use of steroids. Information on these methods has contrary assessments including some that demonstrate increased risk for the use of steroids and antibiotics.

Treatment of dry socket is based upon reduction of the bacterial and inflammatory product burden in the socket via irrigation with normal saline. Such irrigation often removes much detritus form the site including necrotic clot, food, and bacterial film. If pus is noted during examination or irrigation, it is NOT a dry socket. Instead a postoperative infection is present which needs to be treated with drainage and appropriate antibiotic. If, after exam and irrigation, a dry socket remains the working diagnosis, gentle packing of the site with quarter inch plain or iodoform gauze along with a topical local anesthetic and an obtundent is often used. While eugenol is a very effective obtundent, it is also neurotoxic and tissue toxic when concentrated. Thus, other obtundents such as balsam of Peru are often used in dry socket dressings. FDA-approved dry socket dressings, commercially available, attend to these issues adequately.

10.12.3 Postoperative Cellulitis and Abscess

Acute postoperative infection after third molar removal, like other infections after surgery, typically occurs 3–5 days after the procedures. While normal swelling after a surgical procedure typically peaks at 1–3 days after surgery, the patient with a postoperative infection will have a further increase in swell typically at days 3–5 postoperatively. Additionally, fever, dehydration, trismus, redness, pus, difficulty swallowing, tachypnea, and dyspnea may be noted.

Postoperative infection after impaction surgery is often a surgical emergency requiring imminent drainage of the infection, parenteral antibiotics, fluid resuscitation, and airway management.

10.12.4 Osseous Defect, Fracture, and Osteomyelitis

The osseous defect after removal of impacted teeth can be substantial so that measure to minimize this defect has included the use of bone grafts and tissue-guided regeneration. Osteomyelitis after impaction removal is more frequent in older patients and those with medical comorbidities such as osteomyelitis. While fracture of the mandible can occur during removal, it is more frequent in the weeks and months following removal due to progressive osteolysis associated with recovery or subsequent osteomyelitis.

10.12.5 Oral Antral Fistula

Maxillary third molar removal is fairly commonly associated with oral antral communication that is difficult to diagnose since its presenting finding may simply be a deep periodontal pocket to the distal of the maxillary second molar along with

sinusitis. Communication with the sinus can be considered routine for any deeply impacted maxillary tooth, so that careful attention to adequate closure and sinus precautions in postoperative instructions is needed.

10.12.6 Inferior Alveolar Nerve Injury, Buccal Nerve Injury, and Lingual Nerve Injury

Temporary or permanent damage to the inferior alveolar or lingual nerve can result in loss of sensation in the lip, chin, tongue, and cheek and loss of taste in the affected area and neuropathic pain. Such injuries require appropriate referral to an expert in the surgical management of maxillofacial nerve injuries since early treatment is often effective (Figs. 10.8 and 10.9).

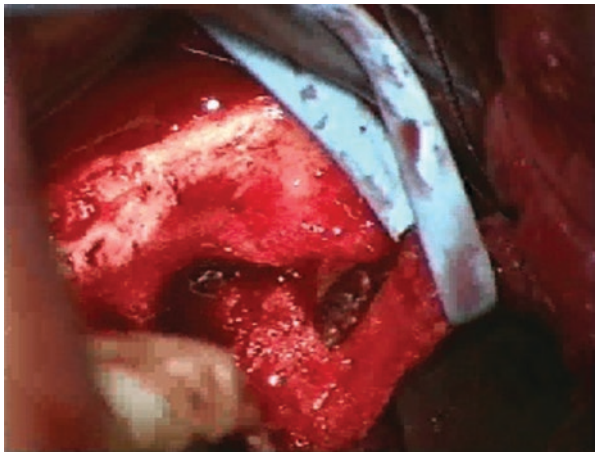

Fig. 10.8 Lingual nerve exposure and injury at the time of third molar removal

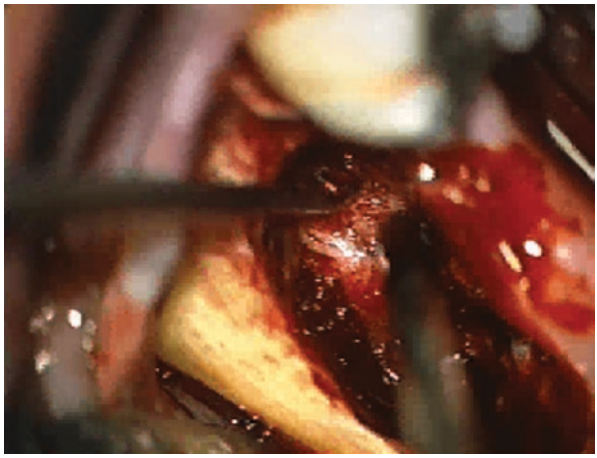

Fig. 10.9 Inferior alveolar nerve in mandibular third molar site, partially severed

10.13 Summary

Careful diagnostic evaluation of unerupted teeth is needed to determine if they are impacted and whether they exhibit the presence or the risk of associated pathology. A decision to remove an impacted tooth should be evidence-based. Removal of impacted teeth is an in-depth surgical procedure with structured procedural, follow-up, and assessment components.

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Surgical Complications

11

Christine Niekrash and Michael T. Goupil

"There is nothing more stimulating than a case where everything goes against you."
Sherlock Holmes in—The Hound of the Baskervilles

Abstract

If a dental practitioner performs surgery, he or she will have complications. This chapter will describe the evaluation and management of the most common surgical complications that might occur when performing dentoalveolar surgery.

11.1 Introduction

A surgical complication can be defined as an unanticipated problem that arises following, and is a result of, a provided treatment or procedure. Since pain and swelling following a surgical procedure is expected, technically they should not be considered surgical complications. But they would be considered complications if there is an inordinate amount of pain and/or swelling, meaning more than anticipated for a particular surgical procedure.

This chapter is divided into three sections: preoperative, intraoperative, and postoperative issues. This chapter covers treatment options and, when possible, prevention strategies. Though most of the surgical complications are well known, there is not necessarily a significant amount of published literature concerning these issues. Much of the available information is anecdotal in nature, being passed from one

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generation to the next. The best way to minimize surgical complications is attributed to Harold Kent in 1947: "Know your patient, know yourself'" (Holland 1948). This advice, seven decades later, continues to be valid.

11.2 Preoperative Issues

The goal of preoperative preparation is to prevent adverse events by excellent preparation and identification of possible threats to patient safety. Provider team members should also be encouraged to speak up if they observe a problem or a potential one.

Review Medical History, Family Medical History, and Medications, Including Over-the-Counter Pharmaceuticals and Herbal Supplements: The goal is to recognize a compromised patient and initiate appropriate adjunct therapy. Past and present illnesses, medications presently taken (prescription and over-the-counter), allergies, tobacco use, and possible need for premedication before dental treatment (antibiotics, sedation, pain control) should be identified. The patient should confirm medications taken the day of the dental procedure, including aspirin. Examples of diseases that could affect a patient's treatment include cardiovascular diseases, hypertension, hypotension, diabetes, blood or clotting disorders, and respiratory disorders. If necessary, the patient's physician should be contacted to provide a medical consultation. The dentist must also identify patients with special medical conditions affecting treatment, such as pregnancy or transmissible diseases, including HIV-/AIDS-positive individuals, active tuberculosis patients, and hepatitis carriers. Medically compromised individuals are associated with increased postoperative complications (Pierse et al. 2012).

Review Dental History: The patient should be asked about his or her primary dental concern, the chief complaint. Addressing patient's concerns improves patient compliance. Patients should report any history of dental, temporomandibular, periodontal, or oral surgery problems.

Review Radiographs: The area affected by the dental procedure should be adequately imaged prior to the procedure. All aspects of the roots should be visualized, and the restorations analyzed, including those in neighboring teeth. The radiographs should be confirmed to be properly mounted.

Clinical and Oral Examination of the Patient: The clinician should perform an overall appraisal of the patient, including the patient's emotional and mental state, attitude and ability to cooperate, and capacity to open the mouth sufficiently to provide access to the involved teeth. Vital signs should be obtained prior to the dental procedure and monitored during the appointment. It should be noted that anxiety and pain may induce transient hypertension.

Intraoral jewelry should be removed before dental procedures begin.

Avoid Wrong-Site Surgery: This avoidable complication can occur through performing a procedure on the wrong patient, on the wrong tooth, or the wrong side of the mouth, viewing the wrong patient record, or performing the wrong procedure. At the start of the patient visit before any treatment occurs, the patient should state their full name and date of birth, and the provider then confirms that it matches the

dental record. Review the dental record, medical history, radiographs, charts, and laboratory results. Record the tooth number(s) to be treated, and mark the tooth or surgical site on a diagram and radiograph to be included in the patient record. Record a description of the condition of the tooth to be extracted and of adjacent teeth and the reason for extraction. The site may be photographed for additional documentation. Inform the patient (or parent/guardian) of the condition and the location of the tooth and the reason for extraction. Verify which tooth is affected and obtain and document *informed consent* for treatment. The patient should understand the risks, benefits, and alternatives for treatment before consent is obtained. Reconfirm that the radiographs are properly mounted, and visually confirm that the proper tooth has been indicated and charted and is adequately visualized in the radiographs. Utilize a "time-out" to validate correct patient, correct tooth, and correct procedure with the dental assistant present at the time of extraction (check and recheck) (Lee et al. 2007). Clinically, count the teeth before applying forceps on the tooth. If a dental prosthesis is to be delivered, validate prior to extraction that the prosthesis design is compatible with the planned extraction.

Comfort of Practitioner with Procedure and Potential Complications: Procedures beyond the scope of the practitioner's competency and comfort should be referred to the appropriate specialist.

Proper Conditions: All instruments necessary for the procedure should be readily available, sterilized, and carefully examined before use for wear or fragility and sharpness and be replaced as necessary.

11.3 Intraoperative Issues

Any dental procedure can result in complications. The difficulty of tooth extraction is increased when there is a large restoration or carious lesion in the tooth, endodontically treated teeth, curved or dilacerated roots, and dense supporting bone (Le and Woo 2007). This increased challenge can lead to intraoperative complications as well as an increase in postoperative problems.

Anesthetic Concerns: Inadequate anesthesia is probably the most common "anesthetic concern" that one would encounter. This more frequently occurs in the mandible and most likely is technique related. A conventional Halstead technique block has an inadequate anesthesia rate of 31–81% of the time (Malamed 2013a). The practitioner needs to first determine whether the problem is technique related or a patient perception issue. Technique issues include anatomical variation, insufficient time to allow the anesthetic to take effect, and improper technique. Repeating the delivery of the anesthetic usually will correct the problem. Patient perception issues may require the addition of sedation such as nitrous oxide or preoperative oral sedation.

Frequently, the lack of adequate anesthesia is attributed to an infection in the area that may alter the local pH. This may be true when a local infiltration technique is used but not when a nerve block has been performed. The site for performing a nerve block should be sufficiently distant from the "infected tooth," so pH change

should not be a factor as long as the infection is localized. In the case of local infiltration anesthesia where the tissue pH may be a concern, a local anesthetic with a more favorable pKa should be considered such as mepivacaine with a p*K*a of 7.6 as opposed to lidocaine with a p*K*a of 7.9 (Malamed 2013b).

Broken anesthetic needles are rare, but they can occur. When providing local anesthesia, the anesthetic needle should be of sufficient length so that the needle never penetrates to the hub. Should the needle inadvertently break, there should be a sufficient length of needle remaining to allow the provider to calmly grasp the broken end of the needle with a hemostat and remove it. When performing an inferior alveolar nerve block, the needle only penetrates 2/3 to 3/4 of the length of a long (35 mm) needle (Malamed 2013c). The best way to avoid the problem of unrecoverable broken needles is to avoid using short (25 mm) anesthetic needles. Most dental local anesthetic procedures can be provided with a long needle, but they cannot all be safely provided with a short needle.

Fracture of Adjacent Tooth or Restoration: This complication can occur but is usually avoidable and most likely is caused by excessive, uncontrolled, and/or improper use of an elevator (Oliver 2014). A thorough clinical and radiographic examination preoperatively should indicate the probability of this complication occurring. If it is a potential complication, then this risk needs to be covered in the informed consent. If a fracture occurs, the use of a posterior pharyngeal curtain will prevent aspiration of any tooth or restoration material. A temporary restoration can be placed after the planned surgery has been completed. In the case of a cast restoration, recementing the restoration may be all that is required.

Fracture of Tooth Being Extracted: Tooth fracture is the most common complication of exodontia (Venkateshwar et al. 2011). This may be an unavoidable complication, but as stated above, a thorough clinical and radiographic examination preoperatively should indicate the probability of this complication occurring. In particular, the amount of unsupported tooth structure remaining is usually the determining factor of crown fracture. Also, note curvature and divergence of the roots. The patient needs to be made aware in advance of the potential risk of fracture and the need for a more extensive procedure. Consideration for sectioning of the tooth as described in Chap. 9 should be entertained.

In the case of fracture of the roots, small root tips (<3 mm) may be retained with minimal associated infection (Matocha 2000). This is especially true if significant bone would be lost in attempting to remove the root tip. The patient needs to be made aware of the situation and advised that the root tip could potentially be perceived by the immune system as a foreign body and cause problems in the future.

Bone Fractures: Even the extraction of a single tooth should be considered preprosthetic surgery, and the treatment plan should include the future proposed treatment of the edentulous space. In the case of plans for an implant restoration, every effort needs to be made to preserve all alveolar bone at the extraction site. Whereas, if the treatment plan calls for no restoration or a removable prosthesis, then bone removal may be desirable because of the need to remove an undercut.

Fracture of the mandible is always caused by excessive force. When the radiograph demonstrates an extremely large radiolucency associated with a tooth that needs to be removed, the risk of jaw fracture increases and extreme care is required. In that circumstance, it would be more prudent for the patient to be referred to a specialist. In the rare instance when a mandibular fracture does occur, the patient should be immediately referred for treatment.

Excessive force and/or an unusual root formation could result in the fracture on the maxillary tuberosity especially when removing a third molar. When this occurs, there are two issues to consider: (1) this is an alveolar bone fracture and (2) there is a high probability of a maxillary sinus exposure. In most cases of a tuberosity fracture, the planned tooth extraction should not continue. The fractured segment needs to be stabilized, and the tooth planned for extraction might be utilized to obtain the stabilization. This tooth might be fixated to the adjacent tooth with composite resin. A similar situation could occur with other teeth that are being extracted. The occurrence of an alveolar bone fracture needs to be detected while the bone is still attached to the periosteum.

Alveolar fractures, including tuberosity fracture, can potentially be avoided by placing the fingers/thumb of the non-dominant hand along the alveolus of the tooth being extracted when using an elevator and/or forceps. This technique can help identify the potential of alveolar bone fracture and necessitate consideration for an alternative extraction technique, such as tooth sectioning before any damage is done.

Small fracture of the alveolar bone may occur and may not be detected until the extracted tooth is delivered from the oral cavity and inspected to ensure that the entire tooth has been removed. Once the tooth has been removed along with a portion of the alveolar plate, the extraction needs to be examined in the context of the restorative treatment plan. Depending on the restorative plan, no further treatment may be required, and the removal of bone may even be desirable. In those situations when restoration of the site is being considered, especially where an implant restoration is planned, then a bone grafting material and/or membrane may be required to maintain critical alveolar dimensions.

Displaced Tooth, Root Fragment, or Broken Instrument: The displacement of a tooth part or an entire tooth is more likely secondary to excessive force or lack of attention to detail during the exodontia procedure. This is also true of breaking instruments, i.e., elevators and curettes. The use of a pharyngeal screen will help prevent the aspiration or accidental swallowing of these foreign bodies (Photo 11.1). When removing a maxillary third molar, it is prudent to place a retractor behind the tooth, distal to the tuberosity. This will prevent the displacement of the tooth into the pterygomaxillary space. Uncontrolled use of an elevator can result in the displacement of roots into the maxillary sinus (Photo 11.2), into the lingual space, or into the inferior alveolar canal.

Once a tooth has been extracted, it should be carefully examined to ensure that the entire root has been removed. Each root end must be examined to ensure that the root apex is intact and indeed has been removed. Fracturing a tooth during removal is always a potential complication. If a tooth or tooth segment is missing, a thorough

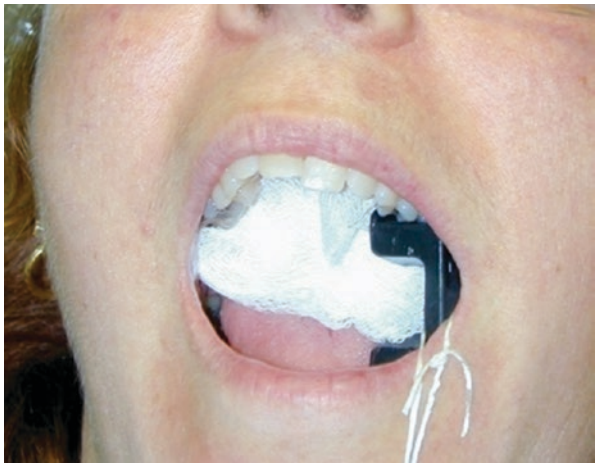

Photo 11.1 Pharyngeal curtain

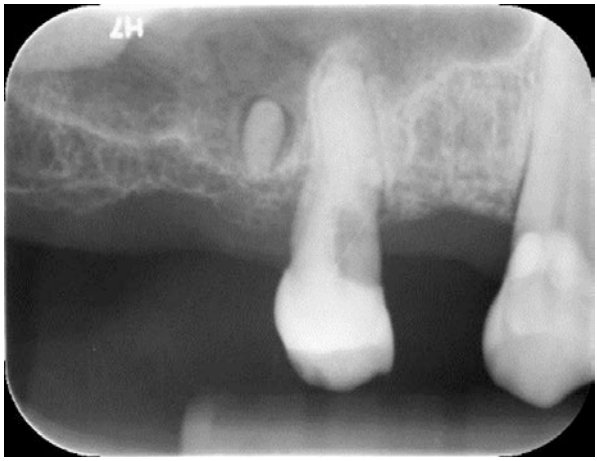

Photo 11.2 Root tip in sinus

examination must be conducted and may include radiographs. First, everything should be removed from the oral cavity. The posterior pharyngeal curtain should be spread out and inspected. The entire oral cavity should be examined with a good light and suction, looking especially under the tongue. Carefully palpate the alveolar ridge in the area of the extraction site. Root tips can be displaced through the alveolar plates. Tooth fragments that have perforated the alveolar plate can usually be easily retrieved by elevating an envelope flap.

If the tooth or tooth segment cannot be located on clinical exam, then dental radiographs are indicated. A panoramic radiograph is initially helpful to locate the missing tooth/fragment. Since this will only locate the missing tooth/fragment in two dimensions, additional films are required for accurate localization. Displacement of a foreign body into the maxillary sinus, inferior alveolar canal,

lingual space, or similar areas has significant consequences, and immediate referral to a specialist is recommended. These displaced teeth/fragments can move deeper into the spaces of the head and neck and result in life-threatening infections.

Maxillary Sinus Exposure: It has been proposed that when maxillary teeth are removed, perforation of the maxillary sinus may be a common occurrence ranging between 0.13% and 4.7% (Krishanappa et al. 2016). In the immune-competent patient, this is usually not a problem and treatment may not be indicated. Checking for a sinus perforation by having the patient perform a Valsalva maneuver may not be a good idea. What may have been only a small perforation requiring no treatment, potentially, could be converted to a larger perforation requiring a complex closure procedure.

Small perforations of less than 3 mm (the size of a small elevator) normally heal well without intervention (Krishanappa et al. 2016). The blood clot in the extraction site provides an adequate barrier between the sinus membrane and the surface oral mucosa. Perforations between 3 and 5 mm in size require minimal intervention. The use of a Gelfoam® plug secured with a "figure 8" suture over the extraction site (Le and Woo 2007) will bring the oral mucosal edges closer together which enhances healing. This, potentially, can also help protect and preserve the clot that is required to act as a barrier between the sinus and the oral cavity. The use of nasal decongestants and antibiotics should be considered. Antibiotics such as amoxicillin or amoxicillin and clavulanate potassium may be preferred as they have a broader coverage that includes sinus cavity organisms, i.e., *Haemophilus influenzae*. The patient should also be placed on sinus precautions, avoiding all types of Valsalva-type maneuvers such as blowing the nose.

Perforations larger than 5 mm require an airtight closure that usually necessitates a flap procedure. A number of flap procedures have been described, including palatal rotation flaps, buccal mucosa advancement flaps, and buccal fat pad flaps (Borgonovo et al. 2012). There are advantages and disadvantages to each technique, but the final result of an air-/watertight closure must be obtained.

The buccal mucosa advancement flap can be performed by most general dentists. A buccal flap is raised using anterior and posterior vertical relaxing incisions. The periosteum may be scored in a horizontal fashion to allow the mucosa to stretch. The buccal flap is then sutured to the palatal mucosa. Once the closure is completed, the patient should be instructed to perform a light Valsalva maneuver to ensure that an air-/watertight closure has been obtained. The patient should be placed on appropriate antibiotics and decongestants. Sinus precautions are required and oral hygiene measures could include a chlorhexidine mouth rinse. Close follow-up is required until satisfactory healing is obtained, and there is no evidence of an oral-antral communication.

Aspiration and Ingestion of Foreign Bodies: Inadvertently swallowed foreign objects enter the GI tract 92.5% of the time and the tracheobronchial tract 7.5% (Wevv et al. 1984). Individuals at higher risk are young children under 2 years old, elderly, sedated, inebriated, mentally handicapped, or traumatized with loss of

conscious, patients with functional impairment of swallowing, and denture wearers (Fields and Schow 1998). A patient under local anesthesia and a patient in a supine or semi-recumbent position are also at increased risk in the private practice setting. Many objects can be aspirated or swallowed. The most common aspirated objects are teeth and root tips. Impression material may be aspirated and may not be seen clinically or on radiographs. Therefore, impressions should be obtained with the patient in an upright position and only after the patient has recovered sufficiently from sedation.

Signs of aspiration are varied and often subtle. Early signs include coughing, gagging, choking, inspiratory stridor, paradoxical breathing, hoarseness, cyanosis, decreased oxygen saturation, tracheal shift, and dullness to auscultation. Aspiration may also result in complete airway blockage or respiratory compromise (Fields and Schow 1998). Dental procedure aspiration is reported to be the second most common reason for foreign body aspiration in the lung (Tiwana et al. 2004).

Ingestion of foreign objects is usually asymptomatic and confirmed after complete passage and identification in the stool. A swallowed object may result in bowel perforation, abscesses, fistula, or obstruction.

Prevention of aspiration or ingestion is key. Place a 4 × 4 in. gauze screen posterior to the surgical site to protect the oropharynx. Patient position may be adjusted to place the patient more upright with the head turned to the side. In addition, small devices should be fastened to a long length of dental floss hanging out of the mouth to allow retrieval if necessary. Instruments should be properly maintained and examined. Broken burs and instruments should be retrieved and pieced together to make sure that all parts have been removed.

Intraoral jewelry and removable dental prostheses should be removed from the mouth before dental procedures are initiated.

If aspiration or ingestion occurs, determine the patient's stability. If the patient is stable, determine whether the object was aspirated or ingested, usually by radiographic examination of the abdomen by PA and lateral radiographs. The patient should be informed and reassured. If the patient is unstable with respiratory distress, summon emergency personnel. An algorithm for treatment has been published by Abusamaan et al. (Abusamaan et al. 2014) and is shown in Fig. 11.1.

Soft Tissue Laceration or Puncture: This complication should be avoided by proper use of elevators and forceps with controlled forces and proper instrument placement. Tearing of soft tissue may be prevented by performing vertical relaxing incisions. However, vertical incisions should be avoided on the posterior lingual surface of the mandible to avoid damage to the lingual nerve. Trauma and force should be minimized and adequate luxation should be performed. Copious irrigation with saline and chlorhexidine should be performed with adequate suction for visualization and patient comfort.

Excessive Intraoperative Bleeding: The source of excessive bleeding should be determined by careful observation. The major source of bleeding is nutrient vessels in the alveolar process. The causes are usually failure to adequately debride granulation tissue in the socket, tissue tearing, or rebound vasodilation after epinephrine injection.

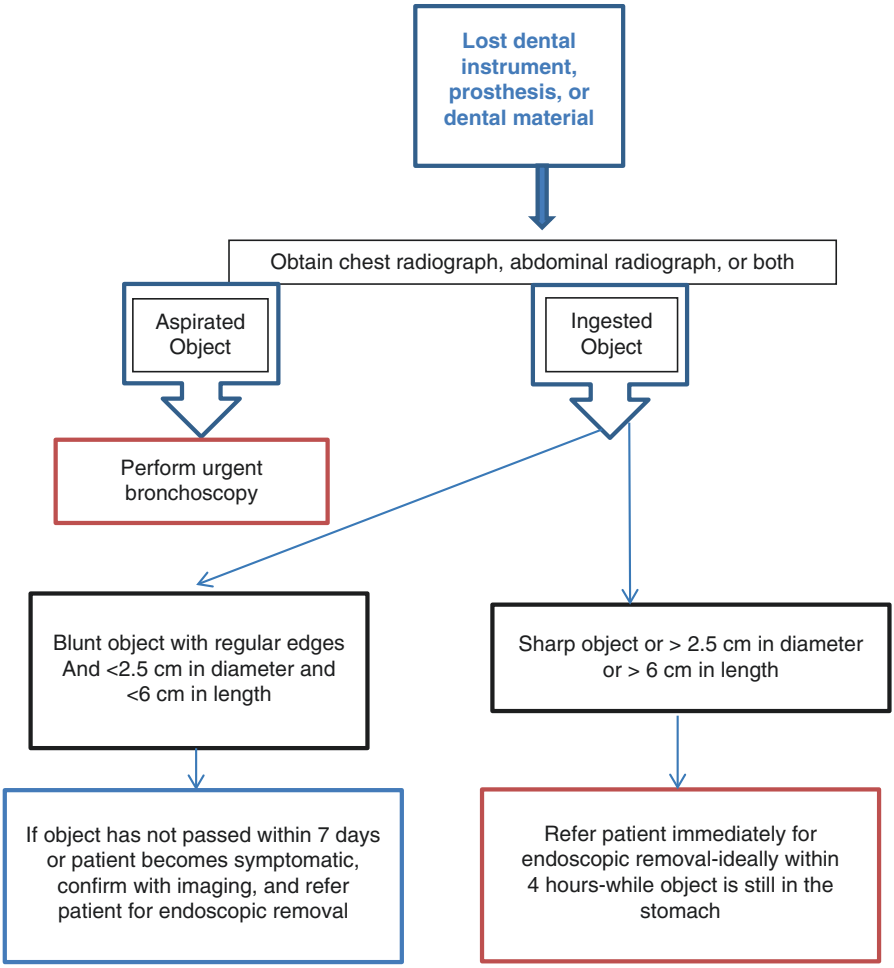

Fig. 11.1 Algorithm for the evaluation and treatment of aspirated or ingested objects. Adapted from Abusamaan M, Giannobile WV, Jhawar P, Guaratnam NT (2014). Swallowed and aspirated dental prostheses and instruments in clinical dental practice. JADA 145(5):462

To treat bleeding, apply pressure by placing a folded 2 × 2 in. gauze in the socket and asking the patient to bite down firmly for at least 15 min. The patient should be in an upright position to diminish venous pressure in the head. The socket is then reexamined. If bleeding persists, then consider placing coagulant materials into the socket. Ligation of a bleeding artery should be performed with resorbable sutures. Some authors recommend burnishing of osseous structures with a curette. Several materials may be placed in the socket to assist in coagulation. Gelfoam® (absorbable gelatin sponge) may be saturated with topical thrombin to form a scaffold for the developing blood clot. It is placed in the socket and a resorbable suture is placed over the top. Gauze is placed on top and pressure is then applied. Surgicel® (resorbable

oxidized regenerated cellulose) or Oxycel® (resorbable oxidized cellulose) may be packed into the socket and held in place with sterile gauze to promote coagulation. Alternatively, bovine purified collagen may promote and stabilize clot formation by promoting platelet adhesion and aggregation. Epinephrine should be used with caution as bleeding may be temporarily controlled with rebound hemorrhage. Tissue may also be cauterized with electrocautery. In this circumstance, profound local anesthesia by block should be obtained. Avoid burning adjacent tissue when cauterizing and alert the patient to expect a noxious odor.

In cases of excessive bleeding, monitor vital signs for hypotension. Do not discharge the patient until hemostasis is successful. Also, advise the patient to avoid rinsing and spitting.

Post-extraction Instructions: Clear, simple postoperative instructions should be delivered to the patient and other adults accompanying him or her. These instructions should be provided orally and in written form. Any questions should be answered prior to discharge.

11.4 Postoperative Issues

Pain: Postoperative pain is an expected risk of any surgical procedure and should not necessarily be considered a surgical complication. For dental extractions, pain will normally peak around 12–24 h postoperatively and should not be an issue after 72 h. The acronym

$$\mathbf{H} + \mathbf{I} + \mathbf{S} = \mathbf{A}$$

is a useful formula to determine whether a patient requires any analgesic and, if they do, what analgesic should be prescribed. The **H** represents the pertinent medical history including current medications, drug allergies, and liver and kidney function. The **I** represents how the patient interprets a painful stimulus. Pain response is very variable and is related to both the physiology and the psychology of the patient. The **S** represents the stimulus of the procedure and includes the procedure complexity, difficulty, and duration. When the **H**, **I**, and **S** are added together, the end result is the **A** representing analgesics.

Pain becomes a complication when it exceeds the level that has been predicted for a particular procedure. Patients complaining of more pain than expected should be examined to determine whether another type of complication has occurred such as an infection or alveolar osteitis which is not treated by prescribing additional or stronger analgesics. The patient should still be evaluated in the context of the **HIS = A** formula. The surgical trauma may have been underestimated. A significant amount of an analgesic's effect is placebo in nature. Thus, the patient may not have interpreted the pain correctly. The potential that the patient is a "drug seeker" must always be kept in mind.

Acute pain management is addressed in Chap. 12. By using the formula **HIS = A**, the dental provider has an evidence-based and defensible approach to analgesic prescribing. This is extremely important with the current concerns of opioid overuse and abuse.

Swelling: Postoperative swelling is an expected risk of any surgical procedure and should not necessarily be considered a surgical complication. The amount of postoperative swelling is directly related to the associated trauma of the surgery (Matocha 2000). For dental extractions, swelling will normally peak around 24 h postoperatively and should start to resolve around day 3 postoperatively. Patients are usually instructed to use cold/ice compresses for the first 24–48 h to minimize the swelling (Le and Woo 2007) and then switch to warm compresses to help reduce the swelling that has occurred. An inordinate amount of swelling may be considered a complication. A significant amount of swelling can restrict the patient's ability to open his mouth. This may lead to alteration of diet and the inability to perform adequate oral hygiene procedures.

The patient should be examined to ensure that the swelling is secondary to surgical trauma edema. There is the possibility that the swelling is related to a postoperative infection, but one should not jump to this conclusion and should not immediately prescribe antibiotics. Watchful waiting is an appropriate course in an immune-competent patient. Surgical edema is self-limiting and should start to decrease around the third or fourth postoperative day especially if warm compresses are being used.

Bleeding: Many oral surgical procedures may result in a wound that is not or cannot be closed primarily. Subsequently, some postoperative bleeding should be expected. Clot formation usually takes 6–12 h (Pierse et al. 2012). This may be extended for patients that are on anticoagulant therapy including aspirin. Currently, the use of anticoagulant medication is not considered an increased risk factor, and they are usually not discontinued prior to uncomplicated office oral surgery procedures (Malmquist 2011; Verna 2014). When a patient presents and there is a concern about postoperative bleeding, an initial assessment includes a review of the medical history especially current use of medications or herbal supplements that may contribute to prolonged bleeding. An assessment needs to be made of the amount of bleeding that may have occurred, ranging from a small amount of blood mixed with saliva to spitting out blood clots. It should be determined how often the gauze pressure packings were changed and how much blood was on them because the frequent changing of gauze packs can aggravate rather than enhance the coagulation process.

Next, a thorough clinical examination is conducted with good lighting and suction. All visible blood, clots, and saliva need to be removed to determine the exact source of bleeding—bone, soft tissue, or both. Large "liver" clots need to be removed. "Liver" clots are so named because they look like raw liver. These are clots that extend beyond the confines of the surgical site. If granulation tissue is noted in the extraction site, it should be removed (Malmquist 2011).

Most bleeding can be stopped by applying pressure to the area for a sufficient length of time. A 4 × 4 in. gauze sponge dampened with saline is folded and placed directly over the bleeding site and held firmly in place for at least 5 min. The area is reexamined and the bleeding should have decreased. If this is the case, then the procedure is repeated and the pressure applied for a longer period of time (in the range of 15–20 min). It is important to maintain constant pressure. This will usually correct most cases of postoperative bleeding. It is important to make sure the patient

knows precisely where to place the pressure pack and to maintain constant pressure for at least 15–20 min each time. The patient needs to be reminded not to rinse, spit, or do any sucking activity for the next 24 h.

A wet tea bag is an excellent substitute for a 4 × 4 in. gauze sponge. This is especially useful when responding to a patient who is at home. The "soggy" tea bag is placed over the bleeding site, and pressure is applied as described above. There is a potential that the tannic acid in the tea may act as an astringent or coagulation agent (Soltani et al. 2014).

When direct pressure does not resolve the problem, there are a variety of other measures that can be utilized. The same measures would be indicated even if the patient has an underlying coagulation problem.

Soft Tissue: Bleeding from capillaries and very small vessels can be cauterized. Soft tissue lasers and electrocautery units may be readily available in many dental offices. Chemical cautery, such as the use of silver nitrate, may be available in the office or hospital emergency room. The injection of a vasoconstrictor, such as epinephrine, has been advocated to control the bleeding by injecting local anesthesia containing epinephrine directly into the bleeding site. There are two reasons why this should *not* be done. The vasoconstrictor indeed may stop the bleeding, but the source can no longer be identified. Additionally when the epinephrine wears off, the bleeding may start again. There is also a rebound phenomenon with epinephrine, and the vessels may vasodilate, thus increasing the amount of bleeding (Matocha 2000).

Bone: Using an instrument such as a dental curette or ball burnisher has been described to burnish or crush the alveolar walls to stop bleeding. However, this has the potential to cause a larger bleeding site. An alternative would be to heat the instrument, and then with great care, bony bleeding site can be heat cauterized.

A variety of agents have been described to pack into the bleeding site such as an resorbable oxidized regenerated cellulose (Surgicel®) or absorbable gelatin sponge (Gelfoam®) or a coagulating agent (Hemodent®—a buffered, aluminum chloride, epinephrine-free hemostatic liquid) in a resorbable carrier (Matocha 2000). It is advisable to have at least one of these products available in any office that performs dental extractions. The primary function of any of these agents is to stop localized bleeding and promote clot formation.

In the case of very brisk bleeding from a posterior mandibular extraction site, there is the potential that the bleeding is coming from the inferior alveolar neurovascular bundle. One must be mindful that pressure and some chemical agents may cause nerve damage. Caution also needs to be exercised when treating bone bleeding in the posterior maxilla. Excessive/uncontrolled pressure within the extraction socket may result in a sinus communication.

Clinicians must rely on their experience as there is a lack of reliable evidence on this topic (Sumanth et al. 2016). In the rare case that the above measures do not control the bleeding situation, then an underlying coagulation problem needs to be entertained. Consultation with a hematologist should be considered. The patient needs to be evaluated for factor deficiencies as well as a low platelet count or ineffective platelets. Blood product placement may be required.

Nerve Damage: Oral surgical procedures can result in a neurodeficit. When performing a procedure in the area of a named nerve (i.e., inferior alveolar, mental, lingual), during an extraction or biopsy, every effort needs to be made to avoid damaging the nerve. In the case of a biopsy, small terminal nerve branches may be cut, and the patient may notice an alteration of sensation adjacent to the biopsy site. No treatment is indicated, and the patient should be reassured that normal feeling should return once healing has taken place.

Damage to the inferior alveolar nerve and/or the lingual nerve can occur when third molars are removed, especially if the tooth was impacted or the surgery was difficult. In these instances, a neurologic exam needs to be accomplished. If there is no improvement within a couple of weeks, that patient must be referred to a specialist for further assessment and possible nerve repair procedure.

There is a potential for damage to the mental nerve when mandibular premolar teeth are removed or some type of buccal flap procedure or biopsy is performed in the area. This is a terminal nerve branch and further treatment is not required. The deficit needs to be documented, and the patient needs to be reassured that clinically normal sensation should return. There is always the possibility of a permanent deficit.

Infection: There is always the possibility of a postoperative infection developing after any oral surgical procedure. The use of antibiotics for routine dentoalveolar procedures in healthy patients may not have any effect of wound healing (Gbotolorum et al. 2016). Inadequate irrigation with consequent accumulation of debris beneath a flap is a frequent cause of postoperative infection (Matocha 2000). The infection usually will occur 3–4 days after the procedure (Adeyemo et al. 2006). The presenting signs and symptoms are usually increasing swelling, foul tasting/smelling drainage, and possibly a decrease in oral opening or difficulty in swallowing depending on the location of the surgery.

The treatment for infection is always removal of the source and/or drainage (Lypka and Hammoudeh 2011). If the complaint is post-extraction, radiographic imaging may be required to rule out any residual tooth fragments that are triggering a foreign body reaction. Antibiotics may be indicated if the patient is immune-compromised or the infection is not locally confined, meaning it is spreading or involving deeper spaces of the head and neck region. A useful acronym for guiding therapy is

$$\mathbf{A} = \mathbf{S} + \mathbf{H} + \mathbf{O}$$

S stands for the patient's presenting signs and symptoms, **H** stands for the past and current medical history, and **O** stands for the organism most likely causing the infection. When all three of these are considered, then a decision can be made if an ***A***ntibiotic is indicated and which one should be selected.

When signs and symptoms persist, then the potential of osteomyelitis needs to be a concern. This is uncommon in patients with a competent immune system (Krakowiak 2011). The diagnosis and management of osteomyelitis are covered in Chap. 14.

Alveolar Osteitis (Dry Socket): An alveolar osteitis (AO) or dry socket "is an acute inflammation of the alveolar bone around an extracted tooth, and it is

characterized by severe pain and breakdown of the clot formed within the socket, making the socket empty (devoid of clot) and often filled with debris. There is mild swelling and redness of the gingiva, halitosis, bone exposure, and severe tenderness on examination" (Akinbami and Godspower 2014). The overall incidence of AO is around 3–5%, with most AO being related to the surgical removal of third molars occurring up 30% of the time (Akinbami and Godspower 2014; Blum 2002). There is a higher incidence of AO associated with surgery performed by a less experienced operator (Parthasarathi et al. 2011) due to the longer surgery times and/or more bone trauma. AO also occurs more commonly in patients with a history of a previous AO or when teeth are extracted that are related to infection, non-vital pulp, or periodontitis (Bowe et al. 2012). This may be related to the theory that the cause of AO is a bacterial-related breakdown of the clot (Mudali and Mahomed 2016).

Regardless of the exact etiology of AO, it does not represent an infection and antibiotics should not be considered as part of the treatment. Patients with AO typically complain of an increasing and/or radiating pain occurring 3–4 days after an extraction. The treatment goal is to keep the patient comfortable until the extraction site undergoes healing by secondary intention, and the exposed bone is covered by soft tissue and no longer exposed to the oral cavity. Pain management can usually be obtained with the use of an obtundent dressing placed in the extraction site. The extraction site is gently irrigated to remove any food or residual clot debris. This irrigation may be accomplished using 0.12% chlorhexidine that has antimicrobial properties (Fomete and Saheeb 2015). The socket is then packed with ¼ in. gauze of sufficient length to fill the socket entirely to the apex. The gauze packing is used as a carrier for the obtundent medication. There are several commercially available "dry socket" dressings. The dressing should contain eugenol which acts as a topical local anesthetic (Krakowiak 2011). The dressing will need to be changed every 1–3 days for a period of 7–10 days. Local anesthesia may be required to accomplish the AO treatment, especially the first time when the patient is extremely sensitive and apprehensive. Additional analgesics may need to be prescribed, but opioids can usually be avoided. Since AO is a local inflammation of bone (osteitis), prescribing an anti-inflammatory medication makes more sense.

Chlorhexidine (0.12%) rinses prior to surgery as well as postoperatively for a week have been shown to decrease the incidence of AO (Blum 2002; Bowe et al. 2012; Caso et al. 2005; Hedström and Sjögren 2007; Daly et al. 2012).

Oral-Antral Communication/Fistula: An antral perforation may not be noted at the time of the original maxillary tooth extraction or may develop at a later date secondary to increased sinus pressure, i.e., nose blowing. The patient may complain of fluid draining from the nose, foul drainage intraorally, or air escaping into the mouth and, perhaps, symptoms consistent with a sinus infection. The intraoral examination will usually demonstrate a mucosal perforation in the area of the extraction site. When the patient performs a Valsalva maneuver, an air leak will be noted with or without purulent drainage. A dental radiograph may demonstrate a discontinuity of the sinus floor.

Nasal decongestants and antibiotics should be prescribed. An antibiotic such as amoxicillin would be preferred as it has a broad coverage that includes sinus cavity organisms, i.e., *Haemophilus influenzae*.

The oral/antral communication requires an airtight closure that usually necessitates a flap procedure. A number of flap procedures have been described including palatal rotation flaps, buccal mucosa advancement flaps, and buccal fat pad flaps. There are advantages and disadvantages to each technique, but the final result of an air-/watertight closure must be obtained. In planning the repair, the operator needs to keep in mind that the boney defect will be significantly larger than the mucosal fistula (Borgonovo et al. 2012).

The buccal mucosa advancement flap can usually be performed by most general dentists. A buccal flap is raised using anterior and posterior vertical relaxing incisions connected by an alveolar crest incision that includes the mucosal fistula opening. The periosteum may be scored in a horizontal fashion to allow the mucosa to stretch. The entire fistulous tract must be removed prior to the closure. The free edge of the buccal flap is then sutured to the palatal mucosa. Once the closure is completed, the patient should be instructed to perform a light Valsalva maneuver to ensure an air-/watertight closure has been obtained. The patient should be placed on appropriate antibiotics and decongestants. Sinus precautions are required, and oral hygiene measures could include a chlorhexidine mouth rinse. Close follow-up is required until satisfactory healing is obtained, and there is no evidence of an oral-antral communication.

Loss to Follow-Up: Losing patients to follow-up should also be considered a complication. This is of special concern when a biopsy has been performed or a dry socket dressing has been left in place. Attempts to reestablish contact with a patient for the purpose of follow-up care should be attempted both by telephone and written communication emphasizing the importance of follow-up. These attempts to follow-up should be well documented in the patient's dental record.

11.5 Documentation

Record documentation is always important but especially so when a complication has occurred. The patient record should reflect the nature of the complication, what measures have been made to correct the situation or may be needed in the future, and that the patient has been made aware of the complication with a full and complete explanation. Claims of negligence related to the postoperative course have been made due primarily to poor documentation (Curley 2011). Follow-up is necessary and should be well documented as to the resolution of the problem.

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Acute Pain Management

12

Joseph F. Piecuch

"For me, there still remains the cocaine-bottle."
Sherlock Holmes in—The Sign of the Four

Abstract

Dentists are frequently called upon to provide short-term acute pain management. Traditional over-the-counter medications such as acetaminophen, ibuprofen, and similar drugs are generally effective. Yet the prescription of opioid medications has steadily grown, with dentists now prescribing 12% of the initial opioid prescriptions written in the United States.

As the use of opioids has grown, the country has experienced a growing epidemic of opioid-related deaths, due primarily to respiratory depression. Recent studies indicate that a small percentage of patients who begin opioid medication for legitimate reasons continue their use of these drugs long term. A national effort is aimed at decreasing opioid prescriptions.

Multimodal analgesia using local anesthetics and nonsteroidal anti-inflammatory medications is very effective, both in relief of pain as well as elimination of need for opioids.

12.1 Introduction

Dentists are frequently called upon to provide acute pain management. The term "acute" signifies recent onset and generally a type of pain that is limited in duration and will not become a long-term issue. Such situations include trauma, infections, and posttreatment pain, particularly after invasive surgical procedures.

Chronic or long-term pain management, on the other hand, is typically managed by pain specialists and is not managed by the dentist. However dentists should be aware that when a patient mentions that he or she is in a pain management program,

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that person has usually signed a contract with a pain specialist. Typically such contracts specify the drug and the number of doses that will be prescribed each month, particularly for opioids. In addition, such contracts typically specify that there will be a single provider, the pain management specialist. Thus, for the patient who has signed such a contract, the dentist should not prescribe additional opioid doses (American Society of Anesthesiologists Task Force on Pain Management 2010).

In dentistry, a variety of options are available for acute pain control, including local anesthetics, aspirin, acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDS), and opioids. Local anesthetics, typically used for procedural pain control, may also be used for post-procedural pain. Since virtually all of the medications used for pain control do have other potential systemic effects and can be harmful to some patients, it is critical that the dentist be knowledgeable concerning the patient's health history. Of particular importance are cardiac and pulmonary function, renal disease, hepatic disease, psychiatric issues, current medications, and allergy history. If the prescribing dentist is not familiar with the possible drug interaction with the patient's current medications, the dentist must look up the medication prior to prescribing pain control. If not certain about possible interactions with the patient's medical condition or medications, the dentist should contact the patient's physician for guidance.

Special considerations are pregnancy and the nursing mother. Generally if there are any questions the patient's obstetrician should be consulted. A brief review of the use of pain medications in these specific conditions follows.

12.2 Postoperative Pain and Analgesic Medications

Acute postoperative pain occurs following tissue trauma, which activates sensory receptors, nociceptors, that detect noxious stimuli and which conduct the painful sensation to the CNS via A delta and C fibers. The noxious input, arriving in the CNS, increases nociceptive neurons in the CNS, thus creating central sensitization.

Local and systemic mediators, such as cytokines, are released at the site of injury. Cytokines are extracellular polypeptides which have multiple actions. These include interleukins (IL-1 to IL-35) and tumor necrosis factor (TNF). These "pro-inflammatory" mediators increase production of prostaglandins, which produce hyperalgesia, inflammation, and pain. Cyclooxygenase isoenzymes (COX-1 and COX-2) are important in the synthesis of prostaglandins (PG), which increase blood flow and thus permit edema and inflammation. Prostaglandin E2 (PGE2) promotes blood flow and microvascular permeability, causing redness and edema. PGE2 also directly affects sensory neurons causing pain. TNF-alpha produces inflammation, pain, and hyperalgesia. Substance P is a peptide which is rapidly released following noxious stimuli and causes vasodilation, promotes expression of the cytokines, and assists transmission of pain to the CNS (Barrow de Oliviera et al. 2011).

Modification of this inflammatory response by means of blocking the effects of cyclooxygenases is the goal of pain management. COX-1 has effects on the gastric mucosa, where it produces protective prostaglandins for gastric epithelial cells.

COX-1 also decreases platelet aggregation. COX-2 effects are antipyretic, analgesic, and anti-inflammatory. Traditional nonsteroidal anti-inflammatory medications (NSAIDs) are nonselective and inhibit both cyclooxygenase isoenzymes COX-1 and COX-2, thus inhibiting synthesis of prostaglandins and other mediators and decreasing edema, inflammation, and pain. NSAIDS also block the effects of substance P, decreasing chemotaxis of inflammatory cells. But the nonselective NSAIDS also have COX-1-mediated undesirable gastric and platelet effects. The COX-1 effects for most of these agents are reversible, except for aspirin. Specific COX-2 inhibitors (coxibs) do not inhibit COX-1 and therefore have fewer effects on the gastric mucosa.

12.2.1 Acetaminophen

Is not considered an NSAID and acts primarily in the CNS. It is useful for mild-to-moderate pain. The mechanism of action is not completely understood, but it does act centrally to inhibit cyclooxygenase (COX) enzymes with selective COX-2 activity (Graham et al. 2013)**.** It does not do so peripherally. It also modulates the endogenous cannabinoid system, centrally. Peak activity is reached in ½ to 2 h, and overall duration is 4–6 h (Ghanem et al. 2016)**.** It is available in doses of 325 and 650 mg and typically is dosed every 4 h.

Acetaminophen can be hepatotoxic, and as a result it should be avoided in patients with hepatitis or other liver disease. The maximum adult daily dose as recommended since 2011 by the manufacturer is 3000 mg per 24 h period.

12.2.2 Nonsteroidal Anti-Inflammatory Agents (NSAIDS)

Act by inhibition of prostaglandin synthesis. Their action is local, at the site of inflammation, where they prevent the development of pain pathways during their period of activity. A large number of NSAIDS have been studied for post-procedural pain, including several selective COX-2 inhibitors, such as rofecoxib (Vioxx) and valdecoxib (Bextra), which have been taken off the market, in 2004 and 2005, respectively, due to an association with negative cardiac outcomes and other serious side effects. The most commonly NSAIDS currently used in dentistry are ibuprofen and naproxen.

Aspirin (acetylsalicylic acid, ASA) is classed with the nonsteroidal anti-inflammatory agents, with effects on both COX-1 and COX-2, blocking prostaglandin production and producing both analgesic and antipyretic effects. The anti-inflammatory effects are achieved only at very high doses (4–8 g per day) which risk auditory and gastrointestinal toxicity. It is useful for mild-to-moderate pain at doses of 325–650 mg every 4–6 h. The higher dose should be spaced out every 6 h to reduce total daily amount.

The gastric effects of aspirin are irreversible, in contrast with other NSAIDS, which have reversible gastric mucosal effects. Aspirin also produces irreversible inhibition of platelet aggregation, which lasts for the life of the platelet (7–10 days).

COX-1 inhibitory effects of ASA include blocking the formation of thromboxane A2, which is necessary for platelet aggregation. This does occur at lower doses, and for this purpose 81 mg per day is usually recommended for persons at risk for thrombotic events. Other side effects include allergy, gastrointestinal pain and ulceration, as well as hepatotoxicity. Aspirin is not generally recommended as first-line therapy for post-procedural pain.

Ibuprofen achieves peak activity in 1–2 h, with a half-life of 2–4 h. It is potentially nephrotoxic, and thus the Food and Drug Administration (FDA) has limited the recommended daily dosage to 3200 mg. It should not be used for patients with renal compromise. Ibuprofen is available without prescription as 200 mg tablets, and usual adult doses for post-procedural pain are 400 or 600 mg every 4–6 h.

Naproxen, like ibuprofen, is an NSAID of the propionic acid class and is a non-selective COX inhibitor, similar to ibuprofen. It has the smallest potential cardiovascular risk (Angiolillo and Weisman 2017) of all NSAIDS. On the other hand, its relative risk for gastrointestinal complications such as peptic ulcer and GI bleeding is significantly higher than that of ibuprofen (Castellsague et al. 2012). The active life of naproxen is longer than ibuprofen, and it is generally prescribed as 250–500 mg every 8–12 h.

Celecoxib (Celebrex) is a selective COX-2 inhibitor usually prescribed as a long-term analgesic for chronic arthritic pain. Because it has no effects on the gastric mucosa, it is better tolerated over time than the nonselective NSAIDS. A Cochrane review of its use in immediate post-procedural pain, first published in 2013 and updated in 2017, identified ten studies with 1785 participants. Celecoxib in 200 and 400 mg doses were compared with placebo. The time till need for rescue medication was 6.6 h for the 200 mg dose and 8.4 h for the 400 mg dose. The authors concluded that celecoxib 400 mg is similar in effect to 400 mg of ibuprofen (Derry and Moore 2013).

12.2.3 Opioids

Opioids as a class of drugs have been used for analgesia for thousands of years, yet the modern formulations, other than morphine and heroin, have appeared mostly in the last century. Opioids act centrally on mu opioid receptors in the CNS to dull the perception of pain. Opioids also act to decrease transmission of nociceptive stimuli by the spinal cord. They do not have a significant local effect and do not decrease inflammation at the site of injury. It is thought by some that when such drugs bind to central receptors they release other mediators which are associated with euphoria, and this explains some of the effects that chronic users obtain from these drugs.

Opioids are primarily absorbed in the gastrointestinal tract. Lipid-soluble opioids can be absorbed through buccal or nasal mucosa, and those with the greatest lipid solubility can even be absorbed transdermally. All opioids are metabolized in the liver and excreted by the kidneys. They should be used with caution in patients with hepatic or renal compromise.

Tolerance, dependence, and addiction can occur with opioids. Tolerance is defined as a gradual decrease in effectiveness after repeated doses, over days to weeks, and can result in doses becoming less effective over time. Cross-tolerance can occur between drugs of the same class, such as those affecting mu receptors. Dependence is an adaptation to chronic use which produces significant physical and emotional symptoms upon withdrawal of the drug. Addiction is the compulsive use of a drug. While the euphoric effects of opioids during recreational use may lead to addiction, the most common motivation for addiction is the avoidance of withdrawal symptoms.

Currently the most commonly used opioids for dental pain are codeine, hydrocodone, and oxycodone. Codeine has a low affinity for opioid receptors, but about 10% of an administered dose is metabolized to morphine, which is responsible for the analgesic effect. Hydrocodone and oxycodone are codeine analogs which act in a similar manner.

The major difference between *codeine*, *hydrocodone*, and *oxycodone* is potency. One milligram of codeine is equivalent to 0.15 mg (0.15 M.E.) of morphine, while 1 mg of hydrocodone equals 1 morphine equivalent (1.0 M.E.), and 1 mg of oxycodone provides 1.5 M.E. All three of these opioids have an onset between 1/2 and 1 h and durations of 3–5 h. Oxycodone should only be prescribed in its immediate release (IR) form for dental-related pain. It also has delayed release forms (marketed primarily as OxyContin) which last up to 12 h. Such drugs are inappropriate for dental post-procedural pain and should not be prescribed by dentists.

Opioids are usually prescribed as combination drugs with acetaminophen or ibuprofen as the other component. A listing of commonly prescribed commercial combinations is found in Table 12.1. Notably, combinations which include acetaminophen limit that drug to 300 mg in order to decrease the possibility of hepatotoxicity.

Other opioids occasionally used in dentistry include propoxyphene, meperidine, tramadol, and fentanyl. *Propoxyphene* is a weak opioid, formerly marketed as Darvon, which was commonly used for post-procedural pain. It was taken off the market in 2010 due to the risk of cardiac toxicity. *Meperidine* is sometimes used in

Table 12.1 A listing of commonly prescribed commercial combinations of opioids and acetaminophen or ibuprofen

Commercial drug name	Opioid dose in mg	Combination drug dose
Tylenol # 2	Codeine 15 mg	Acetaminophen 300 mg
Tylenol # 3	Codeine 30 mg	Acetaminophen 300 mg
Tylenol # 4	Codeine 60 mg	Acetaminophen 300 mg
Vicodin	Hydrocodone 5 mg	Acetaminophen 300 mg
Vicodin ES	Hydrocodone 7.5 mg	Acetaminophen 300 mg
Vicodin HP	Hydrocodone 10 mg	Acetaminophen 300 mg
Vicoprofen	Hydrocodone 7.5 mg	Ibuprofen 200 mg
Percocet	Oxycodone 5 mg	Acetaminophen 300 mg
Percodan	Oxycodone 5 mg	Aspirin 325 mg
Tylox	Oxycodone 5 mg	Acetaminophen 500 mg

this setting if the patient has had significant side effects (nausea) from codeine and related drugs. *Tramadol* is another synthetic codeine analog not commonly used in this setting. *Fentanyl* is a powerful short-acting and rapidly metabolized opioid with poor gastric absorption. It is rapidly absorbed transbuccally and transdermally and has been used as oral lozenges and as skin patches, mostly in cancer patients with chronic pain. Due to significant side effects, it should not be used in this fashion for dental post-procedural pain. Fentanyl is used as an adjunct to anesthesia due to its rapid onset and rapid termination when used intravenously. The risk of respiratory depression in this setting is significant.

When prescribing opioids, the dentist *must* be cognizant of the ongoing opioid epidemic which currently takes the lives of 33,000 Americans per year.

12.3 Special Considerations in Prescribing

12.3.1 Pregnancy

Continuation of dental care throughout pregnancy is recommended by both the American Dental Association and the American College of Obstetrics and Gynecology. One study (Hagai et al. 2015) compared 210 patients given local anesthesia for dental care during pregnancy (53% during the first trimester) with 794 pregnant women who did not have such treatment. Although three quarters of the treatment group had invasive procedures such as endodontics or extractions, only 8% used postoperative pain medication, either acetaminophen or NSAIDS. There were no differences in pregnancy outcomes between the two groups.

In general when pain medication is contemplated for posttreatment care for pregnant patients, it is recommended that the dentist obtain consultation with the patient's obstetrician concerning appropriate medications. For patients who have been scheduled in advance for the procedure, this consultation should be obtained prior to the appointment.

12.3.2 The Nursing Mother

Clinical guidance of the use of pain medications in the nursing mother has been provided by the American Academy of Pediatrics (Sachs and Committee on Drugs 2013) as well as by a number of scholarly publications. The following comments provide a brief overview of this topic.

Aspirin: Salicylate excretion into human milk is low, approximately 4–8%. A study which included low-dose aspirin (Bell et al. 2011) showed that low doses (<100 mg per day) did not produce any adverse effects. However higher, therapeutic doses have resulted in complications including neonatal purpura and metabolic acidosis (Bar-Oz et al. 2003). Thus aspirin is not recommended for the nursing mother.

Acetaminophen: The maximum dose passed to the nursing infant is estimated to be only about 1.5% of the daily maternal dose. Consequently use of acetaminophen is compatible with breastfeeding.

Ibuprofen: Maternal doses of this drug do not appear to pass to the infant in detectable amounts, so it is also compatible with breastfeeding.

Naproxen: Less than 1% of the maternal dose is excreted into human milk, consequently Naprosyn is acceptable in this setting.

Codeine: This drug definitely passes to the nursing infant and should be avoided. Some studies suggest that it can cause neonatal respiratory depression only in high doses (60 mg every 4–6 h) (Sachs and Committee on Drugs 2013)**,** but another study (Lam et al. 2011) specifically measuring CNS depression in neonates whose mothers were using codeine and other opioids found that 16.7% of the babies exhibited CNS depression. This paper also cited an FDA warning that codeine is not safe for infants in this setting. A systematic review by Madadi et al. (2008) concluded from available evidence that respiratory depression will occur in infants whose mothers use codeine. These authors had previously reported a fatality of a breastfed infant whose mother had been taking codeine (Madadi et al. 2007).

Hydrocodone: Timed breast milk samples from 30 nursing mothers were tested, and only 1.6% of the maternal dosage passed to the infant. Thus these authors considered hydrocodone to be safe in this setting (Sauberan et al. 2011)**.**

Oxycodone: Infants of nursing mothers taking oxycodone for postpartum pain had a 20.1% rate of infant CNS depression (Lam et al. 2011). These authors concluded that oxycodone is not safe in this setting.

The above should not be taken as definitive recommendations as new information may contradict previous publications. In any event when prescribing pain medications for the nursing mother, the dentist should strongly consider contacting the patient's obstetrician or the child's pediatrician for advice.

12.4 The American Opioid Epidemic

While opioid addiction, and overdose death, is certainly not confined to the United States, it is clear that the steady rise in the death rate has reached epidemic proportions. In the year 2014, there were 47,055 drug overdose deaths, with 28,647 due to opioids. In 2015 these numbers had increased to 52,407 and 33,091, respectively (Centers for Disease Control and Prevention 2016). In October 2017 it was announced that overall drug overdose deaths had reached 64,000 in 2016, (Centers for Disease Control and Prevention 2017) many now due to powerful synthetic opioids such as fentanyl. How did this happen?

Opioids have been used for pain control for several millennia, yet as recently as the late twentieth century, they were not commonly prescribed. In the 1980s and 1990s, many practitioners became concerned about pain control, and pain management groups and associations proliferated. Meetings were cosponsored by the pharmaceutical industry, which of course had an interest in the topic. Pain control is an admirable goal. Based on a small number of relevant publications which purported

to show that addiction was rare after medical use of these drugs, pain management groups emphasized the use of opioids, spurred on by drug manufacturers which sponsored scientific presentations favoring their lucrative products. These papers, referred to as "landmark studies" by some, were repeatedly cited in the literature by authors who perhaps, in the pre-Internet age, did not make the effort to actually read them and perhaps just repeated the praises of others. By 1996, pain, a subjective symptom, was redefined as "the fifth vital sign," along with objective measurement of heart rate, blood pressure, respiratory rate, and temperature (Van Zee 2009). Simultaneously drug manufacturers aggressively promoted their products. One company funded all or part of over 20,000 educational programs focusing on OxyContin, a sustained release oxycodone formulation, between 1996 and 2002. Prescriptions of this drug increased from 670,000 nationally in 1997 to 6.2 million in 2002 (Van Zee 2009).

In 2000, accrediting standards for healthcare organizations were changed to include statements requiring documentation of pain assessment and appropriate pain management for all patients. As a result control of pain became a major focus in the care of hospitalized patients, and the use of immediate release opioids proliferated. The concept rapidly spread to outpatient facilities, including dental offices, and the result was a significant increase in opioid prescriptions, as well as the amounts prescribed. It remains common for postsurgical patients to receive prescriptions for large numbers of opioids upon discharge to home. Based on the 2015 National Survey on Drug Use and Health (NSDUH), it was estimated that over a third of the adult civilian non-institutionalized population of the United States used prescription opioids in 2015 (Han et al. 2017).

Thus in the early twenty-first century, medical use of opioids became very common. As addiction and drug overdose deaths increased, studies have belatedly been done to assess the risk of addiction from post-procedural use. Not surprisingly these new studies contradicted previous assumptions and beliefs. Using de-identified insurance claims data, one study of 36,177 opioid-naïve (never used before) adults undergoing surgery who filled an opioid prescription following surgery found that 6% were still filling opioid prescriptions 6 months later (Brummett et al. 2017). A similar study found that some patients become habituated or addicted after the first prescription (Sun et al. 2016). Another study found that "legitimate opioid use before high school graduation is independently associated with a 33% increase in the risk of future opioid misuse after high school." (Miech et al. 2015) This association seemed to be concentrated among persons with no history of opioid use and strong disapproval of drug use at baseline.

Belated review of two of the best-known early papers supporting opioid use without need for concern about addiction revealed they were not studies at all. One paper was a retrospective chart review of 38 patients maintained on opioids for nonmalignant pain, and it actually showed that 5% developed a "drug management problem" (Portnoy and Foley 1986). The other, cited in the scientific literature over 900 times, was neither an article nor research but an 11-line "Letter to the Editor" in which the authors simply expressed an opinion (Porter and Jick 1980).

In 2016 the Joint Commission issued a "Statement on Pain Management" (Joint Commission 2016) clarifying current accreditation standards regarding pain. The

Statement pointed out that the standard "Pain is assessed in all patients" had been removed in 2009 and that it had not required that pain be treated until the pain score is zero. The Commission felt that the 2001 pain standards did not require only use of opioids and denied that the 2001 standards caused a rise in opioid prescriptions. A graph of yearly US opioid prescriptions accompanying this Statement showed opioid prescriptions nationally to be 126 million in 2000 and 219 million in 2011.

These comments are not meant to imply that the medical and dental professions are solely responsible for the opioid epidemic. Certainly industry marketing (Van Zee 2009), illegal drug distribution, and new synthetic narcotics smuggled into the country play a very large role.

For physicians, dentists, and other providers, however, prescribing patterns must be relearned. Many states have taken a lead role in requiring mandatory opioid education for licensure, mandatory registration in prescription monitoring programs, and limiting the amount of drug which may be prescribed. In some states opioid prescriptions may be sent only electronically, eliminating the possibility of duplication of prescriptions or changing the amounts. The recent declaration of a National Opioid Emergency (October 2017) hopefully will amplify a multifaceted approach to the problem.

12.4.1 Role of Dentists in the Opioid Epidemic

Although dentists likely do not initially see themselves as part of this problem, one should be aware that over 12% of all narcotics prescribed in the United States are prescribed by dentists (Denisco et al. 2011). Of patients prescribed opioids by dentists, 72% had leftover medications, and 71% of the group with leftover pills kept them. Further, 41% of the prescribing dentists expected leftover medications (Denisco et al. 2011).

A recent study of opioid prescriptions after surgical extraction of teeth (Baker et al. 2016) evaluated a de-identified Medicaid database of all Americans covered by Medicaid over an 11-year period (2000–2010). Of the 2,757,273 patents who underwent these procedures, 42% of this total filled opioid prescriptions. The drugs prescribed were hydrocodone (78%), oxycodone (15.4%), propoxyphene (3.5%), and codeine (1.6%). The range of morphine equivalents (M.E.) in this group was 75–225 M.E., with a mean of 120 M.E. This dose is equivalent to 24 tablets of 5 mg hydrocodone or 16 tablets of 5 mg oxycodone.

Another study evaluated opioid prescribing in a single state in the previous 2 years. All patients recorded in that state's drug monitoring program who were given at least one opioid prescription by a dentist were studied (McCauley et al. 2016). A total of 653,650 patients fit this parameter. Although dentists had written only 8.9% of the opioid prescriptions in that state over the 2-year span, dentists wrote 44.9% of those patients' initial opioid prescriptions.

While dentists certainly are not the primary cause of the opioid epidemic, they do play a role. Each practitioner *must* become familiar with their state's guidelines, including any recent changes, for opioid prescribing.

12.4.2 Alternatives to Opioids for Postoperative Pain

The American Dental Association has published a "Statement on the Use of Opioids in the Treatment of Dental Pain," which was adopted by the ADA House of Delegates in October 2016 (American Dental Association 2017). This statement emphasizes the need for a thorough medical history, for consulting state prescription drug monitoring programs (PDMP), and for coordination with other prescribers when considering opioids. In addition the statement urges dentists to consider nonsteroidal anti-inflammatory analgesics as first-line therapy for acute pain management (American Dental Association 2017).

The American Association of Oral and Maxillofacial Surgeons has issued its own statement on opioid prescriptions (American Association of Oral and Maxillofacial Surgeons 2017). This statement emphasizes the use of NSAIDS as first-line analgesic therapy, with acetaminophen as a substitute when NSAIDS are contraindicated. These AAOMS guidelines also encourage adjunctive pain control treatments such as presurgical NSAIDS, long-acting local anesthetics, and perioperative steroids. An example of the use of these multiple techniques is illustrated in a 2013 article in JADA (Laskin 2013).

Daniels et al. (2011) evaluated 678 patients who underwent third molar extraction using 2% lidocaine with 1/100,000 epinephrine. The patients were randomized into five groups:

- Ibuprofen 400 mg plus acetaminophen 1000 mg
- Ibuprofen 200 mg plus acetaminophen 500 mg
- Ibuprofen 400 mg plus codeine 25 mg
- Acetaminophen 1000 mg plus codeine 30 mg
- Placebo

The results of this study showed that *both* ibuprofen and acetaminophen combinations were more effective than the combinations that included codeine.

A similar randomized study evaluated effectiveness of pain medication given in emergency departments for extremity pain while waiting for radiographs. Acetaminophen was combined with one of four other drugs: ibuprofen, codeine, hydrocodone, and oxycodone. At 2 h, the acetaminophen and ibuprofen combination was equally effective to the opioid combinations (Chang et al. 2017).

A systematic review of randomized controlled trials compared acetaminophen plus an NSAID drug (ibuprofen, diclofenac, ketoprofen) versus one or both drugs alone. The results of this review showed that the combination was more effective than either acetaminophen alone or the NSAID drug alone (Ong et al. 2010). Moore and Hersh (2013) published a critical analysis of published scientific evidence for avoiding narcotics and using a combination of ibuprofen and acetaminophen for dental pain relief, using primarily evidence-based systematic reviews published by the Cochrane Collaboration. These reviews demonstrate improved efficacy of the combinations without an increase in adverse effects, which might occur with large doses of a single drug. Several of their references showed more frequent adverse drug reactions when opioids were added to the combinations.

12.5 Preemptive Analgesia

Preemptive analgesia is a technique of decreasing pain perception by preventing the establishment of central sensitization caused by incisional injury and by postsurgical inflammation. To be preemptive, pain must be addressed prior to the start of the procedure and continued through the initial postoperative period.

This concept is not new. In 1913 Crile published his observations of human patients as well as animal studies suggesting that surgical procedures might cause permanent changes in the brain. Specifically he noted that inhalational general anesthesia did not protect against CNS changes. Yet these changes could be reduced by applying a regional (local) anesthetic prior to the procedure (Crile 1913). Prospective studies in the early 1990s confirmed that modern techniques of local anesthesia decreased short- and long-term surgical pain. Jebeles et al. (1991) compared pre-tonsillectomy bupivacaine infiltration of the surgical site with placebo (saline) infiltration. All patients were operated with general anesthesia. On the second postoperative day, pain scores were four times lower in the bupivacaine group, and this difference persisted through the tenth postoperative day. Tverskoy et al. (1990) compared patients undergoing inguinal herniorrhaphy under general anesthesia with patients under general anesthesia who also received bupivacaine injections in the line of incision 5 min prior to surgery. In the general anesthesia only group, the first request for pain medication averaged 1 h after the conclusion of the procedure, while the general plus local group asked for pain medication on average 9 h postsurgery. In the general plus local group, incisional pain was almost completely absent at 24 and 48 h, and significantly lower pain persisted in this group through the tenth postsurgical day. A summary of early studies concerting preemptive analgesia was published in 2000 by Kirsin, who was a co-author of the Jebeles and Tverskoy papers cited above (Kissin 2000).

A systematic review of 66 studies with data from 3261 patients undergoing a variety of operations has shown that the most effective methods involve epidural anesthesia started prior to the procedure, local anesthesia given prior to surgery, and systemic NSAIDS begun either before or immediately after the procedure (Ong et al. 2005). Opioids showed the least proof of efficacy. Subsequently studies involving oral surgery began.

Gordon et al. (2002) presented four groups of oral surgery patients undergoing surgical extraction of lower third molars under general anesthesia:

- Pre-op lidocaine and post-op saline
- Pre-op lidocaine and post-op bupivacaine
- Pre-op saline and post-op bupivacaine
- Pre-op saline and post-op saline

Measurement of circulating endorphins during the procedure showed a significant increase in the two groups receiving a preoperative saline injection, while there was no increase in the two groups with preoperative lidocaine. At 1 h after completion of the procedures, there was still a decrease in in circulating

endorphins in the three groups which had local anesthesia in comparison with significant elevation in the saline/saline group. At 48 h the pain intensity was similar in the saline/saline and lidocaine/saline groups, while both groups receiving bupivacaine (lidocaine/bupivacaine and saline/bupivacaine) showed a significantly decreased pain intensity.

Nayyar and Yates (2006) reported a comparison of patients undergoing third molar surgery under general anesthesia. On one side the patient did not receive local anesthesia, while on the other side the patient received bupivacaine 0.5% with epinephrine 1/200,000. These authors found a significant decrease in pain on the local anesthesia side at 6, 12, and 72 h and also at 7 days. In summary preemptive local anesthesia is effective in the dental setting, and longer-acting agents appear to be more effective. Nonsteroidal anti-inflammatory agents decrease the inflammatory response and thus act in concert with the local anesthesia as the most effective measure.

In 2011 the FDA granted approval for use of liposomal bupivacaine injectable solution for several soft tissue procedures (Chahar and Cummings 2012; Charous and Ilfeld 2015). In 2015 approval for use was extended to several other sites, including intraoral infiltration. A recent Cochrane review of nine studies with 1377 patients undergoing five procedures (none were oral surgery) suggested that liposomal bupivacaine was better than standard bupivacaine for postoperative pain control (Hamilton et al. 2017). This form of bupivacaine has been used to date by many oral surgeons with reported excellent results, although actual controlled studies are still ongoing. It is important for the dentist to understand the restrictions on intraoral use: it may not be used for nerve blocks; it should not be used in patients under age 18, and the dentist must be aware of interactions with other local anesthetics.

Preemptive analgesia becomes multimodal analgesia when additional agents are utilized in the postoperative period to decrease pain as well as to prevent central sensitization. Such techniques are advocated by many as an approach which will limit the use of postoperative opioids, which simply become unnecessary. Such methods were formalized in the early 2000s as ERAS (enhanced recovery after surgery) pathways and promulgated by the ERAS Society, founded in 2001 (ERAS n.d.). Current postoperative multimodal options for use in ERAS pathways are found in the 2017 review article by Wick et al. (2017). Current pathways from the ERAS Society focus primarily on general surgery procedures. The following pathway for dental and oral surgical procedures is suggested:

Preoperative:	Lidocaine with epinephrine
Immediate postoperative:	Bupivacaine with epinephrine or
	Liposomal bupivacaine
Early postoperative:	Begin, NSAID, typically ibuprofen 400 or 600 mg
	Add, acetaminophen 325 mg

In this pathway the oral medications can either be taken together every 4 h (Hersh and Moore 2015) or alternated in an overlapping pattern at 2-h intervals, one pill every 2 h. The latter is this author's preference, as the peak effect of one drug occurs when the other is wearing off.

In summary it is now recognized that opioids are not necessary for many dental conditions and procedures. However when they are prescribed, the dentist should make efforts to ensure that proper disposal guidelines be followed, in order to prevent diversion. The most important method of prevention is to prescribe only the amount the patient will likely use, to decrease the possibility of leftover medication. Then, at the next appointment, the patient should be asked how many pills are left over and given instructions for proper disposal.

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Part III

Management of Oral Pathology

Odontogenic Infections

13

Gabe Hayek, Morton H. Goldberg, and Elie M. Ferneini

"It is of the highest importance in the art of detection to be able to recognize, out of a number of facts, which are incidental and which vital."

—The Reigate Puzzle

Abstract

Odontogenic infections are caused by the normal commensal oral flora that spread, most often, through a pathway from the roots of the teeth to enter the periapical region and can subsequently spread to the deeper fascial spaces of the head and neck. The main principle of treatment is to establish drainage of the abscess, either through endodontic therapy or removal of the tooth, and incision and drainage may be required as well. Antibiotics are an adjunctive therapy to surgical intervention. This chapter discusses the basic approach to the evaluation and treatment principles in the management of odontogenic infections. An overview of the microbiology and the deep fascial spaces is also provided to understand the rationale for treatment decisions.

13.1 Introduction

One of the most common presenting problems in general dentistry office is odontogenic infections (Christensen et al. 2013a, b). These tooth-borne infections can arise from caries, periodontal disease, or pulpitis and potentially spread

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to tissues deep in the head and neck or beyond. Although odontogenic infections have the ability to quickly become severe and life threatening, the vast majority are readily treatable in the early stages by the general dentist. An understanding of the signs, symptoms, microbiology, and the fascial planes and spaces is critical to understanding the basic decision-making necessary for the treatment of odontogenic infections. Management of the infection can then be performed with definitive treatment of the source of infection, incision and drainage, and/or antibiotics, and referral to a qualified oral and maxillofacial surgeon, when appropriate.

13.2 Microbiology

Like most infections, the bacteria that cause odontogenic infection are most commonly part of the normal commensal oral flora (Hupp and Ferneini 2016; Hupp et al. 2014). These bacteria are primarily aerobic gram-positive cocci, anaerobic gram-positive cocci, and anaerobic gram-negative rods. These bacteria cause the everyday dental pathologies of dental caries, gingival, and periodontal disease; however, they may gain access to deeper tissue through means such as a necrotic pulp or a deep periodontal pocket, causing the presenting infection. The changing environment of these deeper tissues also changes the predominant type of organism taking hold as they thrive in the now oxygen-depleted space.

The literature on the profile of odontogenic infections has been well established for decades and is important when making antibiotic choices. The underlying principle is that odontogenic infections are generally polymicrobial, mixed aerobic-anaerobic infections. The laboratory is able to identify an average of five species of bacteria in a sample and sometimes much more. A mere 6% of infections are aerobic alone, 44% are pure anaerobic, and 50% are mixed. Despite recurrent questioning as to whether the microbiologic flora of odontogenic infections is changing, multiple studies, including systematic reviews, have concluded that this is not the case as highlighted in Tables 13.1 and 13.2 (Sakomoto et al. 1998; Heimdahl et al. 1985; Haug 2003). Instead, perceived changes are attributed to changes in nomenclature and an increased ability to isolate organisms. Although less extensive in sample size

Table 13.1 Major pathogens in odontogenic infections

Microorganism	Heimdahl et al. (1985)	Sakomoto et al. (1998)
Streptococcus milleri group	31	65
Peptostreptococcus species	31	65
Other anaerobic streptococci	38	9
Prevotella species	35	74
Porphyromonas species	–	17
Fusobacterium species	45	52

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 297

Table 13.2 Major pathogens through the decades show no statistical changes

	Number isolated from 1980s patients (%)	Number isolated from 1990s patients (%)	Chi-square statistic	*P*-value
Gram-positive cocci	56	70	5.357	0.021
Other gram-positive bacteria	5	4	0.066	0.8
Gram-negative anaerobes	23	13	4.323	0.038
Other gram-negative bacteria	16	13	0.520	0.5

From: Storoe W, Haug RH, Lillich TT. The changing face of odontogenic infections. J Oral Maxillofac Surg 2001;59:739–48

Table 13.3 Increasing penicillin resistance rates among oral pathogens

Year	Penicillin resistance (% of cases)	Country
1991	33	United States
1992	38	Sweden
1995	55	United Kingdom
1999	54	United States

From: Hupp, J., and Ferneini, E. Principles of Antibiotic Therapy for Head, Neck, and Orofacial Infections. *Head, Neck, and Orofacial Infections* 2016; p 143

and only single studies, newer literature from the 2010s continues to show no statistical changes in the microbial flora of odontogenic infections (Yuvaraj et al. 2012; Farmahan et al. 2014).

On the other hand, antibiotic resistance has been shown to be changing. Table 13.3 shows that the percentage of odontogenic infections yielding one or more penicillin-resistant strains increased from 33% to 55% during the 1990s (Flynn et al. 2006a; Brook et al. 1992; von Konow et al. 1992; Lewis et al. 1995). Of note, clindamycin resistance is also increasing in peritonsillar abscesses, with resistant strains noted in as many as 33% of cases.

The predominant aerobic bacteria in odontogenic infections are the *Streptococcus milleri* group composed of *S. viridans* bacteria that include *S. anginosus*, *S. intermedius,* and *S. constellatus* (Hupp and Ferneini 2016; Hupp et al. 2014). These bacteria are facultative organisms, meaning they can grow in the presence or absence of oxygen. Numerous studies have been consistent in showing that these bacteria make up approximately 65% of odontogenic infections. Other less common aerobic bacteria include staphylococci, group D *Streptococcus* organisms, other streptococci, *Neisseria* species, *Corynebacterium* species, and *Haemophilus* species.

The anaerobic bacteria of odontogenic infections include a greater variety of species; however, the gram-positive cocci, specifically *Streptococcus* and *Peptostreptococcus*, predominate in 65% of cases. Gram-negative anaerobic rods, *Prevotella*, and *Porphyromonas* are found in nearly 75% of cases. *Fusobacterium* organisms are found in more than 50% of cases.

13.3 Fascial Planes and Spaces

As a general rule, infection erodes through the thinnest adjacent bone (most commonly the buccal plate, except for mandibular molars which most commonly perforate the lingual plate), to cause infection in the adjacent tissue. While most infections penetrate the cortical plate to become a vestibular abscess, depending on the anatomy of adjacent muscle attachments relative to where the infection erodes, the abscess may spread into the deeper fascial spaces. The fascial spaces are fascia-lined tissue compartments filled with loose, areolar connective tissue that serve to provide a cushion for the adjacent muscles, vessels, nerves, glands, and other surrounding structures. It is important to recognize that these are only potential spaces and do not exist in normal anatomy. When microorganisms invade the tissue, the resulting inflammatory process results in an edematous response and corresponding tissue exudate; and eventually the tissue becomes indurated as the polymorphonuclear leukocytes, lymphocytes, and macrophages migrate into the interstitial spaces. The final step of this process is a liquefactive necrosis of white blood cells and connective tissue, resulting in an abscess formation. These stages are what are clinically referred to as edema (bacterial inoculation), cellulitis (intense inflammatory response), and abscess formation (pus formation). Table 13.4 provides a comparison of the clinical parameters of the stages of infection, while Table 13.5 provides an overview of the potential spaces.

13.3.1 Infections Arising from Maxillary Teeth

Maxillary incisors and the palatal root of maxillary first molars whose apices may lie toward the palate may perforate the palatal cortical plate causing a palatal space infection (Hupp and Ferneini 2016; Hupp et al. 2014; Flynn and Topazian 1987). The buccal space is commonly infected from maxillary molars (Fig. 13.1). This will clinically be apparent as swelling below the zygomatic arch but above the inferior border of the mandible.

Table 13.4 Comparison of the clinical stages of infection

Characteristic	Edema (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	Jellylike	Board-like	Soft center
Progression	Increasing	Increasing	Decreasing
Pus	Absent	Absent	Present
Bacteria	Aerobic	Mixed	Anaerobic
Seriousness	Low	Greater	Less

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 298

Table 13.5 Potential spaces involved in odontogenic infections

Deep fascial space infections associated with any tooth
• Vestibular
• Buccal
Deep fascial space infections associated with maxillary teeth
• Infraorbital
• Infratemporal
• Canine
• Palatal
• Periorbital
• Orbital
• Cavernous sinus (venous plexus)
• Peritonsillar
• Maxillary or other paranasal sinus
Deep fascial space infections associated with mandibular teeth
• Space of the body of the mandible
• Submandibular
• Sublingual
• Submental
• Masticator
• Submasseteric
• Pterygomandibular
• Superficial temporal
• Deep temporal
Deep fascial spaces of the neck (most commonly mandibular)
• Lateral pharyngeal
• Retropharyngeal
• Pretracheal
• Danger space
• Prevertebral

From: Hupp, J., and Ferneini, E. Anatomy Relevant to Head, Neck, and Orofacial Infections. *Head, Neck, and Orofacial Infections* 2016; p 71

Posterior maxillary teeth may also erode through the floor of the maxillary sinus. This route accounts for almost 20% of maxillary sinusitis cases. Rarely, these infections may spread superiorly through the ethmoid sinus or orbital floor to cause periorbital or orbital infections. These cases require prompt surgical intervention and can be recognized by vascular and neural involvement of the orbit in addition to the traditional signs and symptoms of infection. Also rare, maxillary odontogenic infections can erode into the infraorbital (via the infraorbital space) or inferior ophthalmic vein (via the maxillary sinus). These vessels are part of the pathway through the superior orbital fissure directly into the cavernous sinus (Fig. 13.2). This is the one pathway of potential cavernous sinus thrombosis.

Deeper infections from maxillary teeth may include the infratemporal space, which lies just posterior to the maxilla and is continuous with the deep temporal space. It is rare for this space to become infected, most commonly from maxillary third molars, but this space contains a number of important structures including branches of the internal maxillary artery and the pterygoid venous plexus. The pterygoid plexus contains emissary veins that pass through the foramina of the skull

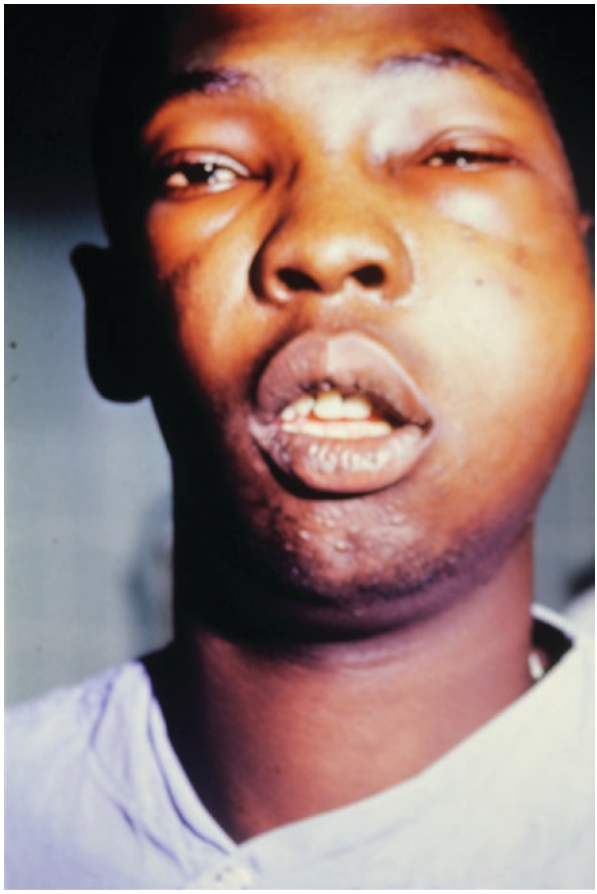

Fig. 13.1 Patient with a left buccal space infection

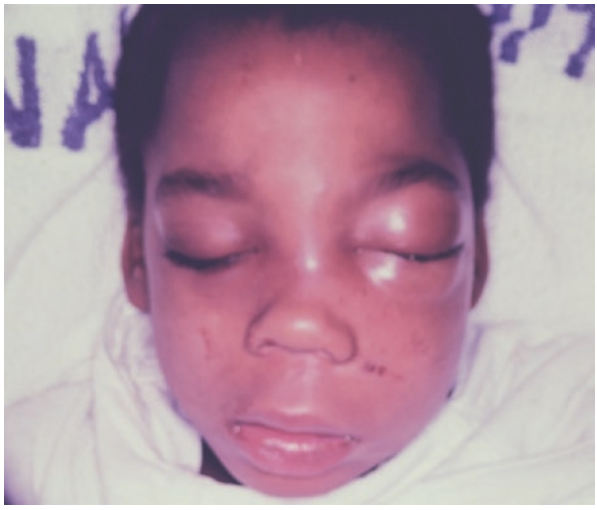

Fig. 13.2 Patient with a left cavernous sinus infection

to connect with the intracranial dural sinuses and can result in cavernous sinus infection. These rare but serious cases highlight the importance of recognizing the potential seriousness of the spread of infections.

13.3.2 Infections Arising from Mandibular Teeth

In the mandible, infections spreading beyond the vestibular space tend to enter the space of the body of the mandible and the submandibular, sublingual, submental, or masticator spaces and may subsequently enter the deep fascial spaces of the neck and, rarely, can extend to the mediastinum, causing a threat to the heart, lungs, and great vessels (Fig. 13.3).

The space of the body of the mandible is a subperiosteal space, and as such, an infection may simply lift the periosteum and clinically appear as if the mandibular bone itself is enlarged. If an infection of this nature penetrates the buccal cortical bone and the periosteum inferior to the attachment of the buccinator muscle, a buccal space infection ensues.

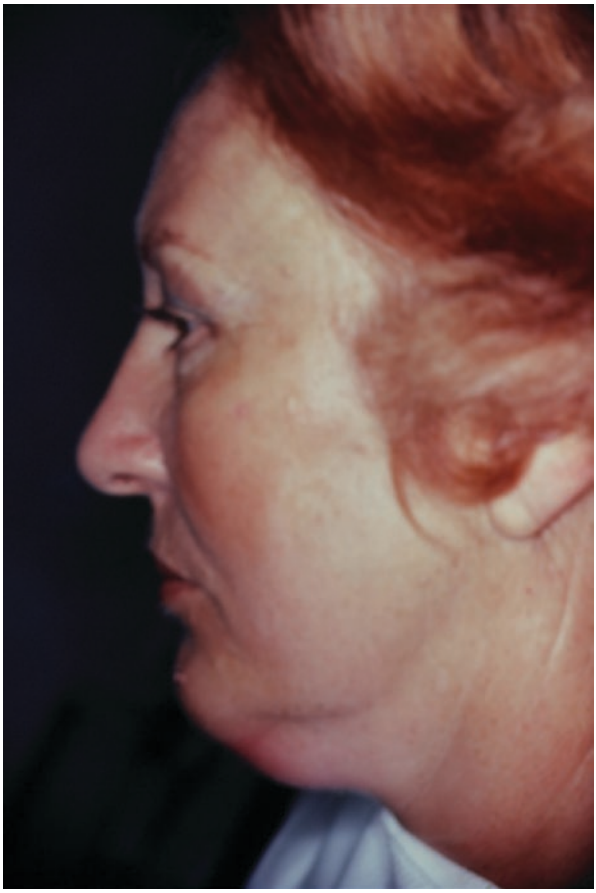

Fig. 13.3 Patient with a submental space infection

Sublingual and submandibular space infections are usually the result of a lingual cortical plate perforation from mandibular molars and occasionally premolars. The attachment of the mylohyoid muscle on the mylohyoid ridge of the medial aspect of the mandible is the separation of these two spaces with the sublingual space (usually from premolars and first molars) being above this demarcation and the submandibular space (usually from third molars) below. Infections from the mandibular second molars may involve either space, depending on the length of the roots. It should be noted that clinically, a sublingual space infection would appear as floor of mouth swelling with the tongue elevated. Swelling below the border of the mandible can identify an infection of the submandibular space. The posterior portion of the sublingual space is in open communication with the submandibular space. The submandibular space similarly communicates posteriorly freely with the deep fascial spaces of the neck. The third component of the "perimandibular space" is the submental space just adjacent to the mandibular midline. Though rarely seen as an isolated infection, it is most commonly the result of mandibular incisors. It is much more common to see this develop as a submandibular space infection that has passed around the anterior belly of the digastric muscles.

When all three perimandibular spaces (submandibular, sublingual, submental) are involved bilaterally, it is known as *Ludwig's angina*. This is a surgical emergency that can quickly obstruct the airway and spread to the deep fascial spaces of the neck. These patients clinically present with severe swelling, elevation of the tongue, and a bilateral induration of the submandibular space. Patients often have trismus, drooling, and difficulty and pain to swallowing and may have difficulty breathing. Prompt, aggressive treatment is required to secure the airway and provide surgical intervention, or death can ensue.

Numerous studies have shown that the most commonly infected spaces are the submandibular and masticator spaces in 54–78% of non-vestibular infections, with the third molar being the most common offending tooth. The masticator space can be further divided into four compartments: the submasseteric space (between the masseter muscle and the lateral surface of the ascending ramus), the pterygomandibular space (between the medial pterygoid muscle and the medial surface of the ascending ramus), the superficial temporal space (between the temporalis fascia and the temporalis muscle), and the deep temporal space (between the temporalis muscle and the skull). The zygomatic arch separates the submasseteric and superficial temporal spaces, while the lateral pterygoid muscle separates the pterygomandibular and deep temporal spaces. The commonly referred to infratemporal space is the inferior portion of the deep temporal space.

Generally, only one of these four subspaces is infected, though long-standing or severe infections may involve multiple. The submasseteric space most commonly results from the spread of a buccal space infection or a mandibular third molar pericoronitis infection. The resulting inflammation of the masseter muscle results in trismus. Pterygomandibular space infections generally arise from mandibular third molars. It should be noted that this is the space into which local anesthetic solution is deposited when providing inferior alveolar nerve blocks, and this space may thus

be infected via needle tracking. Clinically, an infection of this space does not result in much, if any, swelling; however, there will be significant trismus, and the lack of swelling in the presence of trismus can be a diagnostic sign. It may also be possible to identify swelling and inflammation of the anterior tonsillar pillar on the affected side with deviation of the uvula. The superficial and deep temporal spaces are rarely infected, and their involvement is generally indicative of a severe infection. Clinically, swelling will be observed in the temporal region, superior to the zygomatic arch, and posterior to the lateral orbital rim.

13.3.3 Infections Spreading to the Deep Cervical Spaces

Involvement of the deep cervical spaces, though rare, can have life-threatening consequence as the airway can become compressed, deviated, or even completely obstructed; vital structures, such as the great vessels, can become invaded; and extension into the mediastinum and its contents can occur (Flynn et al. 2006a). As described above, the perimandibular spaces extend posteriorly into the deep cervical spaces, with the lateral pharyngeal space being the first to encounter the spread of infection (Hupp and Ferneini 2016; Hupp et al. 2014).

The lateral pharyngeal space includes a relatively benign anterior compartment containing loose connective tissue and a posterior compartment, which contains the carotid sheath and cranial nerves IX (glossopharyngeal), X (vagus), and XII (hypoglossal). Clinically, an infection of this space will include trismus and lateral neck swelling. Patients often have difficulty swallowing and will appear sick with a significant fever. An infection of this space indicates a severe infection that is often rapidly spreading. The contents of the lateral pharyngeal space put the patient at risk for internal jugular vein thrombosis, carotid artery erosion, and interference with the functions of the associated cranial nerves.

Beyond the lateral pharyngeal space lies the retropharyngeal space, just posterior to the pharynx. This space contains only loose connective tissue and lymph nodes. As such, there are essentially no barriers to the spread of infection from one lateral pharyngeal to its contralateral side, effectively surrounding the airway.

Involvement of the retropharyngeal space is most concerning for rupture of the alar fascia posteriorly, thus allowing the infection to invade the danger space. The danger space extends from the skull to the diaphragm, continuous with the mediastinum. The mediastinum runs between the lungs and contains the heart, lungs, and trachea, in addition to the phrenic and vagus nerves, main stem bronchi, esophagus, and great vessels such as the aorta and inferior and superior vena cava. Infection of the mediastinum puts the patient at risk for compression of the heart and lungs, neurological interference with the control of heart rate and respirations, and rupture of the lungs, trachea, or esophagus with potential resulting spread to the abdominal cavity. The mortality rate in mediastinitis is high.

Table 13.6 highlights the anatomy of the above-described potential spaces, while Table 13.7 summarizes the clinically relevant information, including the most likely offending tooth and optimal approach for surgical drainage.

Table 13.6 Borders of the fascial spaces of the head and neck

Space	Anterior	Posterior	Superior	Inferior	Superficial or medial	Deep or lateral
Buccal	Corner of the mouth	Masseter muscle, pterygomandibular space	Maxilla, infraorbital space	Mandible	Subcutaneous tissue and skin	Buccinator muscle
Infraorbital	Nasal cartilages	Buccal space	Quadratus labii superioris muscle	Oral mucosa	Quadratus labii superioris muscle	Levator anguli oris muscle, maxilla
Submandibular	Anterior belly digastric muscle	Posterior belly digastric muscle, stylohyoid muscle, stylopharyngeus muscle	Inferior and medial surfaces of mandible	Digastric tendons	Platysma muscle, investing fascia	Mylohyoid muscle, hyoglossus muscle, superior constrictor muscles
Submental	Inferior border of mandible	Hyoid bone	Mylohyoid muscle	Investing fascia	Investing fascia	Anterior belly of digastric muscle
Sublingual	Lingual surface of mandible	Submandibular space	Oral mucosa	Mylohyoid muscle	Muscles of tongue	Lingual surface of mandible
Pterygomandibular	Buccal space	Parotid gland	Lateral pterygoid muscle	Inferior border of mandible	Medial pterygoid muscle	Ascending ramus of mandible
Submasseteric	Buccal space	Parotid gland	Zygomatic arch	Inferior border of mandible	Ascending ramus of mandible	Masseter muscle
Lateral pharyngeal	Superior and middle pharyngeal muscles	Carotid sheath, scalene fascia	Skull base	Hyoid bone	Pharyngeal constrictors and retropharyngeal space	Medial pterygoid muscle
Retropharyngeal	Superior and middle pharyngeal constrictor muscles	Alar fascia	Skull base	Fusion of alar and prevertebral fascia at C6-T4		Carotid sheath and lateral pharyngeal space
Pretracheal	Sternothyroid-thyrohyoid fascia	Retropharyngeal space	Thyroid cartilage	Superior mediastinum	Sternothyroid-thyrohyoid fascia	Visceral fascia over trachea and thyroid gland

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 323

Table 13.7 Clinical findings relevant to fascial space anatomy

Space	Likely causes	Contents	Neighboring spaces	Approach for I&D
Buccal	Upper premolars Upper molars Lower premolars	Parotid duct Anterior facial artery and vein Transverse facial artery and vein Buccal fat pad	Infraorbital Pterygomandibular Infratemporal	Intraoral (small) Extraoral (large)
Infraorbital	Upper canine	Angular artery and vein Infraorbital nerve	Buccal	Intraoral
Submandibular	Lower molars	Submandibular gland Facial artery and vein Lymph nodes	Sublingual Submental Lateral pharyngeal Buccal	Extraoral
Submental	Lower anterior teeth Fracture of symphysis	Anterior jugular vein Lymph nodes	Submandibular (on either side)	Extraoral
Sublingual	Lower premolars Lower molars Direct trauma	Sublingual gland Wharton's ducts Lingual nerve Lingual artery and vein	Submandibular Lateral Pharyngeal Visceral (trachea and esophagus)	Intraoral Intraoral-extraoral
Pterygomandibular	Lower third molars Fracture of angle of mandible	Mandibular division of trigeminal nerve Inferior alveolar artery and vein	Buccal Lateral pharyngeal Submasseteric Deep temporal Parotid Peritonsillar	Intraoral-extraoral
Submasseteric	Lower third molars Fracture of angle of mandible	Masseteric artery and vein	Buccal Pterygomandibular Superficial temporal Parotid	Intraoral Intraoral-extraoral
Infratemporal and deep temporal	Upper molars	Pterygoid plexus Interior maxillary artery and vein Mandibular division of trigeminal nerve Skull base foramina	Buccal Superficial temporal Inferior petrosal sinus	Intraoral Extraoral Intraoral-extraoral
Superficial temporal	Upper molars Lower molars	Temporal fat pad Temporal branch of facial nerve	Buccal Deep temporal	Intraoral Extraoral Intraoral-extraoral
Lateral pharyngeal	Lower third molars Tonsils Infection of neighboring space	Carotid artery Internal jugular vein Vagus nerve Cervical sympathetic chain	Pterygomandibular Submandibular Sublingual Peritonsillar Retropharyngeal	Intraoral Intraoral-extraoral

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 324

Table 13.8 Relative severity of deep fascial space infections

Low severity—low risk to airway or vital structures
• Vestibular
• Subperiosteal
• Buccal
• Space of the body of the mandible
• Infraorbital
Moderate severity—hinders airway access
• Submandibular
• Sublingual
• Submental
• Masticator
• Submasseteric
• Pterygomandibular
• Superficial temporal
• Deep temporal
High severity—direct threat to airway or vital structures
• Perimandibular
• Lateral pharyngeal
• Retropharyngeal
• Pretracheal
• Danger space
• Mediastinum
• Intracranial infection

From: Hupp, J., and Ferneini, E. Principles of Antibiotic Therapy for Head, Neck, and Orofacial Infections. *Head, Neck, and Orofacial Infections* 2016; p 127

Whichever deep fascial space is infected, it is important to understand that the risk to the airway is real and compromise can occur quickly. Thus, it is important to quickly recognize the affected space so that treatment can be initiated. The relative severity of each potential space infection can be classified by the likelihood of threatening the airway or other vital structure (see Table 13.8). Low-severity infections are not likely to threaten any vital structure. Moderate-severity infections can hinder access to the airway via trismus or tongue elevation, potentially making endotracheal intubation difficult. High-severity infections can compress or deviate the airway or damage vital organs such as the heart, lungs, or brain.

13.4 Management and Treatment

When treating infections, the clinician must keep in mind all of the preceding information. Applying this information to a series of principles can be used stepwise to make treatment decisions.

13.4.1 Determine Severity of Infection

Though the above discussion on fascial planes can be intimidating, as previously mentioned, most odontogenic infections are mild and require only minor surgical therapy. The severity of infection can be determined with a complete history and

physical examination to evaluate airway patency, anatomic location, and rate of progression. The history should be obtained as any other history would be, by starting with the chief compliant in the patient's own words. The provider should then determine the onset of the infection. This can be obtained by asking the patient when they first began to experience symptoms such as pain, swelling, or drainage. The provider will want to know if the infection has been constant, waxed and waned, or steadily grown worse. These questions will help the practitioner determine the rate of progression of the infection.

The signs and symptoms of the infection should be assessed at this time as well. An infection is the body's response to severe inflammation, and as such, the cardinal signs of inflammation are what to look for in on examination. These include dolor (pain), tumor (swelling), calor (warmth), rubor (erythema), and functio laesa (loss of function).

Pain is generally the most common complaint from patients. The clinician will want to know where the pain started and where the pain has spread. Swelling can range from subtle and difficult to notice to quite obvious. In cases of subtle swelling, the patient may be able to point out an area of their own body that doesn't look right to them better than the practitioner, and as such the patient should be specifically asked if they have noticed any swelling. Similarly, the patient should be asked whether they have noticed any warmth over the area in question or whether they perceive a color change. Loss of function can be assessed by checking for trismus (limited mouth opening), as well as asking the patient if they are having any difficulty chewing, swallowing (dysphagia), or breathing (dyspnea). Finally, the patient should be asked how they feel in general. Malaise is a feeling of fatigue, fever, weakness, or just "sickness" and is often indicative of the body's general reaction to infection.

Any history of treatment for the current infection should be discerned at this time. This can include self-treatments such as taking previously leftover antibiotics or professional treatment by other dentists or physicians. The patient's complete medical history should be obtained.

The physical exam should include the patient's vital signs (temperature, blood pressure, pulse rate, and respiratory rate). Patients with systemic involvement will have elevated temperatures (a temperature of 101.5 °F or 38.6 °C is considered a true fever). The pulse will increase with temperature, and 100 beats/min is a potential sign of a severe infection requiring more aggressive treatment. Blood pressure is the vital sign that will deviate from baseline the least due to infection. Its increase is generally due to patient pain or anxiety; however, hypotension is a sign of septic shock. Respirations are important for the assessment of partial or complete airway obstruction. A normal respiratory rate is between 14 and 16 breaths/min. If the only vital sign that is altered is a mild temperature elevation, this is indicative of a mild infection that can be readily treated. Alterations of other vital signs are potential indicators of a more severe infection that may need a higher level of care.

The physical exam should then continue with an inspection of the general appearance of the patient. Patients with more severe infections will appear more "toxic" with apparent fatigue and general malaise.

The head and neck should be closely examined for the cardinal signs of infection. The patent should be asked to open wide, swallow, and take deep breaths as the

dentist inspects for trismus, dysphagia, and dyspnea. These are signs of more severe infections that may require referral.

Areas of swelling should be examined by palpation, gently touching the area to check for tenderness, warmth, and consistency. The consistency may range from indurated (hard) to fluctuant (soft, fluid-filled balloon feeling). The latter is indicative of purulent accumulation.

An intraoral exam should be completed in an attempt to identify the source of infection. The exam should include inspection for carious teeth, severe periodontal disease, infected fracture of tooth or bone, or any combination of the above. The dentist should also feel for areas of gingival swelling and for localized vestibular swellings or sinus tracts.

The next step of the initial exam is radiographic. This may consist of periapical or panoramic radiographs, which are especially useful in patients with limited mouth opening or tenderness. Deep cervical space infections will require evaluation with computed tomography (CT).

At this point, the dentist should have a sense of the presenting stage of the infection and severity of the infection. Soft, mildly tender, edematous swellings indicate inoculation; induration represents cellulitis; and central fluctuance indicates abscess. Cellulitis is generally acute, painful, with more swelling than edema, and with diffuse borders. They are hard, do not contain visible pus, and can rapidly spread. Abscesses are a more mature infection with more localized pain, less swelling, and well-circumscribed borders. They represent the body's host resistance in an attempt to wall off the infection. It is often difficult to distinguish between cellulitis and abscess, and both may be present in a given area or different spaces may be at different stages of infection.

13.4.2 Evaluate Host Defenses

One of the reasons it's so important to take a complete and accurate medical history is the opportunity for the dentist to evaluate the patient immune system's ability to defend itself against infections. Several common disease states and medications can significantly alter the patient's ability to do so. Not only are immunocompromised patients more likely to get infections, but the infection is also more likely to become serious and spread rapidly.

Uncontrolled metabolic diseases result in decreased function of leukocytes. The most common of these disorders are type 1 (insulin-dependent) and type 2 (insulin-independent) diabetes but also include end-stage renal disease with uremia, malnutrition, and severe alcoholism. It should be noted that worsening control of hyperglycemia is directly correlated with lowered resistance to infection. The second significant category of immunocompromised patients is those that suppress the immune system in general and includes malignancies, HIV, and immunologic disease. In these disease states, the patient will have decreased white blood cell function and decreased antibody synthesis and production.

Patients taking certain medications can also be immunologically compromised. These include chemotherapeutic agents that decrease circulating white blood cells

and patients taking immunosuppressive drugs, most commonly for organ transplantation, which decrease T and B lymphocyte and immunoglobulin production. If the medical history indicates a history of disease state that may have required these drugs, the dentist should inquire as to not only current use but past use of these drugs as the immunosuppressive effects of certain chemotherapeutic agents can last for up to 1 year after cessation.

When the patient's history indicates any of the above concerns, the risk of rapid spread is much greater, and the patient will need to be treated more aggressively. Consideration should be given for prompt referral to an oral and maxillofacial surgeon for treatment and initiation of parenteral antibiotics, as well as the possibility of prophylactic antibiotics for even routine oral surgical procedures.

13.4.3 Determine the Care Setting

The vast majority of odontogenic infections can be treated by the general dentist with minor surgical intervention and antibiotics if indicated. However, the previous discussion should highlight that severe infections do have the potential to become life threatening. The dentist needs to know when to refer cases to an oral and maxillofacial surgeon for care in an outpatient or hospital inpatient basis, summarized in Table 13.9. The dentist should use the following set of criteria to quickly evaluate the severity of infection. If some or all of these criteria are met, immediate referral should be considered.

There are three main criteria that should indicate immediate referral to a hospital emergency department due to an impending airway threat. The first is a history of rapidly progressing infection—that is, one that began only 1 or 2 days ago and has rapidly gotten worse with increasing swelling, pain, and other signs and symptoms. These patients are at increased risk of infection involving the deep cervical spaces and compressing the airway. The second criterion is difficulty breathing (dyspnea), which may be due to the infection encroaching on the soft tissue surrounding the airway. The dentist can recognize this by looking for obvious signs of breathing difficulties, patients who refuse to lie down, or those with muffled or

Table 13.9 Oral and maxillofacial surgeon referral criteria

• Difficulty breathing
• Difficulty swallowing
• Dehydration
• Moderate-severe trismus (MIO <20 mm)
• Swelling extending beyond the alveolar process
• Fever (>101.5 °F)
• Severe malaise and toxic appearance
• Immunocompromised patient
• Need for general anesthesia
• Failure of prior treatment

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 303

distorted speech. The third criterion is difficulty swallowing (dysphagia), which is also a sign of deep cervical space involvement. True dysphagia can be identified by the presence of drooling, as a patient's inability to handle his or her own secretions is a sign of a narrowed oropharynx. In all three of these cases, the immediate concern is monitoring the airway and, if necessary, securing with endotracheal intubation or surgical intervention. The infection can then be dealt with appropriately.

There are other criteria that the dentist needs to be aware of that may require referral to an oral and maxillofacial surgeon. The first is that certain spaces are more appropriately treated by a transfacial incision and drainage procedure for drainage by gravity, as was seen in Table 13.7. The second is a temperature greater than 101.5 °F, which indicates a greater severity of infection. The third criterion is severe trismus—an inability to open the mouth fully due to inflammation of the muscles of mastication. Trismus can be defined as mild, moderate, or severe by a maximum incisal opening (MIO) of 20–30 mm, 10–20 mm, and <10 mm, respectively. Moderate-severe trismus is a potential sign of involvement into the masticator space and beyond to the deep cervical spaces. Infection of these spaces may require evaluation by an oral and maxillofacial surgeon to determine airway patency. Systemic involvement is another reason for referral, which can be identified by the previously described "toxic" appearance. Lastly, an oral and maxillofacial surgeon may be more appropriate to treat patients with severely compromised host defenses, as the surgeon has the ability to admit these complicated patients to the hospital for more definitive care.

13.4.4 Treat Surgically

Once the first three factors have been evaluated and the dentist has decided to treat the patient, the first step in the management of odontogenic infections is removal of the source of infection and surgical drainage, which can range from simple endodontic access to soft tissue dissections in the neck or mediastinum in truly severe, life-threatening situations.

The primary goal of surgical management is to remove the source of infection, most commonly a necrotic dental pulp, with a secondary goal of draining any accumulated purulent or necrotic debris. If the dentist chooses to save the tooth, endodontic therapy should be initiated to remove the necrotic pulp, which is the source of infection. Extraction of the tooth both removes the source of infection and provides drainage from the periapical region. If the infection has spread beyond the periapical region, an incision and drainage (I&D) should be performed. This decreases the bacterial load, and the removal of the purulent and/or necrotic debris will decrease the pressure in the region, thus decompressing the tissue and increasing local blood flow to deliver host defenses and antibiotics to the region. Given that the goal of surgical intervention is to achieve adequate drainage, it should be noted that if endodontic access does not provide adequate drainage, an I&D is still indicated. Lastly, the dentist should consider insertion of a drain to prevent premature closure of the mucosal incision, allowing the abscess to reform. It should be noted that

removal of the source and evacuation of the bacterial and necrotic debris is the treatment that must be performed. Antibiotics are an adjunctive treatment, and failure to perform surgical intervention for infections beyond the inoculation stage may result in the lack of resolution or worsening of the infection.

Generally, infections in the inoculation stage can generally be cured with removal of the source of infection with or without supporting antibiotics, whereas cellulitic or abscessed patients are at a more advanced stage requiring removal of the source, as well as incision and drainage and antibiotics.

Within the surgical community, there continues to be disagreement as to whether cellulitis cases require incision and drainage versus removal of the source and antibiotics alone. Literature suggests that if a true cellulitis exists, intravenous antibiotics alone, with empiric coverage against aerobic and anaerobic pathogens, are enough for treatment in addition to source removal (Flynn et al. 2006b; Shanti and Shahid 2011). However, one landmark study by Flynn and colleagues noted that clinical examination was able to identify a drainable collection only 63% of the time; other studies show this percentage as low as 33%. Flynn's same study found the presence of pus in 76% of cases. Even the accuracy of CT scans in the evaluation of deep neck infections has been shown to have variable accuracy, with false positives for abscesses ranging from 11.8% to 25%. Literature suggests that a combination of CT scan and clinical examination together is the most accurate method of identifying a drainable collection. Given that clinical examination often underestimates suppuration, this may be a reason to drain even suspected cellulitis, which at the very least changes the environment of the often-facultative anaerobes living in the infection (Hupp and Ferneini 2016; Hupp et al. 2014).

Figure 13.4 outlines the suggested algorithm for the treatment of odontogenic infections. The optimal site for a straightforward vestibular abscess or cellulitis is directly over the area of maximum swelling and inflammation; however, the dentist should take care to note relevant anatomy such as a frenum or the mental nerve and alter their incision site appropriately in such cases. The site should be anesthetized either locally or with a regional block, and the needle subsequently discarded so as not to infect other tissue if it is used again.

Before starting, the dentist should determine whether a culture and sensitivity (C&S) test of the specimen should be obtained. Table 13.10 outlines the indications for such a procedure. As the previous discussion on microbiology of odontogenic infections highlighted, the microbes of these infections are highly consistent, and C&S is not needed for routine odontogenic infections. If the test is to be obtained, after anesthesia, the dentist should disinfect the mucosal surface with a solution such as povidone-iodine (Betadine) and dry the tissue with sterile gauze. A large-gauge needle (e.g., 18 g), with a small syringe (3 mL is usually sufficient), will be used to collect the specimen. The needle should be inserted into the abscess or cellulitis and 1 or 2 mL of fluid aspirated. Even if no apparent pus is obtained, there is usually a sufficient bacterial load to suffice. The specimen should then be transferred to an appropriate culturette, which is a sterile tube that contains a swab and bacterial transport medium. This will be sent to the lab with a request for gram stain, aerobic and anaerobic cultures, and antibiotic sensitivity testing.

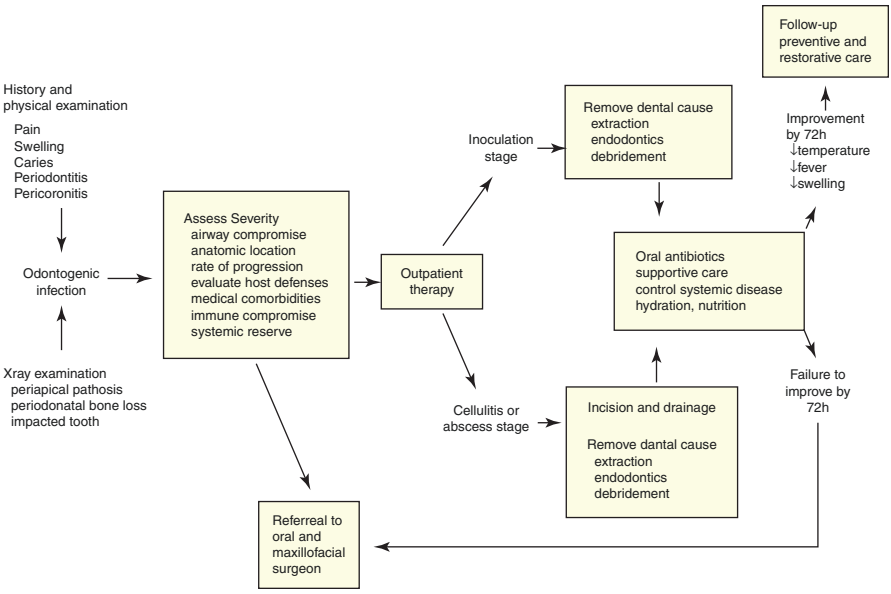

Fig. 13.4 Management algorithm for odontogenic infections. From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 305

Table 13.10 Indications for culture and antibiotic sensitivity testing

• Infection spreading beyond the alveolar process
• Rapidly progressing infection
• Previous, multiple antibiotic therapy
• Nonresponsive infection (after 48 h)
• Recurrent infection
• Immunocompromised patient

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 304

A scalpel blade should be used to incise through mucosa, submucosa, and periosteum to bone. The incision should be short, around 1 cm. A closed curved hemostat is then inserted through the incision and opened in several directions to explore the space and breakup and loculations (cavities of pus) that weren't incised by the original incision. Care should be taken not to close the hemostat within the wound so as not to crush any tissue. The cavity should then be thoroughly irrigated with solution, most commonly normal sterile saline, in order to fully wash out any remaining debris.

Once the abscess cavity has been fully opened and evacuated, a small drain should be inserted to ensure that the access stays open. For intraoral I&Ds, this is most commonly a ¼″ Penrose drain, but anything that will keep the mucosa open will suffice. The drain should be of adequate length to reach the depth of the abscess.

It is then inserted into the cavity with a hemostat and sutured to one edge of the incision with a non-resorbable suture. The drain should remain in place until drainage has stopped, usually 2–5 days. The drain can be removed by simply cutting the suture and gently pulling on the end of the drain.

13.4.5 Support Medically

Although the mainstay of infection management is surgical therapy, supportive medical therapy cannot be overlooked. Medical therapy should be aimed at supporting the host's systemic response to the infection through appropriate antibiotic therapy, management of comorbidities, and special attention to appropriate hydration and nutrition. For example, diabetics may require insulin adjustment as the infection raises the blood sugar level; cardiovascular disease decreases the ability of the patient to respond to stress, thus potentially necessitating the need for hypertension or cardiac arrhythmia control; and patients on Coumadin may require reversal prior to surgical intervention. Patients with compromise of the cardiovascular, respiratory, hematologic, or metabolic systems may need appropriate medical support from a team of specialists.

Even healthy patients can have reduced or altered physiologic reserves required for the body to fight the infection. Children, for example, are much more susceptible to dehydration and high fevers, while the elderly are less able to mount a fever but are also susceptible to dehydration (Chi et al. 2014). Fever increases daily fluid requirements and daily caloric requirements. Fevers up to 103 °F may help to fight the infection; however, it is important to monitor this closely so that dangerous levels are not reached. Dentists can help patients in this regard with thorough postoperative instructions, as patients often need to be encouraged to have adequate fluid and caloric intake in the face of pain and/or difficulty swallowing.

13.4.6 Choose and Administer Appropriate Antibiotics

Antibiotics are an often-needed adjunctive agent in the management of odontogenic infections that need to be carefully chosen and used in the appropriate situations, especially given the growing concerns regarding antibiotic resistance. The following discussion serves as a guideline for appropriate antibiotic prescribing.

It is commonly assumed that all infections require antibiotics, though this is certainly not the case—there are even situations in which they are contraindicated. Antibiotics, in short, should be used when there are clear indications of bacterial invasion into deeper tissues, in patients with compromised immune systems, in patients not able to receive immediate surgical intervention, and in patients with a systemic response (Rosenthal et al. 2011; Flynn 2011). The following three factors should be considered when deciding whether to prescribe an antibiotic, and Table 13.11 further lists indications.

Table 13.11 Antibiotic indications

• Swelling extending beyond the alveolar process
• Cellulitis
• Trismus
• Lymphadenopathy
• Fever >101.5 °F
• Severe pericoronitis
• Osteomyelitis

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 307

Table 13.12 Situations in which antibiotics are not indicated

• Patient demand
• Pain, toothache
• Periapical abscess
• Alveolar osteitis (dry socket)
• Extractions in non-immunocompromised patients
• Mild pericoronitis (inflammation of the operculum only)
• Successfully drained alveolar abscess

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 307

1. The seriousness of the infection. Infections that have caused swelling, rapidly progressed, or is a diffuse swelling all have literature support for antibiotics in addition to incision and drainage.
2. Failure to obtain adequate drainage. As previously stated, removal of the tooth—or source of infection—does not spread the infection but rather aids in the resolution of infection and limits complications. Multiple studies have supported this statement and also shown that antibiotics are not necessary prior to extraction. If extraction fails to achieve appropriate drainage, an I&D will be indicated in addition to antibiotics.
3. The state of the patient's host defense response. Aggressive antibiotics are indicated in patients with an immunocompromised state, as has been discussed previously.

Antibiotics are not indicated for minor, chronic, well-localized abscesses in which removal of the source of infection will result in complete evacuation of the infectious material, provided that the other factors previously discussed, such as an immunocompromised state, are not met. Alveolar osteitis (dry socket) is not an infectious process, and thus treatment should be limited to palliative care. Patients with mild pericoronitis with minor gingival edema and pain also do not require antibiotics and can be treated with light irrigation with hydrogen peroxide or chlorhexidine and removal of the tooth. Patients who demand antibiotics also should not be prescribed unless clinically indicated. Table 13.12 further describes situations in which antibiotics are not indicated. Antibiotics do not increase wound healing, nor do they play a role in nonbacterial infectious processes. Patients with

Table 13.13 Antibiotics used for odontogenic infections

Narrow-spectrum antibiotics	Broad-spectrum antibiotics
• Penicillin	• Amoxicillin with clavulanic acid (Augmentin)
• Amoxicillin	• Azithromycin
• Clindamycin	• Moxifloxacin
• Metronidazole	

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 308

significant pain of pulpal origin, without spread into deeper tissues, also are not indicated for antibiotics treatment, as this is a local inflammatory response.

The earlier discussion on odontogenic infection microbiology highlights the predictability of these infections; thus antibiotic therapy should be directed at these organisms with proven medications in an empiric fashion. Oral antibiotics that have been proven to be effective include penicillin, amoxicillin, clindamycin, azithromycin, metronidazole, and moxifloxacin. Systematic reviews have shown that none of the newer antibiotics have a greater efficacy than the traditional amoxicillin or penicillin. Metronidazole should be reserved for situations in which there are significant numbers of anaerobes and should be given in addition to an antibiotic with antiaerobic properties. With the exception of metronidazole, which targets anaerobes only, these antibiotics all cover aerobic and facultative streptococci in addition to oral anaerobes.

When choosing an antibiotic, the dentist should note to use the narrowest-spectrum antibiotic possible and with the lowest toxicity and side effects, as well as using the least complicated dosing schedule possible to encourage patient compliance. Using a narrow-spectrum antibiotic ensures that the therapy is targeting only the offending organisms and not other bacteria that may be part of the GI tract, skin, etc. and are part of the patient's normal flora and can lead to other problems. See Table 13.13 for a list of narrow- versus broad-spectrum antibiotics, all of which have been proven effective in the treatment of odontogenic infections. Note that simple odontogenic infections are ones in which the swelling is limited to the alveolar process or vestibule, has not been treated before, and is not taking place in an immunocompromised patient. Complex odontogenic infections include those in which the swelling has extended beyond the vestibular space, has failed previous therapy, and is attached to an immunocompromised patient.

Toxicities range from mild to severe. It should be noted that the time-tested antibiotics used in dentistry have a relatively benign side effect profile. The most common side effect of penicillin is allergy with approximately 2–3% of the population affected. Azithromycin and clindamycin also have generally benign side effect profiles. Clindamycin is most commonly associated with severe diarrhea and pseudomembranous colitis, though any antibiotic can cause this condition. This is a rare side effect with appropriate prescribing patterns. Moxifloxacin, a fluoroquinolone, is rarely used in dentistry and should be limited to severe infections. It has significant

potential toxicities including muscle weakness, mental clouding, and potential life-threatening drug-drug interactions. It is contraindicated in children and pregnant females. Cephalosporins are no longer commonly used in dentistry as many of them have lost much of their effectiveness against oral bacteria. They should be used with caution, if at all, in penicillin allergic patients due to a 10–20% cross-reactivity. Similarly, tetracyclines are no longer considered effective for the treatment of odontogenic infections with the exception of their use as topical agents in periodontal infections. Tetracyclines can cause GI upset and photosensitivity and also should not be used in pregnant patients or children. Lastly, metronidazole has only mild side effects, most commonly GI disturbances. Patients must refrain from all alcohol intake due to the disulfiram-like reaction of this drug in which even a small amount of alcohol can cause violent abdominal cramping and vomiting.

Dentists should try to choose bactericidal antibiotics when possible. These types of antibiotics kill bacteria themselves, whereas bacteriostatic antibiotics interfere with bacterial reproduction and rely on the body's host defenses to kill the organism. The use of bactericidal antibiotics is thus especially important in immunocompromised patients. Bactericidal antibiotics include the penicillins, cephalosporins, fluoroquinolones, and metronidazole.

Antibiotics should be prescribed in the least taxing dosing schedule as possible in order to encourage compliance—that is, patients are more likely to be compliant if they have to take a pill less often. Current literature suggests that for routine odontogenic infections, antibiotics are not required beyond 3–5 days, when combined with appropriate surgical intervention (Rosenthal et al. 2011). If the infection is not resolving at follow-up, additional antibiotic courses may be necessary.

13.4.7 Reevaluate Frequently

Patients should be closely monitored following infection intervention to monitor for response to treatment and complications. For routine odontogenic infections, a follow-up at 2–3 days should suffice. Patients who are improving will exhibit a dramatic decrease in pain and swelling. If there is no purulent output from the drain, it can be removed at this time. The dentist should evaluate the patient's temperature, trismus, and subjective feelings of improvement at this time, in addition to inquiring about drug toxicities and side effects.

If the patient is not showing significant signs of improvement, the dentist should evaluate for possible causes of failure, summarized in Table 13.14. Most commonly, this is due to inadequate surgery, especially if the tooth was endodontically accessed and not removed—it should then be evaluated for extraction. It is also possible in this situation that the area of infection covered a wider amount of tissue and an additional I&D may be necessary.

Other causes of failure may be a more immunocompromised patient than originally suspected, in which the dentist should carefully question the patient to make sure a complete medical history was elicited. Foreign bodies are rarely a cause of odontogenic infection but should be considered in the setting of non-resolution of

Table 13.14 Common reasons for treatment failure

• Inadequate surgery
• Immunocompromised state
• Foreign body
• Antibiotic problems
– Non-compliance
– Antibiotic not reaching site
– Dose too low
– Wrong identification of bacteria
– Wrong antibiotic

From: Hupp, J., Ellis, E., Tucker, M. Principles of Management and Prevention of Odontogenic Infections. *Contemporary Oral and Maxillofacial Surgery* 2014; p 311

infections. Radiographic exam can help identify this, and dental implants should be considered a source of bacterial harbor.

Lastly, the dentist should consider the chosen antibiotic. The dentist should first question the patient on appropriate compliance with the prescribed drug regimen including dose and scheduling. Patients often misunderstand dentist directions and may not even fill the prescription due to cost or other reasons. The dentist will also need to determine whether the antibiotic is reaching the infected tissue as penetration of antibiotics into abscess cavities is poor due to the walled-off nature of the abscess. This highlights the need for appropriate I&D, allowing maximal blood flow to the area in question. Another reason for the antibiotic not reaching the infected tissue is an inappropriately low dose. Incorrect identification of the causative bacteria will also need to be considered, and as has been discussed, a C&S should be obtained for failed resolution, if it wasn't before.

Lastly, even once the infection appears to be resolving, the dentist should perform additional follow-up to check for recurrent infection. Even if the infection appears almost resolved, it is possible that, for example, the patient may end their antibiotic regimen too early or the drain was removed too early, thus reestablishing the infectious process. If reinfection occurs, the dentist should again begin the treatment algorithm.

13.5 Conclusion

Dentistry has made significant advances over the years in the prevention and early treatment of odontogenic infections. Although most odontogenic infections are simple in nature and discovered early, they can become complex and potentially life threatening. It is thus important to follow an organized, meticulous approach to the evaluation and care of these patients: (1) determine the severity of infection, (2) evaluate host defenses, (3) decide on the setting of care, (4) treat surgically, (5) support medically, (6) appropriate antibiotic choices, and (7) evaluate the patient frequently. The dentist must be cognizant to the possibility of treatment failure, whether through an error in diagnosis, antibiotic resistance, or medical compromise, among other reasons. Although there are no guarantees in surgery, following these principles will ensure the highest quality of care for patients.

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Osteonecrosis

14

Johanna M. Hauer, Mo Banki, and Elie M. Ferneini

"I remain an unknown factor in the business, ready to throw in all my weight at a critical moment."
—The Hound of the Baskervilles

Abstract

This chapter explores three different, yet interrelated, topics essential for the practice of oral and maxillofacial surgery. It addresses the current evidence-based treatment recommendations for osteomyelitis, medication-related osteonecrosis of the jaw (MRONJ), and osteoradionecrosis (ORN). Additionally, this chapter addresses the etiology, diagnosis, and staging of MRONJ/BRONJ and ORN, as well as the subcategories of osteomyelitis of the jaws, including acute suppurative osteomyelitis, chronic suppurative osteomyelitis, chronic sclerosing osteomyelitis, and juvenile mandibular chronic osteomyelitis (JMCO).

14.1 Introduction

This chapter encompasses three interrelated topics within the field of oral and maxillofacial pathology—osteomyelitis, medication-related osteonecrosis of the jaw (MRONJ), and osteoradionecrosis (ORN). All of these conditions warrant

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intervention by the oral and maxillofacial surgeons, and this chapter explores the current recommendations based on the literature available to date. Ultimately, each of these conditions involves destruction of the bony structures within the maxillofacial skeleton, and management falls firmly within the scope of oral and maxillofacial surgeons.

14.2 Osteomyelitis

Osteomyelitis is the inflammation of the osseous medulla or cortical bone which may be acute or chronic and encompasses a variety of disease processes (Neville 2009). This disease process dates as far back as the Pleistocene era approximately 1.6 million years ago, but with the advent of modern antibiotics, the frequency of presentation has been dramatically reduced (Krakowiak 2011; Hudson 1993). Due to the highly vascularized nature of the head and neck, healing in this region tends to proceed without complication. However, sometimes, surgical sites or areas exposed by injury or other odontogenic conditions may become infected, and host factors may predispose patients to development of such infections. The mandible is more susceptible to infection due to its dense cortical plates and primary vascular supply from the inferior alveolar artery and limited anastomoses with the facial artery. By contrast, the maxilla has significantly less dense bone and multiple vessels for perfusion, making it less susceptible to infection (Bagheri et al. 2008).

Whereas osteomyelitis in the long bones typically becomes established from local or hematogenous spread, osteomyelitis of the jaws spreads through local extension from the skin, sites in the oral cavity, or the sinuses, but rarely hematogenously. Neonatal osteomyelitis of the jaws typically has a hematogenous source and can be treated by parenteral antibiotics exclusively (Ecury-Goossen et al. 2009). Unlike any other bone in the body, the mandible and maxilla have a direct connection to the external environment by way of the teeth and periodontium, creating a pathway for infection without an obvious source (Krakowiak 2011; Landesberg et al. 2011).

14.2.1 Acute Suppurative Osteomyelitis

Patients with acute suppurative osteomyelitis typically present with acute pain, swelling, purulent drainage, lymphadenopathy, and fever as well as leukocytosis which can differentiate this from the chronic form of disease (Case 1, Fig. 14.1). Additionally, there is a temporal component, where diagnosis is within 1 month of onset of symptoms. Osteomyelitis is a polymicrobial infection, with colonization by microbes comprising "normal oral flora" including *Fusobacterium*, *Porphyromonas*, and *Streptococcus* (Santosh et al. 2017). However, osteomyelitis is distinguished from other odontogenic infections by also featuring colonization by *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Actinomyces*, and *Eikenella* (Krakowiak 2011; Koorbusch et al. 1992). Increasingly, cases of

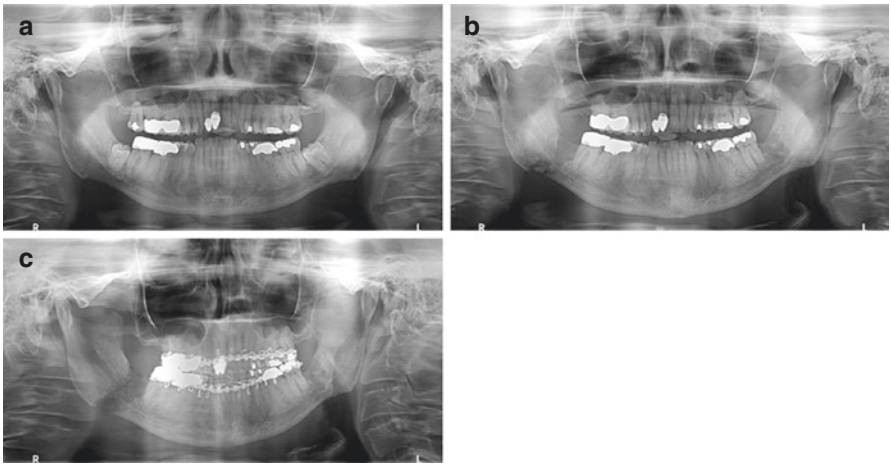

Fig. 14.1 (**a**) Panoramic X-ray showing impacted mandibular third molars. (**b**) Panoramic X-ray reveals a nondisplaced fracture involving the right mandibular angle. (**c**) Panoramic X-ray after debridement, sequestrectomy and saucerization and placement of maxillo-mandibular fixation

osteomyelitis are seeing infection with clindamycin-resistant *S. aureus*, as well as MRSA, with overall presentation with *Staphylococcus* species of upward of 70–90%. For this reason, cultures are important when selecting an antimicrobial agent for treatment. Until culture results are returned, treatment with empirically selected agents is appropriate (Helm et al. 2016).

Unfortunately radiographic signs on conventional radiographs require as much as 50% bone mineral density loss for detection. Plain radiographs may be interpreted as normal for at least 4–8 days and as many as 3–4 weeks. When visualized on orthopantomogram, signs of osteomyelitis include ill-defined radiolucency, which may be closely associated with an extraction socket or radiolucency (Fig. 14.2). Rarely, pathologic fracture may be seen. As the disease state progresses, bony sequestrum may appear as radiodense areas surrounded by irregular radiolucency. In the interim, additional methods of imaging may be used including computed tomography (CT), magnetic resonance imaging (MRI), and radionuclide imaging using technetium. When plain radiographs, orthopantomograms, and CT imaging have negative results in the setting of high clinical suspicion, MRI often demonstrates more extensive subperiosteal disease with high signal on T2 imaging and low signal on T1, while sequestra will appear like cortical bone with low signal in both T1 and T2 (Schuknecht and Valavanis 2003). Radiolabeled technetium Tc99m scintigraphy can show hyperemia associated with osteomyelitis as early as 2–3 days. Typically, early osteomyelitis appears on CT as osteolysis within the cancellous bone, but later changes like sequestration formation will not be visualized for 3–4 weeks (Schuknecht and Valavanis 2003; Koorbusch and Deatherage 2011). Additionally, periostitis ossificans or Garre's osteomyelitis may be visualized on radiographs or CT. However, this finding, while associated with chronic osteomyelitis, actually represents a feature of acute osteomyelitis (Schuknecht and Valavanis 2003).

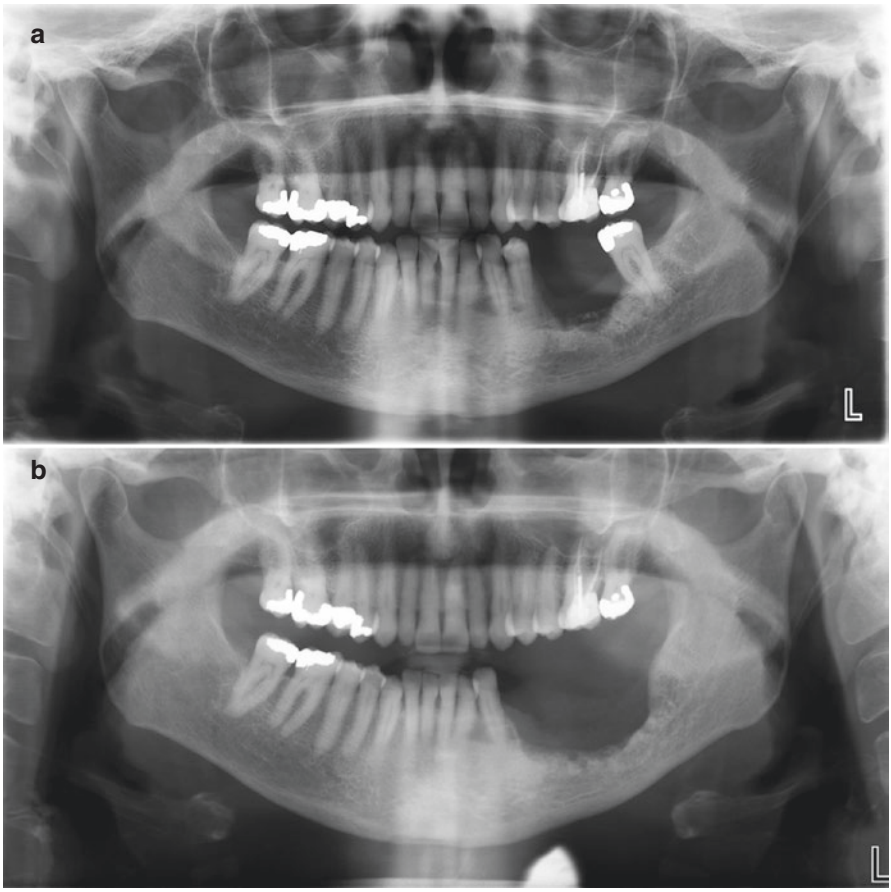

Fig. 14.2 (**a**) Osteomyelitis subsequent to a dental infection in the left posterior mandibular area (Courtesy of Dr. Aditya Tadinada, University of Connecticut). (**b**) 3-week follow-up with a significant increase in size of the involved area (Courtesy of Dr. Aditya Tadinada, University of Connecticut)

Increasingly cone-beam computed tomography is used in the field of oral and maxillofacial surgery. Cone-beam computed tomography (CBCT) findings of osteomyelitis include osteosclerosis and irregular radiolucencies, just as on panoramic or plain films and conventional CT (Fig. 14.3). Despite additional differential diagnoses with similar radiographic presentation, CBCT has a place in the imaging of osteomyelitis (Schulze et al. 2006).

The goal of treatment for osteomyelitis is the removal of the nidus of infection and elimination of the offending pathogens. While antibiotic therapy is a cornerstone of osteomyelitis treatment, surgical therapy is typically required for resolution. The literature reflects a variety of surgical options for approaching acute suppurative osteomyelitis, including debridement, incision and drainage, resection, sequestrectomy, and decortication. Debridement is typically the first line of surgical

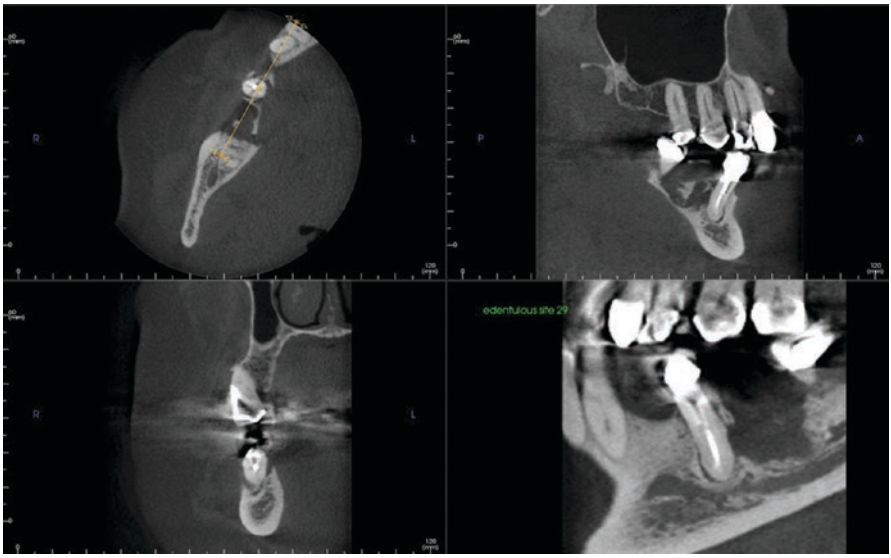

Fig. 14.3 CBCT images showing Osteomyelitis of the right posterior mandibular region (Courtesy of Dr. Aditya Tadinada, University of Connecticut)

intervention, along with stabilization to prevent pathologic fracture (Koorbusch et al. 1992; Hjorting-Hansen 1970). Sequestrectomy may also require saucerization, and typically decortication is reserved for refractory cases (Koorbusch and Deatherage 2011). These surgical techniques function to increase the vascular penetrance of the bone and allow antibiotic therapy access to the infection site. Ideally, antibiotic therapy should not be initiated until after a specimen is obtained from the affected site, and therapy should be tailored once cultures are returned (Hudson 1993). The duration of treatment remains debatable, but it appears that most infections resolve with 3–6 weeks of antibiotic therapy (Helm et al. 2016).

14.2.2 Chronic Osteomyelitis

Chronic osteomyelitis is an overarching term that encompasses a variety of disease states lasting at least 1 month, some of which may be confused with osseous dysplasias (Koorbusch et al. 1992). Chronic suppurative osteomyelitis is a smoldering form of disease that may be attributed to an inadequately treated acute osteomyelitis, whereas primary chronic osteomyelitis, also known as chronic nonsuppurative osteomyelitis, is not associated with any acute presentation (Neville 2009; Hjorting-Hansen 1970; Dym and Zeidan 2017). Patients typically present with deep pain, and malaise, and may exhibit lymphadenopathy, fever, or swelling. Fistulas and sequestrum formation may also be present (Koorbusch and Deatherage 2011). On radiographic examination, there are significant findings on both plain films and CT/MRI. Chronic suppurative osteomyelitis will appear with patchy

radiolucent and radiodense lesions that are contiguous, which is also in contrast to primary chronic osteomyelitis, which will present with multifocal areas of mixed lucency/density (Schuknecht and Valavanis 2003).

Treatment of chronic suppurative osteomyelitis involves removal of all necrotic and affected bone, as well as long-term antibiotic therapy. Persistence of disease after treatment is usually due to incomplete removal of diseased tissue. Tetracycline administered for 48 h prior to surgery or doxycycline administered for 10 days prior to surgery may be of assistance, as it allows for fluorescence of unaffected bone (Hjorting-Hansen 1970). Decortication, with removal of any involved cortices, with the exception of the lingual cortex, and exposure of the cancellous bone should be performed. Cortical removal is aggressive and should extend 1–2 cm into the bleeding bone. Some advocate packing the site and allowing for healing by secondary intention, while others suggest primary closure. Despite perforations in the lingual cortex, it is left intact, as the lingual of the mandible typically exhibits improved vascularity due to the mylohyoid muscle attachments (Neville 2009). Treatment for chronic suppurative osteomyelitis is similar to that of acute osteomyelitis, but often use of intravenous antibiotics can be limited to 2 weeks before switching to oral antibiotics. In general, chronic disease should be treated with a longer duration of antimicrobial therapy, and, as always, an infectious disease specialist should be consulted regarding therapy duration. Surgical techniques for removal of affected tissues are the same as for acute forms of disease, with debridement and sequestrectomy being most frequently used, but more aggressive decortication for intractable cases (Krakowiak 2011).

Chronic diffuse sclerosing osteomyelitis is a much debated condition that is poorly understood. In the literature, chronic diffuse sclerosing osteomyelitis is also referred to as chronic nonsuppurative osteomyelitis or primary chronic osteomyelitis (PCO). This condition is often confused with florid osseous dysplasia, as it can present with only radiographic findings, but patients typically have pain. Florid osseous dysplasia, on the other hand, typically presents as a painless condition that is confined to the alveolus (Schneider and Mesa 1990). It has long been hypothesized that there is a low-grade bacterial pathogen etiology to chronic diffuse sclerosing osteomyelitis with no identified pathogen. However, Marx et al. have identified *Actinomyces* and *Eikenella* species in patients with chronic diffuse sclerosing osteomyelitis. This research suggests that chronic diffuse sclerosing osteomyelitis progresses without pus formation and by evading host defenses as a result of a mutualism between *Actinomyces* species or *Arachnia* species and *E. corrodens* (Marx et al. 1994). Unfortunately, this finding is considered dubious by some, and there has been insufficient research to corroborate this finding (Jacobsson 1994).

Juvenile mandibular chronic osteomyelitis [JMCO] has been thought to be the presentation of chronic diffuse sclerosing osteomyelitis in children, but some authors suggest this may be a distinct entity of aseptic osteomyelitis (Sammut et al. 2014). However, some patients treated as adults for primary chronic osteomyelitis that began in childhood have findings of normal oral flora and skin contaminants in surgical specimens (Bevin et al. 2008). These children typically present with pain and swelling of the mandible, and do not respond to antibiotic

therapy or nonsteroidal anti-inflammatory agents, but do have improved pain control with high-dose steroids. Debridement, decortication, and resection have all been employed with success rates around 50% (Renapurkar et al. 2015; Bevin et al. 2008; Sammut et al. 2014).

Hyperbaric oxygen therapy (HBO) is often a beneficial adjunct therapy for all types of osteomyelitis. HBO has been shown to enhance host immune response, as well as produce reactive oxygen species that may prove toxic to pathogens. In addition, HBO has a neoangiogenic response, which allows for superior penetration of host defenses and antimicrobial therapy into the affected site (Hudson 1993; Van Merkesteyn et al. 1984). HBO is helpful for refractory cases.

14.3 Medication-Related Osteonecrosis of the Jaws

MRONJ is defined by the American Association of Oral and Maxillofacial Surgeons as exposed bone or bone that can be probed by way of intraoral or extraoral fistulas that has been present for 8 or more weeks in a patient with history of or current use of antiresorptive/anti-angiogenic agents without previous radiotherapy to or metastatic disease of the jaws (Ruggiero et al. 2014). Oral bisphosphonates were introduced into the US market in the early 1990s for treatment of osteoporosis, and intravenous formulations were introduced to treat cancer metastases to bones. Bisphosphonates are beneficial for these conditions due to their ability to suppress osteoclasts and increase bone density, which thereby reduced the risk of SREs or skeletal-related events like fracture or additional metastases. Some patients treated with oral bisphosphonates experienced esophageal or gastrointestinal sequelae and are therefore switched to intravenous infusions despite requiring therapy for osteoporosis and not metastatic disease (Assael 2011). The first reports of medication-related osteonecrosis of the jaw [MRONJ] came to light in 2003 with a case series presented by Marx of 36 patients with exposed bone in the oral cavity. Each of the 36 patients was taking intravenous bisphosphonate medications, in this case pamidronate [Aredia] or zoledronate [Zometa]. Of these, 80% had painful, necrotic lesions in the mandible, 14% with lesions in the maxilla, and 6% in both. Seventy-eight percent of these lesions appeared after tooth extraction, while the remainder were spontaneous (Marx 2003). Just a year later, Ruggerio reported 63 similar cases, all with patients taking intravenous bisphosphonates (Ruggiero et al. 2004). Initially, this condition was described as bisphosphonate-related osteonecrosis of the jaw. Over the next several years, cases appeared in the literature associated with additional bisphosphonates, including oral preparations, as well as other antiresorptive and anti-angiogenic medications including denosumab, bevacizumab, and long-term steroids and have subsequently been renamed medication-related osteonecrosis of the jaw (Ruggiero et al. 2014; Qi et al. 2014; Neto et al. 2016; Kim et al. 2014; Kyrgidis and Toulis 2011).

The inhibition of osteoclasts by bisphosphonate medications is well documented, although it is unclear why this phenomenon occurs exclusively in the jaws or what the precise etiology entails (Williams 2015; Landesberg et al. 2011). Additionally,

the inhibition of angiogenesis resulting in avascular necrosis is a much hypothesized concept regarding development of MRONJ (Williams 2015). Histologically, specimens will be devoid of osteocytes, indicating necrosis, while absence of osteoclasts lends credence to the concept of osteoclast apoptosis prior to development of disease (Ruggerio 2015).

Hundreds of millions of prescriptions for bisphosphonates and other antiresorptive agents have been written in the United States, yet MRONJ remains relatively uncommon (Shintani et al. 2015; Assael 2011; Lo et al. 2010). Unfortunately uncommon diseases are difficult to study in terms of incidence, as the population sizes studied must be very large before disease is seen. As a result the literature reflects overall risk ranges from 0% to 6.7% (Dodson 2015). In general, the incidence of MRONJ in patients receiving intravenous bisphosphonates or other implicated agents for cancer therapy is approximately 1%, while patients receiving denosumab see approximately 1.9% incidence (Dodson 2015; Ruggiero et al. 2014; Lo et al. 2010). Patients taking denosumab for metastatic prostate cancer also seem to have higher rates of MRONJ (Qi et al. 2014). Bevacizumab alone is associated with MRONJ incidence around 0.2% but increases to about 1% when combined with zoledronate (Ruggiero et al. 2014; Lo et al. 2010). Some of the highest rates of MRONJ reported in the literatures are in renal cell cancer patients with bone metastases who are treated with bisphosphonates and tyrosine kinase inhibitors concurrently at 10% (Beuselinck et al. 2012). Given that 7 in 100 patients receive bisphosphonates for osteoporosis, it is reassuring that the prevalence of MRONJ in patients taking oral bisphosphonates is just 0.1%, and just 0.21% if taking agents for more than 4 years (Lo et al. 2010).

The low incidence of MRONJ may be reassuring; however, as many as 80% of MRONJ cases are related to tooth extraction (Ruggerio 2015; Goodday 2015; Dodson 2015; Tsao et al. 2013; Scoletta et al. 2013). Patients exposed to IV bisphosphonates treated with tooth extraction had many times [with studies showing as much as 16- to 44-fold] the risk of developing MRONJ as patients who did not have tooth extractions (Dodson 2015; Kim et al. 2017; Ruggiero et al. 2014; Kyrgidis et al. 2009). With reports ranging from 1.6% to 14.8%, cancer patients with IV bisphosphonate use are certainly not at low risk for MRONJ when undergoing extraction. Additionally, use of complete dentures was associated with a nearly five times the risk of developing MRONJ (Dodson 2015; Kyrgidis et al. 2008; Holzinger et al. 2013). Studies disagree on whether periodontitis is a significant risk factor for development of osteonecrosis, but there is no question that periodontitis often leads to extraction or surgical therapy, and periodontal disease is found in 71–84% of MRONJ cases. Cases of MRONJ have also been associated with endosteal implants, with and without periimplantitis (Holzinger et al. 2013). It is also possible that pain, drainage, and edema leading to extraction of a tooth could actually reflect osteonecrosis and not an odontogenic source (Ruggerio 2015; Dodson 2015; Tsao et al. 2013; Scoletta et al. 2013; Vahtsevanos et al. 2009). A wide range of incidence rates apply to patients undergoing extraction when taking oral bisphosphonates, with reports ranging from 0% to 3.9%. The current thought is that MRONJ might be seen in about 0.5% of extractions from patients on oral

bisphosphonates (Dodson 2015; Yamazaki et al. 2012). At this time, it remains unknown what risk exists for these patients when undergoing other procedures like dental implants or apicoectomy (Dodson 2015). Ideally, providers should avoid extractions when possible, as patients receiving dental treatment prior to initiating bisphosphonate treatment experience three times fewer rates of MRONJ (Goodday 2015). When extractions or other surgical interventions are required, initiation of bisphosphonate therapy should ideally be delayed until there is sufficient bone healing and full mucosal coverage (Ruggiero et al. 2004).

14.3.1 Staging and Appearance

The American Association of Oral and Maxillofacial Surgeons released updated staging criteria in 2014, designating four stages of MRONJ ranging from "at risk" to stage 3. At-risk patients have been identified in the staging criteria and include patients with no evidence of necrotic bone but with a history of bisphosphonates and other associated medications. Stage 0 represents patients without clinical evidence of disease, but are symptomatic and have radiographic changes noted. Stage 1 encompasses patients without symptoms but have exposed or necrotic bone. Once patients become symptomatic with pain, erythema, and possibly purulent discharge, a patient has progressed to stage 2. In stage 3, patients have symptomatic exposed bone that extends beyond tooth-bearing regions to include the inferior border of the mandible or the ramus, the maxillary sinus, or the zygoma. Pathologic fractures may be present in this patient (Ruggerio 2015; Ruggiero et al. 2014) (Fig. 14.4).

MRONJ can appear with lesions in the maxilla, mandible, or both jaws, while there is a clear predilection for the mandible, which is twice as likely to develop areas of necrosis (Marx 2003; Chiandussi et al. 2006; Neto et al. 2016). However, patients

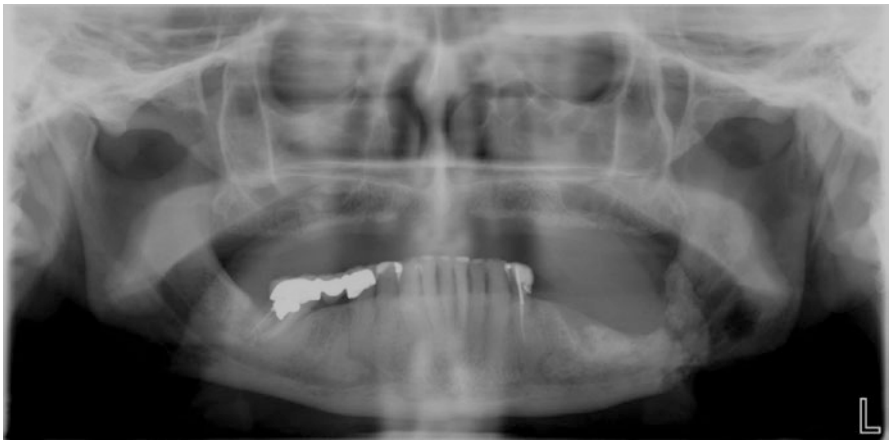

Fig. 14.4 Medically Related Osteonecrosis of the Jaw (MRONJ) in a patient with bisphosphonate exposure. Osteonecrosis is most prominent in the left posterior mandibular region with a pathological fracture

may present with symptoms before areas of exposed bone are detectable, like discomfort, mobility of teeth, or mucosal changes, hence the designation of stage 0 patients (Ruggerio 2015). Stage 1 patients will have no symptoms but visible necrotic bone, while stage 2 patients will have clinically evident disease and symptoms.

Areas of osteonecrosis can be visualized in multiple imaging modalities. Panoramic radiography will demonstrate these lesions as ill-defined patchy radiolucencies with possible radiopaque sequestra, and sometimes previous extraction sites will be visualized. On CT, the lesions will show irregular cortical margins with destruction of cortical bone. Again, sequestra are often demonstrated. MRI produces enhancement of T2-weighted images and low signal intensity on T1-weighted images and will also clearly demonstrate soft tissue changes. Scintigraphy will also show areas of increased uptake of technetium in affected locations and may show decreased uptake associated with sequestrum formation. This imaging modality will show increased uptake in symptomatic patients, as the radionuclide uptake corresponds to osteoblast hyperactivity in subchondral areas, while asymptomatic patients will show decreased activity that reveals decreased osteoblast activity. For this reason scintigraphy is an advantageous imaging type for evaluating early or asymptomatic lesions (Assael 2011; Chiandussi et al. 2006). It is also important to note that changes may be seen on imaging prior to development of classic findings of osteonecrosis. Thickened lamina dura, osteosclerosis, and reduced healing or trabeculation over previous extraction sites may indicate early stages of disease (Ruggerio 2015).

14.3.2 Management

While there is no definitive consensus on managing patients with MRONJ, AAOMS recommends medical management of these lesions prior to attempting any surgical intervention. Often used treatments include antibiotics [used intravenously, orally, and/or topically], adjunct medications like teriparatide, and hyperbaric oxygen [HBO]. Prevention of MRONJ is essential, and AAOMS recommends that patients who might benefit from agents associated with MRONJ receive a comprehensive dental evaluation before initiating therapy (Ruggiero et al. 2014). Incidence of MRONJ can be reduced by 50% by evaluation and treatment of oral health and dental needs prior to starting therapy (Lo et al. 2010). Symptomatic stage 0 patients should be managed carefully, with close evaluation and treatment of oral health, including caries management and management of periodontal disease (Ruggiero et al. 2014).

Drug holidays in anticipation of dental treatment have been much debated, but AAOMS no longer recommends drug holidays, as the research does not support the efficacy of this method in patients with osteoporosis (Holzinger et al. 2013). Evidence is minimal for patients taking antiresorptive agents for cancer treatment but may be considered in this setting (Ruggiero et al. 2014). Overall, discontinuation of therapy [with other treatments] results in 35.2% of patients experiencing complete healing (Fliefel et al. 2015).

Topical antimicrobial agents such as 0.12% chlorhexidine gluconate are widely used in oral and maxillofacial surgery and are a mainstay in treatment of MRONJ (Williams 2015). Often, chlorhexidine is used to aid in the reduction of bacterial load, as well as the development of biofilm, which contributes to the overall disease process (Goodday 2015; Kumar et al. 2010). Topical antimicrobial rinses alone are suggested for the treatment of asymptomatic, stage 1 MRONJ, but are also part of the treatment therapy for both stage 2 and stage 3 diseases (Williams 2015; Ruggiero et al. 2014). When extractions are performed in at-risk patients, use of chlorhexidine two or three times daily until full mucosal healing is achieved is recommended (Goodday 2015).

Oral antibiotic therapy is a critical component of MRONJ treatment and should be tailored to pathogens implicated in MRONJ. Selection should also be tailored based on patient tolerance and previous exposures. Typically, penicillins are first-line therapy, as most normal oral flora involved in MRONJ are susceptible to this class of antibiotics (Ruggiero et al. 2014; Hinson et al. 2014). Specifically, stage 2 and stage 3 will require antibiotics, and stage 0 patients will likely need them as well (Ruggiero et al. 2014). When oral antibiotics fail or particularly pathogenic bacteria are found, intravenous antibiotics are often used with increased success. Typically 6 weeks of IV antibiotics are used, but colleagues in infectious disease should be consulted (Williams 2015).

Teriparatide is used as an adjunct therapy in the management of MRONJ when patients are taking or have taken bisphosphonates for osteoporosis. Use is contraindicated in patients with metastatic bone disease. This medication is a parathyroid hormone analogue and promotes bone remodeling. It is believed to stimulate both osteoblasts and osteoclasts, allowing for improved bone remodeling (Williams 2015), and is also believed to have angiogenic properties (Spanou et al. 2015). Teriparatide [TPTD] is especially useful for patients with intractable MRONJ. A 2014 study by Kim et al. showed that 62.5% of patients receiving teriparatide, vitamin D, and calcium for 6 months had one-stage improvement in presentation while 37.5% improved by two or more stages, including complete healing of the lesions (Kim et al. 2014).

Hyperbaric oxygen therapy [HBO] has recently been used to augment surgical intervention in MRONJ treatment. While 26.7% of patients saw complete healing, 37.8% experienced worsening lesions, casting doubt on the efficacy of this treatment (Fliefel et al. 2015). HBO is also very time-consuming for the patient and expensive and may not provide statistically significant improvement in patients with MRONJ (Williams 2015; Spanou et al. 2015). Ozone treatment is another treatment that may show good healing results [up to 57.8%], but small study populations limit the generalizability of the result (Fliefel et al. 2015).

Surgical intervention for MRONJ based on the 2014 AAOMS guidelines is stage specific, and conservative therapy is recommended for all stages before attempting surgical intervention. Stage 0 and 1 patients usually do not require surgery, and medical management is the recommended treatment. However, stage 2 patients have a wide spectrum of presentation, and some of these patients may benefit from localized surgical intervention based on the extent of disease and patient-specific

factors. Most commonly, debridement, marginal resection, and segmental resection are utilized, based on patient presentation (Assael 2011). Overall, minimally invasive approaches see 39.2% of patients with complete healing, while upward of 80% of patients undergoing major surgery experience full healing (Williams 2015; Ruggiero et al. 2014; Holzinger et al. 2013). Holzinger et al. reported 59% of patients treated with surgical procedures saw improvement or healing of lesions (Holzinger et al. 2013). While surgery typically results in high success rates, patients taking oral bisphosphonates are more likely to heal than patients taking intravenous bisphosphonates, and maxillary resections are the most likely to result in success (Carlson and Basile 2009).

Because it is essential to remove all necrotic bone and remove sharp edges or bony spicules that may interfere with healing, the use of tetracycline fluorescence may be beneficial in determining the extent of affected bone intraoperatively. Primary closure is recommended when possible, and all specimens should be sent for microbial analysis to more appropriately direct therapy and to rule out underlying malignancy. Stage 3 patients who present with extensive disease often require segmental resection or wide areas of debridement (Williams 2015; Ruggiero et al. 2014).

Research shows that comprehensive care prior to beginning bisphosphonates as well as more frequent monitoring while taking bisphosphonates results in reduced rates of disease and earlier intervention for MRONJ (Vandone et al. 2012). In fact, prevention of MRONJ with close monitoring of oral health and noninvasive management of oral health concerns can reduce the incidence of MRONJ by threefold (Dimopoulos et al. 2009). Many patients often start bisphosphonates before receiving dental care and do not have adequate monitoring of oral health. Scoletta et al. have published a protocol for preoperative management of patients taking intravenous bisphosphonate medications or other anti-angiogenic agents that require extraction. In 62 out of 63 patients, Scoletta reported normal healing after extraction following the protocol which involved periodontal scaling and oral hygiene instruction, beginning a 6-day regimen of amoxicillin/clavulanate potassium or erythromycin the night before the procedure, a split thickness vestibular incision, and primary closure over extraction sockets packed with PRGF [plasma rich in growth factors] (Scoletta et al. 2013). Other studies show that use of platelet-rich plasma and bone morphogenic protein can result in healing in 81.5% of patients. These studies, while limited in number, represent similar results to major surgical treatment (Fliefel et al. 2015). Despite Scoletta's recommendation for primary closure, there is debate whether primary closure is actually beneficial (Goodday 2015).

The 2009 version of the AAOMS guidelines, but not the most recent 2014 version, discourages immediate reconstruction with vascularized or nonvascular bone, as disease may not have been eliminated at resection margins and result in failure of the reconstruction. Nevertheless, there are a variety of case reports in the literature reporting success with this strategy (Neto et al. 2016; Vercruysse et al. 2014). Recently, Kim et al. published results that patients undergoing extensive surgery had better outcomes. This study utilized curettage, sequestrectomy, saucerization, and mandibulectomy for management of these patients. Patients receiving curettage

had the poorest outcomes, with 57% relapsing and requiring additional surgery. Nearly 30% of patients treated with sequestrectomy required additional surgery, while only 21% of patients who underwent saucerization did. While only five patients were treated with radical mandibulectomy, 100% of those patients saw complete healing of their lesions (Kim et al. 2017).

There are a plethora of options available in the treatment of medication-related osteonecrosis of the jaw, and typically resolution requires use of multiple treatment modalities. Complete resolution is the goal with any and all of these therapies, but "success" is defined as complete mucosal healing and radiographic healing for 1 year after treatment (Fliefel et al. 2015). Of patients with MRONJ, those treated with oral bisphosphonates are more likely to see healing with treatment. Thirty-four percent of patients taking oral bisphosphonates and treated for MRONJ with antibiotics [topical and systemic] saw healing of lesions, while only 19% of patients receiving IV bisphosphonates did when treated the same way. When invasive treatment is performed, this difference persists, as 94% of patients taking oral bisphosphonates and treated with sequestrectomy had complete healing, while just 50% of IV bisphosphonate patients healed (Shintani et al. 2015).

14.4 Osteoradionecrosis

Since the first report of osteoradionecrosis in 1922, ORN has had a much debated history in the literature. In the 1970s, ORN was thought to be an infection caused by the introduction of bacteria [by way of unintentional trauma or intentional trauma-like extractions] into bone that has reduced defenses to bacterial onslaught after irradiation (O'Dell and Sinha 2011; He et al. 2015; Schwartz and Kagan 2002; Marx 1983). Initially, treatment for ORN was penicillin. However this concept was challenged by Marx, when he proposed his "three H" theory that osteoradionecrosis arises from tissue hypoxia, hypovascularity, and hypocellularity. He also found that bacteria were only located in the most superficial aspect of exposed bone and had not invaded deeper layers, nor did the features of ORN follow the course of an infection. Furthermore, Marx argued that the previously accepted "radiation, trauma, and infection" theory could not explain the high percentage [35% in his study] of cases that lacked a traumatic episode (Marx 1983). Marx's hypoxic-hypocellular-hypovascular theory stood until recent development in research supported a new radiation-induced fibroatrophic theory (O'Dell and Sinha 2011). This new theory proposes that radiation results in endothelial cell injury, free radicals, and cytokine release, which in turn cause fibroblast deregulation. Tissues then become vulnerable to inflammation as they become progressively hypocellular and fibrosed (O'Dell and Sinha 2011; Lyons and Ghazali 2008).

Osteoradionecrosis [ORN] is defined as exposure of irradiated bone exposed by a skin or mucosal wound that persists for 3–6 months (O'Dell and Sinha 2011; He et al. 2015; Moon et al. 2017; Schwartz and Kagan 2002; Lyons and Ghazali 2008). This diagnosis excludes any recurrence of malignancy, metastasis, or tumor necrosis during treatment. While disease has been reported in the mandible, maxilla, hyoid,

and temporal bones, ORN is most commonly found in the mandible. The mandible has less vascular supply than other bones in the head and neck, as it is only supplied by the inferior alveolar and facial arteries. Additionally, the mandible is more likely to be exposed in the field of radiation for oropharyngeal cancer (O'Dell and Sinha 2011). This condition can be exceedingly painful with significant impact on patient quality of life (Schwartz and Kagan 2002; Bruins et al. 1998).

Several decades ago, incidence of ORN approached 20%, and rates have been declining with advances in radiotherapy (Moon et al. 2017). Recent studies have shown slight variation in incidence rates from 5.5% (Moon et al. 2017) to 6.6% (Lee et al. 2009) to 7.7% (Kojima et al. 2007) of patients who have undergone head and neck radiotherapy, for neoplasms in this region go on to develop ORN.

Primary tumors of the tongue, floor of mouth, alveolus, retromolar pad, and tonsils are most likely to result in a large volume of radiation to the mandible, and thus patients are at increased risk for developing ORN. Additionally, the more advanced the primary tumor, the more likely patients are to develop ORN (O'Dell and Sinha 2011; Kluth et al. 1988). ORN is rarely seen at less than 50 Gy of radiotherapy. Doses of more than 60 Gy increase the risk for ORN (O'Dell and Sinha 2011; Lyons and Ghazali 2008). Trauma, extractions, or other dental procedures may precede development of osteoradionecrosis; however, as many as 48% of patients report no previous trauma (O'Dell and Sinha 2011). The existence of periapical radiolucencies prior to beginning radiotherapy predisposes patients to develop ORN (Kojima et al. 2007). Patients who have poor oral hygiene are significantly more likely to develop ORN, as are tobacco users and heavy drinkers [six drinks or more per day] (Lyons and Ghazali 2008; Kluth et al. 1988).

14.4.1 Staging and Classification

There have been multiple proposals for classification of osteoradionecrosis (O'Dell and Sinha 2011; He et al. 2015), but Schwartz and Kagan (2002) have proposed a staging system that is widely accepted. Stage I is superficially exposed bone that has small soft tissue defects and necrosis confined to the exposed cortical bone. Stage II features necrosis of cortical and cancellous bone. Lesions in stage IIA would feature small soft tissue defects, while stage IIB would have more extensive soft tissue involvement and cutaneous fistula formation. Stage III has more widely involved including basal bone and possibly pathologic fracture. Stage IIIA is associated with small soft tissue defects, while stage IIIB also has soft tissue necrosis and possibly cutaneous fistula formation (Fig. 14.2, O'Dell and Sinha 2011).

While ORN is diagnosed and staged based on symptoms, clinical exam, and history, radiographic evaluation is also important (O'Dell and Sinha 2011). Panoramic radiographs are often the first imaging obtained when evaluating for possible osteoradionecrosis, and these lesions typically appear as heterogeneous radiolucency with areas of radiodensity. As with the appearance in osteomyelitis, sequestra may be

visible, but in contrast, early lesions may be visualized radiographically before disease becomes clinically evident, with osteolytic lesions (Owosho et al. 2015). Stage III lesions may be associated with pathologic fractures, and these may be visualized on orthopantomogram. CT imaging will assist with visualizing perforation in the cortical plates, as well as sequestration formation. On MRI, lesions will appear with low intensity on T1, and some changes may be seen in T2 as well. Development of these lesions distant from the primary tumor or more than 2 years later strongly suggests ORN over tumor recurrence but cannot be excluded without biopsy (O'Dell and Sinha 2011). Both gallium and technetium scans have proven to be of little additional benefit, except that technetium scanning may help identify early lesions and gallium scans may aid in evaluation of treatment (O'Dell and Sinha 2011).

14.4.2 Treatment

Prevention of ORN is important, as ORN typically worsens over time and is difficult to manage (Kojima et al. 2007; Delanian et al. 2005). Poor oral hygiene during and after radiotherapy with increasing rates of caries is associated with three times greater odds of developing osteoradionecrosis. Ideally, teeth with moderate-severe periodontitis or probing depths of more than 5 mm, teeth with periodical radiolucencies, partially impacted or partially erupted teeth, root tips, and teeth with extensive caries should be extracted, and extractions should be completed 2 weeks prior to initiation of radiotherapy (O'Dell and Sinha 2011; Kojima et al. 2007; Bruins et al. 1998). However, pre-radiation extractions are an independent risk factor for developing ORN (Moon et al. 2017). Persistent vigilance should be practiced, as osteoradionecrosis can develop at any time after undergoing radiotherapy to the head and neck. The majority of cases will be diagnosed within 1 year of radiation; however, a significant number may develop longer than 5 years after treatment (He et al. 2015).

Conservative management of ORN includes avoiding irritating the exposed site. Denture wearers should refrain from wearing prostheses, and tobacco users should be counseled regarding cessation (Wong et al. 1997). Topical antimicrobial agents like chlorhexidine are often used. Unlike osteomyelitis, systemic antibiotics are reserved for acute infection of exposed necrotic bone (O'Dell and Sinha 2011). Debridement and sequestrum removal can be very effective in producing mucosal coverage of defects (O'Dell and Sinha 2011).

Hyperbaric oxygen is also routinely used in cases of osteoradionecrosis, but its use is currently controversial (Ceponis et al. 2017). Pressurized oxygen results in increased oxygen in tissues, which leads to angiogenesis. HBO can be used both as prophylaxis for patients with a history of head and neck radiation who must undergo extraction, but it can also be used to promote wound healing in existing lesions (O'Dell and Sinha 2011). However, HBO is typically unsuccessful when used as the sole treatment modality (Lyons and Ghazali 2008; Ceponis et al. 2017). Currently,

the recommended treatment is 20–30 dives for 90–120 min and 20–30 preoperative dives followed by 10 postoperative dives when extraction is planned. Ultrasound is another therapy that can promote angiogenesis, and 40–50 ten-min sessions can be used until mucosal coverage is achieved (O'Dell and Sinha 2011).

Medical management is less common with ORN than with osteomyelitis, but treatment with pentoxifylline, tocopherol, and clodronate [available as Pentoclo] to stimulate osteogenesis has shown promising results. In an attempt to combat the vascular necrosis that occurs early in the initiation of ORN, pentoxifylline has been used to dilate remaining blood vessels in the bone and prevent continuing fibrosis while reducing inflammation. It has been paired with vitamin E [tocopherol], which scavenges reactive oxygen species during oxidative stress, for a synergistic treatment option. Clodronate is a nonnitrogenous bisphosphonate that inhibits bone resorption and has been used in the most severe cases of ORN, but pentoxifylline and tocopherol may also be used alone (O'Dell and Sinha 2011; Lyons and Ghazali 2008). In this protocol, 800 mg pentoxifylline and 1000 IU tocopherol were administered for 6 months and continued as long as healing progressed. If ORN was severe, 1600 mg clodronate was added daily five times per week. This regimen resulted in complete healing for 89% of patients (Delanian et al. 2005). Pentoxifylline may also be used for 6 weeks prior to extraction, with the addition of tocopherol 1 week prior to extraction or surgery for prophylaxis. If the response is insufficient, clodronate can be added 3 months postoperatively (Lyons and Ghazali 2008).

When patients have failed conservative therapy or have current or impending pathologic fracture [with involvement of the inferior border of the mandible], surgery is indicated. Resection should be continued until bleeding bone is encountered at the margins (O'Dell and Sinha 2011). While stage II lesions typically heal with conservative management or surgery, stage III requires more significant surgical procedures. With extensive resections, free flaps may be required. These patients have an increased risk of complications with free flap surgery, but often it is the only remaining option. Despite the increased complication risk, free flap reconstruction still has a 91% success rate (O'Dell and Sinha 2011).

14.5 Conclusion

Despite the varied etiology of osteomyelitis, medication-related osteonecrosis of the jaw (MRONJ), and osteoradionecrosis (ORN), all of these conditions ultimately stem from cellular destruction within the bony skeleton of the maxillofacial region. This chapter has explored the current recommendations based on the literature available, but investigations into the pathogenesis and treatment of these diseases are ongoing. Due to the significant economic, psychosocial, and physiologic damage these conditions wreaked on patients, this further investigation is absolutely necessary in order to provide curative treatment for all of those affected.

Case 1

A 65-year-old male was referred to us for the management of a right mandibular third molar with a history of recurrent pericoronitis (Fig. 14.1a). The patient was otherwise in good general health. He denied tobacco or alcohol use. The patient underwent an uncomplicated surgical extraction of the third molar and was placed on a 7-day course of amoxicillin. Postoperative course was only remarkable for pain and trismus mostly due to muscle spasm. A panoramic radiograph obtained on postoperative week 4 revealed the mandible to be intact and devoid of any obvious signs of osseous pathology. On the eighth postoperative week, patient returned to clinic with a complaint of sudden return of right mandibular pain and malocclusion of 3-day duration. The patient denied any history of trauma and was afebrile. Examination of mandible was difficult due to trismus and presence of focally intense pain. Additionally, a small quantity of purulent exudate was noted at the sight of the previous extraction. Culture of the drainage was obtained and submitted to the laboratory for culture and sensitivity studies. A radiograph obtained revealed a non-displaced fracture involving the right mandibular angle region (Fig. 14.1b). Radiolucencies consistent with osteolysis as well as ragged osseous borders and presence of a sequestrum were noted. Patient underwent exploration of the wound along with debridement, sequestrectomy, and saucerization, and he was placed into maxillomandibular fixation (MMF) (Fig. 14.1c). Two days postoperatively, patient reported increased malaise, and decision was made to have the patient admitted for further workup. The patient had a low-grade fever with a slight leukocytosis (13,000 mm^{-3} consisting of 78% polymorphonuclear leukocytes and 16% bandemia). Computed tomography (CT) scan was interpreted as being most consistent with a diagnosis of osteomyelitis of the mandible due to the presence of soft and hard tissue changes. An infectious disease consultation was obtained to assist with the management of the patient. The patient was treated presumptively for osteomyelitis pending the results of the biopsy and the culture and sensitivity studies. He was empirically placed on intravenous broad-spectrum antibacterial coverage. Vancomycin and ampicillin/sulbactam (Unasyn) were recommended by the infectious disease consultant and implemented. Rigid fixation was also applied to the fracture site on post-admission day 4. Bone biopsy result returned was consistent with osteomyelitis, and the culture revealed mixed oral flora. Patient was placed on a 4-week course of intravenous penicillin followed by a 3-month regimen of amoxicillin/clavulanate (Augmentin). The patient tolerated the antibiotic course and had a full recovery from the infection. The pathological fracture of the mandible fully healed without any sequelae. He has been symptom-free for 12 months since the initial presentation.

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Evidence-Based Principles of Antibiotic Therapy

15

Thomas R. Flynn

"I have no desire to make mysteries, but it is impossible at the moment of action to enter into long and complex explanations."
Sherlock Holmes in—The Adventures of the Dancing Men

Abstract

Oh, for the days when I could just write a prescription for penicillin and know that it would be effective for my patient! Those days are over. Now, I have to worry about whether the antibiotic will cover the usual organisms in the infection; if there are highly antibiotic-resistant bacteria present; if my prescription will select for resistant organisms in the patient, or her family, or his community; if the patient will have a toxic or allergic reaction; or if it will interact with one of the many other drugs the patient is taking. What if my patient can't afford the antibiotic or doesn't take it as prescribed? How long will he really take the antibiotic for? Just until he feels better? Should I be prescribing this antibiotic at all?

Modern antibiotic therapy for odontogenic infections has become quite complex. This chapter will provide the available evidence that answers the above questions as well as is possible with our current knowledge. It lists the ten principles of the modern use of antibiotics and provides the evidence supporting those principles. Some of these principles apply to the issue of antibiotic selection and others to proper administration of antibiotics.

15.1 The Principles of Modern Antibiotic Therapy

The modern evidence-based use of antibiotics can be summarized in the following ten principles:

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1. Surgery to remove the cause and establish drainage is primary; antibiotics are adjunctive treatment.
2. Use therapeutic antibiotics only when clinically indicated.
3. Use specific antibiotic therapy as soon as possible, based on culture and sensitivity testing.
4. Use the narrowest-spectrum empiric antibiotic effective against the most likely pathogens.
5. Avoid the use of combination antibiotics, except in specific situations where they are shown to be necessary.
6. Use the least toxic indicated antibiotic, considering interaction with concurrent medications.
7. Minimize the duration of antibiotic therapy, as appropriate to the presenting type of infection.
8. Use the most cost-effective appropriate antibiotic.
9. Use prophylactic antibiotics only when proved effective or according to professional guidelines.
10. Follow the guidance of evidence-based recommendations and professional guidelines when they are available.

Each of these principles will be discussed, and the evidence supporting them will be cited. In some cases there are highly reliable scientifically obtained data (randomized clinical trials and meta-analyses) to support each usage, and in other cases, data such as the pharmacologic profile of given antibiotics are used to guide usage recommendations.

15.1.1 Principle 1: Surgery to Remove the Cause and Establish Drainage Is Primary; Antibiotics Are Adjunctive Treatment

In the 1940s, two landmark studies of the treatment of Ludwig's angina provided the first evidence supporting this principle in severe odontogenic infections. Dr. Williams (1940) presented a retrospective case series of 37 consecutive cases of Ludwig's angina treated at Boston City Hospital. The airway management policy at the time was emergency tracheotomy when necessary. Fifty-four percent of those patients died. Three years later, Williams and Guralnick (1943) published the first prospective study of severe odontogenic infections. In this study, the airway management protocol was changed to immediate stabilization of the airway by endotracheal intubation or tracheotomy as appropriate. Necessarily, general anesthesia was induced immediately after the airway was secured, so the surgeons also performed aggressive surgical incision and drainage of all infected spaces. In those 3 short years, before penicillin was available to civilians because of World War II, the mortality of this dreaded infection was reduced to 10% ($N = 20$). Thus, in one of the most severe of all odontogenic infections, early airway security and aggressive surgery provided a dramatic decrease in mortality without the benefit of antibiotics.

The importance of surgical treatment in odontogenic infections may be related to the flora of these infections and to the anatomy of the teeth, jaws, and deep fascial

spaces of the head and neck. The bacteria that have been associated with severe odontogenic infections are abscess formers, and many of them also form biofilms. The blood supply of an abscess is nil; antibiotic penetration into abscesses is by diffusion from surrounding vascularized tissues. Further, biofilms forming on hard or tough surfaces, such as teeth, bone, and fascia are not well penetrated by antibiotics. Bacteria found in biofilms are also less metabolically active than planktonic bacteria, rendering them less susceptible to the action of antibiotics. Therefore, surgical drainage and physical debridement of necrotic tissues and biofilms may be of special benefit in odontogenic infections, because they reduce the bacterial bioburden in the deep tissues of the face, neck, and jaws (Socransky and Haffajee 2002).

More recent evidence supports principle 1 as well. Igoumenakis et al. (2015) compared extraction of the involved teeth with nonextraction in patients with severe infections requiring hospitalization. Patients with non-restorable teeth were assigned to the extraction group, and those with restorable teeth did not have any teeth extracted during or just prior to hospitalization. All underwent incision and drainage. On postoperative day 2, temperature, white blood cell count, and C-reactive protein (an inflammatory marker) were all significantly less in the extraction group on the second postoperative day. Further, the length of hospital stay was significantly less in the extraction group. This study indicates that extraction of the causative teeth, even in the presence of acute infection, resulted in decreased overall inflammation and a shorter time to the clinical endpoint (resolution of swelling, pain, and fever).

When patients present to a hospital emergency room with toothache, the emergency room physician will commonly prescribe an antibiotic in order to prevent the spread of infection beyond the tooth, plus an analgesic. Brennan et al. (2006) performed a study of 134 patients presenting with toothache and randomized them into antibiotic and non-antibiotic (placebo) groups. Thirteen patients (10%) developed a spreading infection, defined as swelling, fever, pus drainage, or trismus, but there was no difference between the two groups. On multivariate analysis of the outcome of spreading infection, the only parameters predicting spreading infection were periapical pathosis larger than 1.5 mm on periapical X-ray and the presence of an amalgam filling in a causative tooth. This study indicates that antibiotics used for toothache do not play a role in preventing subsequent infection spreading beyond the tooth.

In emergency medicine, there are two meta-analyses, Fahimi et al. (2015) and Singer and Thode Jr (2014), that found no difference in the outcome of skin and soft tissue infections treated with incision and drainage comparing effective vs. noneffective or no antibiotic (Fahimi et al. 2015) or an antibiotic vs. no antibiotic (Singer and Thode Jr 2014). A noneffective antibiotic was defined as one to which the cultured organism(s) were not sensitive. These two high-quality studies indicate that surgery alone is also effective in skin and soft tissue infections not related to the teeth.

There is one randomized clinical trial comparing two antibiotics in odontogenic infection that used a control group receiving no antibiotic. Matijević et al. (2009) compared patients with spreading odontogenic infections, all receiving incision and drainage plus extraction or root canal therapy, in three groups, amoxicillin,

cephalexin, and no antibiotic. There was no significant difference among the groups. The two antibiotic groups had a statistically insignificant shorter time to clinical resolution, but all patients were considered resolved by 1 week after surgery. This clinical trial indicates that surgery alone is effective in the treatment of odontogenic infections that have spread beyond the tooth itself.

The Infectious Diseases Society of America recommends clinical follow-up and reexamination of the patient at approximately 3 days after a course of antibiotics has begun (Bartlett et al. 2005). Since odontogenic infections inherently require a surgical approach, close clinical follow-up is required after incision and drainage, tooth extraction, and root canal therapy in the setting of acute infection. At the same visit, evaluation of the effectiveness of and continuing necessity for the antibiotic regimen is performed.

In summary, significant high-quality evidence indicates that surgical therapy of odontogenic infections can lead to desired clinical outcomes (practically speaking, the resolution of the infection) without the use of antibiotics at all. This confirms what dentists observed even before antibiotics were discovered. In fact, it is ethically impossible to design a study comparing surgery alone with antibiotics alone in the management of odontogenic infections, because we know that some type of surgery, extraction, root canal therapy, gingival curettage, or incision and drainage, or combinations of these, is necessary.

15.1.2 Principle 2: Use Therapeutic Antibiotics Only When Clinically Indicated

The indications for antibiotic therapy for odontogenic infections are listed in Box 15.1. This section discusses the use of antibiotics for established infections. Sections 15.1.9 and 15.1.10 discuss the use of prophylactic antibiotics.

When an odontogenic infection spreads beyond the immediate periapical region into the bone of the jaw, or through the cortical plate into the soft tissues of the oral vestibule, or the deep fascial spaces of the head and neck, therapeutic antibiotics are indicated. The

Box 15.1 Indications for Antibiotic Therapy in Odontogenic Infections

Fever
Swelling
Lymphadenopathy
Prophylaxis of infection following dental procedures:
- Endocarditis[a]
- Immunocompromised patients[a]
- Surgical site infection[b]

[a]Guidelines from professional associations apply
[b]High-quality evidence supports prophylactic antibiotics for third molar and periodontal surgery

clinical signs of such a spreading infection include fever, swelling, and lymphadenopathy. Trismus (limited mouth opening) is seen in 73% of severe odontogenic infections requiring hospitalization, and dysphagia (difficulty swallowing) is seen in 78% of them (Flynn et al. 2006); so these are ominous signs as well. An unfortunate diagnostic error is made when trismus due to infection is diagnosed as temporomandibular disorder. The resulting treatment delay can allow a virulent infection to spread deeply into the fascial spaces of the head and neck, with potentially life-threatening consequences.

This principle of antibiotic therapy, like the first one, was established by decades of clinical experience before randomized clinical trials became the scientific standard by which new clinical approaches are validated. The one study by Matijević et al. (2009), compared amoxicillin, cephalexin, and no antibiotic in patients receiving appropriate surgical therapy for odontogenic infections. There was no significant difference among the three groups, although time to clinical resolution of the infection was shorter in the two antibiotic groups. This is the only high-quality evidence that supports the use of therapeutic antibiotics for dental infections, but the result was not statistically significant. Ethical considerations may preclude directly testing the hypothesis that such therapeutic antibiotics are clinically beneficial.

When a dentist writes a prescription for antibiotics, he or she is causing the selective survival of antibiotic-resistant bacteria. That course of antibiotics selects for resistant bacteria not only within the patient but also within the patient's family. In 1988 Brook took throat swab cultures of children with sore throats before a 7-day course of penicillin. At the end of treatment, he cultured the throats again, not only of the patients but also of their parents and siblings. Before treatment, 12% of the children harbored one or more penicillin-resistant organisms. After treatment, carriage of resistant organisms increased to 46%. Interestingly, however, 45% of the parents and siblings carried at least one penicillin-resistant species, even though they had not received the antibiotic. This figure had not returned to baseline by 3 months after treatment, when 27% of the subjects carried penicillin-resistant bacteria. Thus, prescribing antibiotics selects for resistant bacteria not only in the patient but also in the patient's family.

In a follow-up study, Brook and Gober (1997) took monthly throat swab cultures of children in a metropolitan school system for 2 consecutive years. In September, the mean carriage of one or more penicillin-resistant bacteria was at its trough, in 13% of children. That figure increased to its peak in April, at 60% of children. The explanation for these results is that at the beginning of the school year, the children are relatively healthy, but as the weather declines in the colder months, more children are given courses of antibiotics for ear and throat infections and other common illnesses. By springtime, even children who may not have taken antibiotics during the school year have acquired resistant bacteria from their schoolmates. As the weather improves, the need for antibiotics decreases, and then the children disperse for summer vacation. This allows the rate of carriage of antibiotic-resistant bacteria to decline in the study population. This study demonstrates that by prescribing antibiotics, we are affecting entire communities, such as schools and workplaces.

In fact, the rate of penicillin resistance has been increasing over the past decades. Table 15.1 shows that penicillin resistance has increased from 33% of patients with severe odontogenic infections (those with head and neck or oral swelling) to 63% in

2017. Clindamycin resistance has increased also, from 13.7% of strains in 2006 (Rega et al. 2006) to 32% in 2017 (Kim et al. 2017).

In summary, therapeutic antibiotics do provide added benefit when combined with appropriate dental and surgical treatment. Rigorous observance of the indications for antibiotic therapy, such as swelling, fever, and lymphadenopathy can minimize the development of antibiotic-resistant strains, which are increasing among patients with odontogenic infections.

15.1.3 Principle 3: Use Specific Antibiotic Therapy as Soon as Possible, Based on Culture and Sensitivity Testing

Almost all oral disease is infectious. Caries, pulpitis, periodontitis, periapical abscess, and deep fascial space infection are all caused by oral pathogens. Over its history, dentistry has developed surgical therapy for each of these manifestations of infectious disease. Table 15.2 lists the most frequent pathogens that have been isolated from odontogenic infections.

In the earlier phase of the antibiotic era, often called "The Golden Age of Antibiotics," dentists were able to prescribe penicillin for most patients with oral infection and erythromycin for penicillin-allergic patients. In recent years we have entered the age of increasing antibiotic resistance, as demonstrated for oral infections in Table 15.1. Therefore, the need for culture and sensitivity testing, even for dental infections, is likely to increase in coming years. In fact, culture and sensitivity testing is now being used in periodontitis as well as swellings extending beyond the alveolar process. With routine oral infections, often the infection is completely resolved before the culture results become available. Culture and sensitivity testing in a hospital microbiology laboratory can be quite expensive. Therefore, reasonable indications for culture and sensitivity testing are listed in Box 15.2.

Table 15.1 Increasing rates of antibiotic resistance in odontogenic infections

Year	% of cases PCN resistant	Country
Brook et al. (1991)	33	USA
von Konow et al. (1992)	38	Sweden
Lewis et al. (1995)	55	UK
Flynn et al. (2006)	54	USA
Kim et al. (2017)	63	USA

PCN penicillin, *UK* United Kingdom, *USA* United States of America

Table 15.2 Most frequent pathogens in odontogenic infections

Microorganism	% of cases
Streptococcus milleri group	65
Peptostreptococcus species	65
Other anaerobic streptococci	9
Prevotella species (oralis, melaninogenica, etc.)	74
Porphyromonas species (gingivalis, etc.)	17
Fusobacterium species	52

Data from: Sakamoto H, Kato H, Sato T, Sasaki J (1998) Semiquantitative bacteriology of closed odontogenic abscesses. Bull Tokyo Dent Coll. 39:103–7

Box 15.2 Indications for Culture and Sensitivity Testing

Serious, potentially life-threatening infections

Chronic, recalcitrant infections

Previous, multiple antibiotic therapy

Immunocompromised patient:

- Diabetes
- IVDA
- HIV

Practical considerations for dentists taking cultures include that both aerobic and anaerobic specimens should be harvested, which in general requires separate aerobic and anaerobic culturettes. Modern microbiology laboratories will not perform anaerobic cultures on a specimen that has not been transported in anaerobic media, because the anaerobes will not likely have survived. Further, such culturettes have a short shelf life, and outdated culturettes will be rejected as well.

It is not necessary to harvest pus for valid cultures. Serosanguineous fluid obtained from a cellulitis yields viable bacteria that can successfully be grown in the microbiology laboratory. In suspected osteomyelitis, a specimen of affected bone from the jaw should be cultured aerobically and anaerobically. Specific antibiotic therapy, meaning that the choice of antibiotic is guided by the results of culture and sensitivity testing, is required for osteomyelitis of the jaws.

Molecular methods for identification of oral pathogens have been used for some time now, especially in periodontology and endodontology (Haffajee et al. 2009; Sassone et al. 2007). In severe odontogenic infections, such as deep fascial space infections (Flynn et al. 2012) and pericoronitis (Mansfield et al. 2012), we have found that a large percentage of the species identified are unculturable. This means that species identification can be performed using the genetic material of the pathogens involved, but that the appropriate culture methods for growing live specimens of those species have not yet been found. Completely novel species have also been identified using molecular methods. Developing applications of this technology include the rapid identification of pathogens, especially the most virulent and antibiotic-resistant species, such as methicillin-resistant *Staphylococcus aureus* (MRSA) in emergency departments and hospitals (Palavecino 2014).

15.1.4 Principle 4: Use the Narrowest-Spectrum Empiric Antibiotic Effective Against the Most Likely Pathogens

In 2004, the American Dental Association Council on Scientific Affairs published a policy on the use of antibiotics in dentistry, with the purpose of reducing antimicrobial resistance. The American Dental Association acknowledged in this publication that increasing antibiotic resistance is a problem that must be managed in dentistry, and it recommended the use of narrow-spectrum antibiotics in simple cases. Penicillin, metronidazole, and clindamycin (in penicillin-allergic patients) were classified as narrow-spectrum agents. For complex cases, broader-spectrum antibiotics could be

used, which were amoxicillin, ampicillin, cephalosporins, macrolides (erythromycin family), and tetracyclines. Amoxicillin-clavulanate (Augmentin®) was recommended for sinus infections only. However, the policy did not define simple and complex cases. Box 15.3 defines the characteristics of simple and complex cases.

The Infectious Diseases Society of America (IDSA) has also recommended that the antimicrobial agent selected should be the most cost-effective, least toxic, and most narrow in spectrum (Bartlett et al. 2005).

The narrow-spectrum antibiotics that are useful for odontogenic infections are generally effective against the major oral pathogens, consisting of the viridans group of streptococci, anaerobic streptococci, and the oral anaerobic Gram-negative pathogens, primarily members of the genera *Fusobacterium*, *Prevotella*, and *Porphyromonas*. They generally are not effective against enteric Gram-negative bacteria found primarily in the gut flora, such as *Escherichia coli*, *Klebsiella pneumoniae*, *Enterobacter* species, Enterococci, *Pseudomonas aeruginosa*, and *Serratia marcescens*. Many of the most virulent Gram-positive pathogens, such as *Staphylococcus aureus*, are also resistant to the narrow-spectrum antibiotics useful in dentistry. Thus, when narrow-spectrum antibiotics, such as the penicillins, are used for odontogenic infections, the most worrisome pathogens that cause complex systemic infections while being resistant to many antibiotics are not affected. They are already resistant to penicillin V, amoxicillin, and clindamycin.

Other advantages of using narrow-spectrum antibiotics are that superinfection, pharmacologic toxicity, and, for the most part, the cost of treatment are reduced. Superinfection is the overgrowth of members of the resident flora that are resistant to the antibiotic being used. The bacteria involved are not causing the infection being treated, and in fact, they may be distant from the infected site. An example is overgrowth of vaginal yeast organisms, such as Candida, when an oral infection is being treated. In many sites in the body, the normal resident flora of that location is

Box 15.3 Simple vs. Complex Odontogenic Infections

Simple
- Swelling limited to the alveolar process and vestibular space
- First attempt at treatment
- Non-immunocompromised patient

Complex
- Swelling extending beyond the vestibular space
- Failed prior treatment
- Immunocompromised patient

From: Flynn TR (2008) Principles of management and prevention of odontogenic infections. In: Ellis E, Hupp JR, Tucker MR (eds) Contemporary oral and maxillofacial surgery, 5th edition. Mosby, St. Louis, MO. p. 308. Used with permission

at an equilibrium state among a large number of species, whose interactions tend to keep the relative proportion of each species fairly stable. When an antibiotic is introduced, the susceptible organisms are killed, and the balance is disrupted, allowing resistant organisms to overgrow, causing disruption of the function of the organ system they inhabit. Another example is the overgrowth of *Clostridium difficile* in the gut flora, causing antibiotic-associated colitis. When their numbers increase to a certain level, these *Clostridia* release an exotoxin that causes diarrhea that can be severe and difficult to treat (Lübbert et al. 2014).

Fortunately, the narrow-spectrum antibiotics in common use in dentistry have low pharmacologic toxicity as well. The major toxicity of the penicillin family, for example, is allergy. Severe allergic reactions to penicillins are best prevented by careful history taking.

As the American population ages and suffers from more chronic diseases, the need for lifelong medications increases. With the newer antibiotics currently available, drug interactions have become a mounting problem, many of which are severe. For example, both the macrolides (erythromycin family) and the fluoroquinolones (e.g., cipro-, gemi-, and moxifloxacin) are metabolized by CYP3A4, a liver microsomal enzyme in the cytochrome P450 system, which metabolizes 60% of prescribed drugs. CYP3A4 is responsible for about half of that function, and it is associated with more than half of known interactions between prescribed drugs (Zanger and Schwab 2013). When certain macrolide or fluoroquinolone antibiotics are prescribed in combination with a wide range of other drugs, some of which are listed in Box 15.4, cardiac dysrhythmias and even torsades de pointes, a form of ventricular fibrillation leading to death can occur.

Narrow-spectrum antibiotics can also cost less than broad-spectrum antibiotics. Although many factors contribute to the cost of antibiotics, the narrow-spectrum ones tend to be older and can therefore be marketed generically. Certain new

Box 15.4 Selected Categories and Examples of Drugs That Prolong the QT Electrocardiographic Interval

Antibiotics: macrolides; fluoroquinolones; TMP-SMX; flu-, itra-, vori-, ketoconazole; pentamidine; quinine

Antiarrhythmics: amiodarone, procainamide, sotalol, disopyramide, quinidine

Psychiatric drugs: TCAs (amitriptyline), SSRIs (citalopram Celexa®, escitalopram Lexapro®, fluoxetine Prozac®, paroxetine Paxil®, sertraline Zoloft®), phenothiazines, lithium, butyrophenones (Haldol®, Risperdal®)

Anticonvulsants: felbamate, fosphenytoin

Miscellaneous: diphenhydramine, droperidol, tacrolimus, tamoxifen, serotonin receptor agonists (Imitrex®, Zomig®), smoking

Legend: SSRIs = selective serotonin reuptake inhibitors; TCAs = tricyclic antidepressants; TMP-SMX = trimethoprim-sulfamethoxazole

narrow-spectrum antibiotics, aimed specifically at highly resistant pathogens, such as *S. aureus*, can be quite expensive, however. The cost of antibiotic therapy is discussed more thoroughly in Sect. 15.1.8.

The effectiveness of the commonly used antibiotics for oral infections has been compared in several well-designed randomized clinical trials. These were reviewed systematically by Flynn (2011), who found eight trials comparing a penicillin with another antibiotic for severe odontogenic infections. Appropriate surgical treatment was also used in all patients, consisting of root canal therapy, extraction, and incision and drainage, as appropriate. The outcome was clinical resolution (decrease in pain, swelling, fever) at 5–7 days after treatment. Table 15.3 lists the results. Interestingly,

Table 15.3 Systematic review of antibiotics in odontogenic infections

Reference	Year	*N*	Intervention group	Comparator group	Surgical control	Significant difference between groups?	Comment
Gilmore et al. (1988)	1988	49	PCN	CLI	N	N	Only surgery was I&D; EXT/RCT performed only after study completion
von Konow and Nord (1983)	1983	60	ORN	PCN	N	N	Only surgery was I&D; two subjects in each group did not receive surgery. Fewer days of pain in ornidazole group ($p < 0.05$); more failures in PCN group (NSD)
Mangundjaja and Hardjawinata (1990)	1990	106	CLI	AMP	N	N	Only surgery was I&D; EXT/RCT performed only after study completion. Not all subjects were cured by 7 days
Lewis et al. (1993)	1993	78	AM/CL	PCN	N	N	Surgery was either I&D or EXT or RCT. Greater pain reduction at 1–2 and 2–3 days in amoxicillin/clavulanate group; otherwise NSD in swelling, temperature, lymphadenopathy, or pain

Table 15.3 (continued)

Reference	Year	*N*	Intervention group	Comparator group	Surgical control	Significant difference between groups?	Comment
Davis Jr and Balcom 3rd (1969)	1969	49	LIN (im and po)	PCNG (im and po)	N	N	Nine patients had trauma and fractures, including osteomyelitis
Matijević et al. (2009)	2009	90	AMOX	CEPH	Y	N	Antibiotic groups had shorter treatment time than surgery alone (not statistically significant)
Ingham et al. (1977)	1977	37	MET	PCNG (im once daily)	N	N	Subjects received "appropriate surgery when necessary." at 24–48 h, "marked clinical improvement" was noted in all subjects
Al-Nawas et al. (2009)	2009	19	MOXI	AM/CL	N	N	Only study of hospitalized patients, requiring extraoral and/or intraoral I&D. Cure = improving trismus, no pain on palpation, afebrile

AM/CL amoxicillin/clavulanate; *AMOX* amoxicillin, *AMP* ampicillin, *CEPH* cephalexin, *CLI* clindamycin, *EXT* extraction, *im* ilntramuscular, *I&D* incision and drainage, *LIN* lincomycin, *MET* metronidazole, *MOXI* moxifloxacin, *N* no, *NSD* no statistically significant difference, *ORN* ornidazole, *PCN* penicillin V, *PCNG* penicillin G, *RCT* root canal therapy, *Y* yes
Adapted from: Flynn TR (2011) What are the antibiotics of choice for odontogenic infections, and how long should the treatment course last? Oral Maxillofac Surg Clin North Am 23:519–36

none of the studies found a significant difference in outcome between the control antibiotic (a penicillin) and the test antibiotic (another antibiotic, usually with a broader-spectrum than the penicillin control).

This review allows us to conclude that the usual empiric antibiotic choices for severe odontogenic infections (those causing orofacial swelling) are equally effective, given the appropriate surgery. Thus, antibiotic selection should be based upon pharmacologic safety, cost, and the patient's past medical history, including concurrent medications. Further, one of the studies reviewed in Flynn 2011, found that surgery alone, without antibiotic therapy, was effective, but the time to resolution may be shorter when an antibiotic is added (Matijević et al. 2009).

15.1.5 Principle 5: Avoid the Use of Combination Antibiotics, Except in Specific Situations Where They Are Shown to Be Necessary

Most odontogenic infections are polymicrobial. Using conventional culturing methods, four to six species can be isolated. Using molecular methods, as many as 18 species have been identified from a single sample (Flynn et al. 2012). Nonetheless, a single antibiotic can usually be selected that is effective against the most likely pathogens. Even when one or more of the species identified is resistant to the antibiotic used, clinical resolution is achieved when appropriate surgery is performed (Flynn et al. 2006). For almost all odontogenic infections, a single antibiotic is effective when the appropriate surgical treatment is provided (Flynn 2011).

Combinations of antibiotics may rarely be indicated in severe infections of unknown cause, in severe (hospitalized) polymicrobial infections for which no single antibiotic is effective against all of the pathogens and to prevent the emergence of resistance to a single antibiotic.

However, combining antibiotics can increase toxicities and costs, select for resistant organisms, and cause antagonistic interactions between the antibiotics. For example, vancomycin has minimal renal toxicity when used alone, but in combination with an aminoglycoside, such as gentamicin, renal toxicity is significantly increased.

Combining a bactericidal antibiotic with a bacteriostatic one can reduce or eliminate the effectiveness of the bactericidal antibiotic. Many bactericidal antibiotics, like the penicillins, inhibit cell wall synthesis and are thus effective during the active growth and cellular division phases of the bacterial cell cycle. Bacteriostatic antibiotics, like the macrolides, inhibit protein synthesis, and slow bacterial growth and multiplication. This reduces the number of bacteria that must be destroyed by the immune system. Because bacteriostatic antibiotics restrict bacterial growth, cell wall synthesis, the target of the penicillins and other beta-lactam antibiotics is not active, thus rendering the bactericidal antibiotic largely ineffective. Table 15.4 lists common bactericidal and bacteriostatic antibiotics.

Table 15.4 Bactericidal and bacteriostatic antibiotics

Bactericidal	Bacteriostatic
Beta-lactams	Macrolides
Penicillins	Erythromycin
Cephalosporins	Clarithromycin
Carbapenems	Azithromycin
Monobactams	Clindamycin
Aminoglycosides	Tetracyclines
Vancomycin	Doxycycline
Metronidazole	Tigecycline
Fluoroquinolones	Sulfa antibiotics
Ciprofloxacin	Oxazolidinones
Moxifloxacin	Linezolid
Aminoglycosides	Tedizolid
Glycopeptides	
Vancomycin	
Telavancin	
Daptomycin	

Some antibiotics antagonize each other because they compete for the same receptor sites. Examples are the combinations of clindamycin and the macrolides, such as erythromycin, and the combination of linezolid and vancomycin. Such combinations should be avoided.

Combined antibiotics have been shown to be effective in a few diseases. For example, in endocarditis, the combination of a penicillin with an aminoglycoside allows reduction in the duration of therapy to 2 weeks from 4 weeks, with less frequent relapse and no increase in antibiotic resistance among initially susceptible isolates (Baddour et al. 2005; Bliziotis et al. 2005).

One head and neck infection that is treated with combined antibiotics, at least initially, is necrotizing fasciitis, the dreaded "flesh-eating bacteria" infection. Some head and neck cases of necrotizing fasciitis are odontogenic, and they can result in the loss of large amounts of skin and subcutaneous tissue of the face and neck. When this infection arises in a deeper plane, the necrotizing bacteria can follow the fascial layers of the neck into the mediastinum, the space between the lungs that contains the heart.

There are five subtypes of necrotizing fasciitis, based on the causative bacteria. Since this severe infection progresses rapidly, initial empiric antibiotic therapy is directed at all five bacterial subtypes, requiring a combination of a carbapenem, such as imipenem, plus vancomycin. At emergency surgical debridement, the surgeon samples the infection for culture and sensitivity testing and for histopathologic examination (biopsy). When culture and sensitivity results are available, the antibiotic regimen may be deescalated from the broad-spectrum combination of a carbapenem plus vancomycin to more narrow-spectrum specific antibiotic therapy that is effective against the subtype that has been identified by culturing. Figure 15.1 illustrates the empiric therapy of necrotizing fasciitis and the bacterial subtypes responsible for this infection.

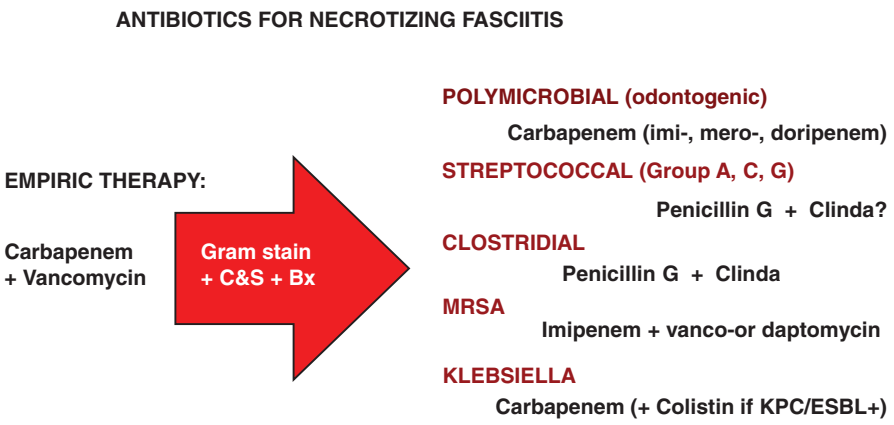

Fig. 15.1 Antibiotic therapy for necrotizing fasciitis. Empiric therapy is with a carbapenem, such as imipenem or meropenem plus vancomycin. After Gram stain, culture and sensitivity testing, and histopathologic examination of involved fascial tissue results are available, specific antibiotic therapy is directed toward one of the five bacterial types of necrotizing fasciitis shown on the right side of the image. *Bx* biopsy, *C&S* culture and sensitivity testing, *MRSA* methicillin-resistant *Staphylococcus aureus*

Certain bacteria undergo frequent mutations that can confer antibiotic resistance. Fortunately, this is not yet common among the usual dental pathogens. Combinations of antibiotics are sometimes used in order to prevent the survival of antibiotic-resistant mutant strains of these bacteria. For such organisms, combining two antibiotics that have independent bactericidal mechanisms can provide impressive synergy in suppressing antibiotic resistance. Specifically, if the frequency of mutation conferring resistance to the first antibiotic is 10^{-5}, and it is 10^{-8} for the second antibiotic, then the probability of both of those mutations occurring simultaneously is 10^{-13}. This strategy is used in staphylococcal osteomyelitis, endocarditis involving prosthetic heart valves, and tuberculosis (Flynn and Shanti 2016).

In summary, there are few, if any, indications for combination antibiotic therapy in dentistry at this time. The only exceptions may rarely occur in the most severe infections, such as necrotizing fasciitis or staphylococcal osteomyelitis of the mandible.

15.1.6 Principle 6: Use the Least Toxic Indicated Antibiotic, Considering Interaction with Concurrent Medications

The various antibiotic families in use today can be ranked in order of their major and most common toxicities, as shown in Table 15.5. The salient pharmacologic features of antibiotics commonly used in dentistry are listed in Table 15.6. Selected antibiotic-drug interactions are listed in Table 15.7. The pregnancy-associated risk categories for various antibiotics can be found in Table 15.8.

The penicillins and cephalosporins are among the best-tolerated antibiotics, as long as allergic reaction is not likely by history. The most commonly used lincosamide is clindamycin. Its major toxicity is antibiotic-associated colitis, due to the overgrowth of *C. difficile*. This complication is most frequent in females and hospitalized patients, after gastrointestinal tract surgery and with a history of inflammatory bowel disease, renal disease, and cancer chemotherapy. Fortunately, these risk factors are not common in dental patients, except for female gender.

The newer macrolides, clarithromycin (Biaxin®) and azithromycin (Zithromax®), are much better tolerated by the digestive tract than are the various other forms of erythromycin. The major toxicity of the macrolides is drug interactions involving the CYP3A4 microsomal enzyme, many of which can lead to or worsen

Table 15.5 Relative toxicity of antibiotic families

Antibiotic family	Major toxicity
Penicillins	Allergy
Cephalosporins	Allergy, superinfection
Carbapenems	Seizures
Lincosamides	Antibiotic-associated colitis
Oxazolidinones	Serotonin syndrome, thrombocytopenia
Macrolides	Drug interactions, ↑QT
Fluoroquinolones	Drug interactions, ↑QT, chondrotoxicity
Glycopeptides	Nephro-/ototoxicity
Aminoglycosides	Nephro-/ototoxicity

Table 15.6 Pharmacology of antibiotics commonly used in dentistry

Antibiotic	Spectrum	Dosage (po unless stated)	Mode of action	Side effects	Comments
Penicillin V	Oral streptococci Oral anaerobes *Resistant*: Staph Enteric flora *Bacteroides fragilis*	500 mg qid *Children*: 25–50 mg/kg/day	Bactericidal Interferes with cell wall synthesis of bacteria in their growth phase	Allergy—may cause anaphylactic shock (~0.05%) Rare GI disturbances Superinfection by resistant bacteria may occur. Rash in 3% of patients, serum sickness in 4%	Produces lower blood levels than IV PCN G Excreted by kidneys Administer before meals
Amoxicillin (semisynthetic penicillin)	Oral streptococci Oral anaerobes *Actinomyces* *Resistant*: Staphylococci *Pseudomonas* sp.	500 mg qid, 875 mg bid, 1000 mg qd *Children*: 20–50 mg per kg/day	Bactericidal Interferes with cell wall synthesis of bacteria in their growth phase	Allergy—may cause anaphylactic shock Most common cause of antibiotic-associated colitis Diarrhea in 10% of patients	Less effective against oral streptococci than PCN V; more effective against oral anaerobes
Amoxicillin + clavulanic acid (Augmentin®)	Oral streptococci Oral anaerobes *Actinomyces* Staphylococci Enteric Gram-negative rods *H. influenzae*	500 mg qid; 875 mg bid; 2000 mg bid *Children*: 20–40 mg per kg/day; 2000 mg bid (high dose)	Bactericidal Interferes with cell wall synthesis of bacteria in their growth phase Clavulanic acid inhibits penicillinase made by staphylococci and some Gram-negative rods	Allergy may cause anaphylactic shock Common cause of antibiotic-associated colitis Diarrhea in 9% of patients; less frequent with bid dosing (less clavulanate)	Not effective against MRSA Improved coverage for staphylococci, oral anaerobes, and enteric flora

(continued)

Table 15.6 (continued)

Antibiotic	Spectrum	Dosage (po unless stated)	Mode of action	Side effects	Comments
Azithromycin (Zithromax®)	Some oral streptococci Atypical pathogens in HIV+ patients *Resistant*: Most staphylococci *B. fragilis* Fusobacteria	500 mg on day 1, then 250 mg/day for days 2–5 *Children*: 10–12 mg/kg on day 1, then 5 mg/kg/day for days 2–5	Bactericidal or bacteriostatic Interferes with protein synthesis during growth phase. Active uptake of the antibiotic by phagocytes may improve coverage over in vitro data	GI upset: less common than with other macrolides Prolongs QT interval Fewer drug interactions than with other macrolides	Fewer drug interactions than with the other macrolides; concentrates in phagocytes at up to 15× concentration in serum
Clindamycin (Cleocin®)	Oral streptococci Some staphylococci Anaerobes *Resistant*: Enteric flora *Eikenella corrodens*	150–600 mg qid *Children*: 15–30 mg per kg/day	Bactericidal or bacteriostatic Interferes with protein synthesis	Common cause of *C. difficile* colitis	Does not cross blood-brain barrier some streptococci are becoming resistant
Cephalexin (Keflex®—first-generation cephalosporin)	Streptococci *Resistant*: Oral anaerobes Enteric flora *B. fragilis*	500 mg qid *Children*: 25–50 mg per kg/day	Bactericidal Interferes with cell wall synthesis of bacteria in their growth phase	Allergy: may cross-react with those that have had an anaphylactoid reaction to penicillins	Does not cross blood-brain barrier in a predictable fashion
Cefdinir (third-generation cephalosporin)	Streptococci Oral anaerobes *Resistant*: Staphylococci	300 mg bid, 600 mg qd *Children*: 14 mg/kg/day	Bactericidal Interferes with cell wall synthesis of bacteria in their growth phase	Allergy: may cross-react with those that have had an anaphylactoid reaction to penicillins	Does not cross blood-brain barrier in a predictable fashion

Metronidazole (Flagyl®)	Obligate anaerobes only *Resistant*: All facultative and aerobic bacteria	500 mg qid Children >1 year: 30 mg/kg/day in four doses	Bactericidal Interferes with folic acid metabolism	Metallic taste Antabuse-like effect Carcinogenic in rats: use only when indicated	Crosses blood-brain barrier. Can be used with other antibiotics
Moxifloxacin (Avelox®)	Oral streptococci and anaerobes, *E. corrodens Actinomyces*, *B. fragilis*, staphylococci, including some MRSA, most enteric flora *Resistant*: enterococci, *P. aeruginosa*	400 mg qd *Children*: *Do Not Use* *Pregnancy*: *Do Not Use*	Bactericidal Interferes with DNA synthesis	Possible ↑QT interval, especially if used with quinidine, procainamide, amiodarone, sotalol, other drugs, or if hypokalemic	Chondrotoxic in pregnancy and children. May cause Achilles tendon rupture. Mental clouding and decreased energy are common
Linezolid (Zyvox®)	MRSA Streptococci Vancomycin-resistant enterococci *Resistant*: Enterobacteriaceae	600 mg bid *Children*: 30 mg/kg/day in three doses	Bactericidal to streptococci Bacteriostatic to staphylococci, enterococci. Interferes with protein synthesis	Epinephrine hypersensitivity; bone marrow suppression; serotonin syndrome; Stevens-Johnson syndrome; seizures	Weekly CBCs for monitoring; monitor BP for hypertension; may be toxic to fetus (insufficient data)

Abbreviations: *bid* twice daily, *BP* blood pressure, *CBC* complete blood count, *GI* gastrointestinal, *HIV* human immunodeficiency virus, *IM* intramuscular, *IV* intravenous, *kg* kilograms, *mg* milligrams, *MRSA* methicillin-resistant *Staphylococcus aureus*, *PCN* penicillin, *po* by mouth, *qd* once daily, ↑ *QT* increased electrocardiographic QT interval, *sp.* species, *qid* three times per day, *X* times

Adapted from: Flynn, TR, Shanti, RM (2016) Principles of antibiotic therapy for head, neck, and orofacial infections. In: Hupp JR, Ferneini (eds) Head, neck, and orofacial infections: a multidisciplinary approach. Elsevier, St Louis, MO. p. 141–63

Table 15.7 Selected interactions between antibiotics and other drugs

Antibiotic	Second drug	Adverse effects	Mechanism
Erythromycin Clarithromycin Ketoconazole Itraconazole	Theophylline	Seizures, dysrhythmias	Antibiotic inhibits cytochrome P450 metabolism of the second drug; ketoconazole not implicated
"	Cisapride	Dysrhythmias (torsades de pointes)	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Alfentanil	↑ Respiratory depression	Antibiotic inhibits cytochrome P450 metabolism of the second drug; ketoconazole not implicated
"	Bromocriptine	↑ CNS effects, hypotension	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Carbamazepine	Ataxia, vertigo, drowsiness	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Cyclosporine	↑ Immunosuppression and nephrotoxicity	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Felodipine Possibly other calcium channel blockers	Hypotension, tachycardia, edema	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Methylprednisolone Prednisone	↑ Immunosuppression	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Lovastatin Possibly other statins	Muscle pain, rhabdomyolysis	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Triazolam Oral midazolam	↑ Sedative depth and duration	Antibiotic inhibits cytochrome P450 metabolism of the second drug
"	Disopyramide	Dysrhythmias	Antibiotic inhibits cytochrome P450 metabolism of the second drug
Erythromycin	Clindamycin	↓ Antibiotic effect	Mutual antagonism
Erythromycin Tetracyclines	Digoxin	Digitalis toxicity, dysrhythmias, visual disturbances, hypersalivation	Antibiotic kills *Eubacterium lentum*, which metabolizes digoxin in the gut

Table 15.7 (continued)

Antibiotic	Second drug	Adverse effects	Mechanism
Erythromycin Clarithromycin Metronidazole	Warfarin Anisindione	↑ Anticoagulation	Antibiotic interferes with metabolism of the second drug
Tetracycline Cefamandole Cefotetan Cefoperazone Sulfonamides Aminoglycosides	Warfarin Anisindione	↑ Anticoagulation	Antibiotic kills gut flora that synthesize vitamin K, which antagonizes the second drug; poor vitamin K intake a factor
Metronidazole Cephalosporins	Alcohol Ritonavir	Flushing, headache, palpitations, nausea	Antibiotic inhibits acetaldehyde dehydrogenase, causing accumulation of acetaldehyde; ritonavir preparations contain alcohol
Metronidazole	Disulfiram	Acute toxic psychosis	
Metronidazole Tetracyclines	Lithium	Lithium toxicity: confusion, ataxia, kidney damage	Antibiotic inhibits lithium excretion by kidney; tetracycline interaction not well established
Tetracyclines Fluoroquinolones	Di- and trivalent cations (dairy, antacids, vitamins) Didanosine	↓ Absorption of antibiotic	Second drug interferes with absorption of antibiotic; didanosine is formulated with calcium carbonate and magnesium hydroxide buffers
Clindamycin Aminoglycosides Tetracyclines Bacitracin	Neuromuscular blocking agents	↑ Depth and duration of paralysis	Additive effect due to inherent minor neuromuscular blocking effect of the antibiotic; seen with clindamycin in the presence of low pseudocholinesterase levels and abnormal liver function tests
Clindamycin	Erythromycin	↓ Antibiotic effect	Mutual antagonism
Penicillins Cephalosporins Metronidazole Erythromycin Clarithromycin Tetracyclines Rifampin	Estrogen- and progestin-containing oral contraceptives	Contraceptive failure	Interference with enterohepatic recirculation of estrogen caused by killing of gut flora; rifampin is the only antibiotic in which this has been clinically proven
Ampicillin Amoxicillin	Allopurinol	Rash	Unknown, possibly due to hyperuricemia in patients taking allopurinol
Cephalosporins	Aminoglycosides	↑ Nephrotoxicity	Additive or potentiating effect

(continued)

Table 15.7 (continued)

Antibiotic	Second drug	Adverse effects	Mechanism
Trimethoprim/ sulfamethoxazole	Thiazide diuretics	Purpura, bleeding in elderly patients	Thrombocytopenia
Vancomycin	Aminoglycosides	↑ Renal toxicity	Additive effect
Fluoroquinolones Sulfonamides Chloramphenicol Fluconazole Itraconazole	Oral hypoglycemic agents	Hypoglycemia	Antibiotic displaces the second drug from plasma proteins
Ciprofloxacin Sulfonamides Chloramphenicol Fluconazole Ketoconazole Itraconazole	Phenytoin	↑ Serum level of phenytoin, confusion, delirium	Interference with phenytoin metabolism
Sulfonamides	Methotrexate	↑ Methotrexate concentration	Antibiotic displaces methotrexate from plasma proteins

↑ increased, ↓ decreased

Note: This list of antibiotic-drug interactions is only partial and selected according to the interests of dentists. Drug prescribers remain responsible to ascertain the complete drug interactions of any medications they may prescribe

From: Flynn, TR, Shanti, RM (2016) Principles of antibiotic therapy for head, neck, and orofacial infections. In: Hupp JR, Ferneini E (eds) Head, neck, and orofacial infections: a multidisciplinary approach. Elsevier, St Louis, MO. p. 154–5. Used with permission

prolongation of the QT interval on the electrocardiogram and possibly life-threatening cardiac dysrhythmias (Box 15.4). Azithromycin, however, is not metabolized by CYP3A4, and it therefore is much safer than the other macrolides. Further, azithromycin's pregnancy risk category is B (no evidence of animal toxicity and studies in humans are inadequate; or animal toxicity but studies show no human toxicity), while the other macrolides' pregnancy risk category is C (animal toxicity; studies in humans are inadequate). Azithromycin is therefore the safest of the currently available macrolides. The disadvantage of the macrolides, however, is that most oral anaerobes and many oral streptococci have become resistant to them.

The most useful fluoroquinolone for dentists is moxifloxacin, because its spectrum includes the usual oral pathogens. In occasional cases caused by *Eikenella corrodens*, which is uniformly resistant to clindamycin, the fluoroquinolones are the antibiotics of choice. The major toxicities of the fluoroquinolones, however, are chondrotoxicity and serious drug interactions. These drugs are toxic to growing cartilage especially and are contraindicated in pregnancy and children under 18 years of age. There is also a low incidence of tendonitis and tendon rupture in adults, especially after 60 years of age. Because the fluoroquinolones are metabolized by CYP3A4 and can cause prolongation of the QT interval even when given alone (Yan et al. 2010), their many interactions with other drugs are particularly concerning. The potential for torsades de pointes exists when the fluoroquinolones are combined with other antibiotics including the macrolides, antiarrhythmic drugs

Table 15.8 Pregnancy risk categories of selected antibiotics

Antibiotic	Pregnancy risk category	Pregnancy risk
Penicillins		
Penicillin G and V	B	
Ampicillin	B	
Amoxicillin	B	
Amoxicillin/Clavulanate	B	
Cephalosporins		
Cephalexin	B	
Cefuroxime	B	
Cefdinir	B	
Macrolides		
Erythromycin	B	
Clarithromycin	C	Increased risk of miscarriage
Azithromycin	B	Fetal defects in mice and monkeys
Antianaerobic		
Clindamycin	B	
Metronidazole	B	
Fluoroquinolones		
Ciprofloxacin	C	Chondrotoxic in growing rats
Moxifloxacin	C	Chondrotoxic in growing rats
Antifungals		
Fluconazole	D	Teratogenic at high doses
Itraconazole	C	Teratogenic at high doses
Voriconazole	D	Teratogenic at high doses
Others		
Vancomycin	C	Potential ototoxicity in human fetuses
Tetracyclines	D	Intrinsic dental staining
Doxycycline	D	Intrinsic dental staining
Linezolid	C	Fetal toxicity in rodents
Trimethoprim/ sulfamethoxazole	C	Increased risk of cleft palate

A studies in pregnant women, no risk, *B* animal studies no risk, human studies inadequate; OR animal toxicity, but human studies no risk, *C* animal studies show toxicity, human studies inadequate, benefit may outweigh risk, *D* evidence of human risk, benefit may outweigh risk, *X* fetal abnormalities in humans, risk outweighs benefit

Adapted from: Flynn, TR, Shanti, RM (2016) Principles of antibiotic therapy for head, neck, and orofacial infections. In: Hupp JR, Ferneini E (eds) Head, neck, and orofacial infections: a multidisciplinary approach. Elsevier, St Louis, MO. p. 141–63

such as amiodarone and sotalol, psychiatric drugs including the selective serotonin reuptake inhibitors commonly used for depression, and tamoxifen, a drug used to prevent the recurrence of breast cancer (Box 15.4). A common sequela of the fluoroquinolones is fatigue and mental clouding.

In summary, the antibiotic families that have been routinely used for decades in dentistry are not only effective when combined with appropriate surgery but also fairly safe. The newer antibiotics that are effective against oral pathogens seem to have increased toxicities, especially drug interactions and increased risk of fetal damage in pregnancy.

15.1.7 Minimize the Duration of Antibiotic Therapy, as Appropriate to the Presenting Type of Infection

In the past, dentists and physicians were taught that if a patient did not complete the entire duration of a prescribed antibiotic course, increased microbial antibiotic resistance would result. The rationale for this approach was that a shortened antibiotic course would allow the survival of partially sensitive strains of bacteria, while eliminating the completely sensitive ones. Thus, over time, the minimal inhibitory concentration of antibiotic necessary to kill those strains would gradually rise.

More recent investigations, however, suggest that in many instances, the acquisition of antibiotic resistance occurs in a single-step transition. Figure 15.2 illustrates

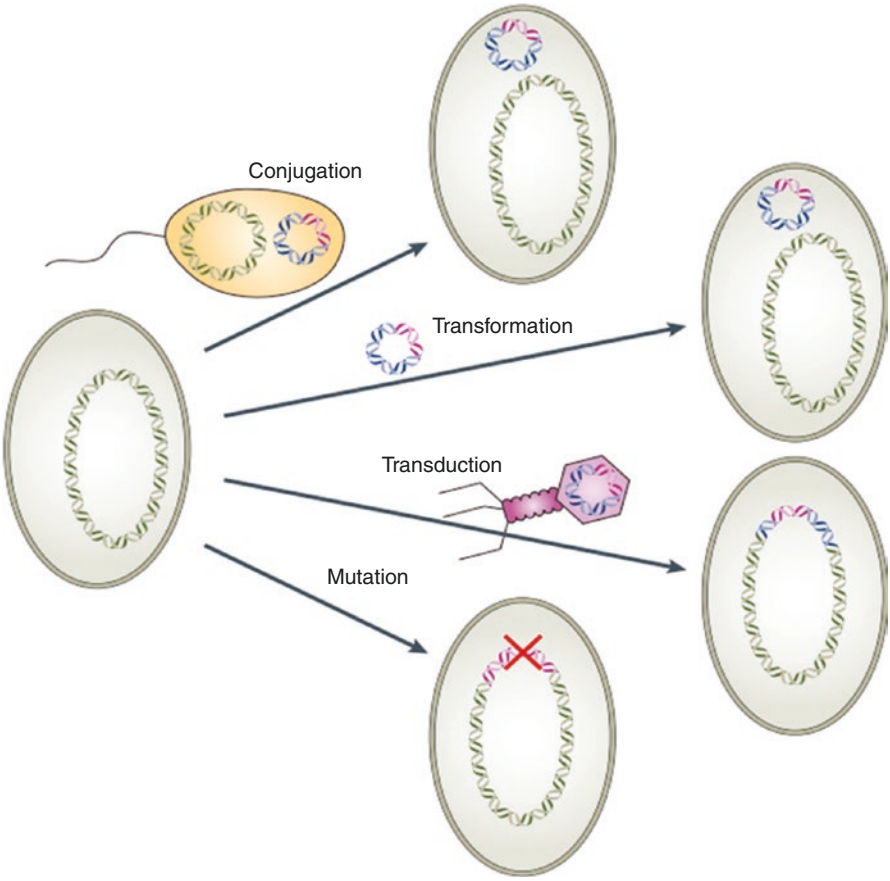

Fig. 15.2 Mechanisms of antibiotic resistance acquisition. DNA from the environment containing an antibiotic resistance gene (pink) can be transferred into a recipient bacterium by several paths: bacterial cell-to-cell conjugation; transformation by free DNA (on plasmids or as uncoiled DNA) that is released by dead bacteria; or viral phage-mediated transduction. Resistance can also arise by de novo mutation (indicated by a red cross). From: Andersson DI, Hughes D (2010) Antibiotic resistance and its cost: is it possible to reverse resistance? Nat Rev. Microbiol. 8:260–71. Used with permission

the mechanisms by which bacteria can transfer genetic material containing antibiotic resistance genes to each other.

With stepwise acquisition of antibiotic resistance, shortening the duration of antibiotic exposure may limit the opportunities for antibiotic-resistant strains to pass resistance mechanisms on to other members of their own species or even bacteria from unrelated species. The carriage of antibiotic resistance mechanisms appears to impose a metabolic cost to bacteria. By not having to develop and maintain these mechanisms, "wild" strains of bacteria can devote more energy to their own metabolism and reproduction. In the absence of antibiotic selection pressure, the wild strains gradually outcompete the resistant strains in a given population. Therefore, shortening the period of antibiotic exposure may reduce the survival of antibiotic-resistant strains (Andersson and Hughes 2010).

The four major types of antibiotic resistance mechanisms are listed in Table 15.9, with examples of bacterial species known to exploit them. Some of these mechanisms are found among oral pathogens, such as beta-lactamases in *Prevotella* and *Porphyromonas*; altered penicillin receptors (penicillin-binding proteins) in *Streptococcus sanguis*, a frequent pathogen in endocarditis; and efflux pumps that allow the antibiotic to be removed from within the bacterial cell in enterococci and staphylococci (Li and Nikaido 2009).

High-quality randomized clinical trials of the duration of antibiotic therapy in odontogenic infections have been performed by Lewis et al. (1986) and by Chardin et al. (2005). Lewis et al. (1986) compared two 3 g oral doses of amoxicillin 8 h apart on the day of surgery with a 5-day course of penicillin V, 250 mg four times per day. Chardin et al. (2005) compared 3- and 7-day regimens of amoxicillin 1 g orally twice per day. There was no difference in clinical parameters of swelling, fever, and lymphadenopathy at 7 days after surgery between groups in either study. Although the Chardin et al. (2005) study claimed that the shorter course of antibiotic would result in less antibiotic resistance, there was no significant difference in the carriage of amoxicillin-resistant organisms between the long and short regimen groups at 30 days after intervention.

In summary, the two included studies found no significant difference in clinical cure at 7 days when either a 1–3 days or a 5–7 days course of antibiotics was used, in combination with appropriate surgery (Table 15.10).

Table 15.9 Antibiotic resistance mechanisms, with examples of pathogenic species known to have them

Mechanism	Pathogens
Beta-lactamases	*S. aureus*, *S. epidermidis*, *H. influenzae*, *Prevotella*, *Porphyromonas*, *Capnocytophaga*, *Eikenella*, *Fusobacterium*
Altered PBPs (trans-, carboxy-, and endopeptidases)	MRSA, *S. pneumoniae*, *S. sanguis*
Reduced permeability	*K. pneumoniae*, *P. aeruginosa*, *S. marcescens*, *E. coli*
Active transport pumps	*S. aureus*, *Enterococcus faecalis*, *C. difficile*, *K. pneumoniae*, *S. pneumoniae*, *E. coli*

Underlined = member of the oral flora

Table 15.10 Clinical trials of the duration of antibiotic therapy in odontogenic infections

Title/ reference	Year	Intervention group	Comparator group	Significant difference between groups?	Comment
Lewis et al. (1986)	1986	AMOX 3 g q8h × 2 doses	PCN 250 mg qid × 5d	Less swelling at 24 h in amoxicillin group	No significant difference in pain, swelling, temperature, or lymphadenopathy at day 7
Chardin et al. (2005)	2009	AMOX 1 g bid × 3d, then placebo	AMOX 1 g bid × 7d	N	No difference in carriage of AMOX-resistant streptococci between groups at 30 days posttreatment

AMOX amoxicillin, *PCN* penicillin V
Adapted from: Flynn TR (2011) What are the antibiotics of choice for odontogenic infections, and how long should the treatment course last? Oral Maxillofac Surg Clin North Am 23:519–536

15.1.8 Use the Most Cost-Effective Appropriate Antibiotic

Cost is not the primary criterion on which antibiotics should be selected for our patients, yet clinicians should be aware of the costs of the antibiotics they prescribe. Table 15.3 lists the results of a systematic review of various antibiotics in dental infections (Flynn 2011). The available randomized clinical trials all found that, given appropriate surgery, no one antibiotic is superior to its comparator antibiotic. Therefore, patient medical history, pharmacologic toxicity, and cost become the major criteria that are used in antibiotic selection in odontogenic infections.

Table 15.11 compares the cost to an uninsured patient of 1 week of oral therapy with selected antibiotics at the usual doses and intervals. The cost of a 7-day prescription for amoxicillin 500 mg, to be taken three times per day, is compared to the other antibiotics listed in the right column, the amoxicillin cost ratio. Thus, the cost of a week prescription for penicillin V, at $18.59, is 55% greater than the cost of amoxicillin. An interesting comparison can be made among different formulations of clindamycin. The cost of generic clindamycin, 150 mg, given four times a day for 1 week is $27.69, more than twice as much as amoxicillin. When the dose is raised to 300 mg by giving two 150 mg capsules four times a day, the cost increases to $52.59 per week, which is 4.39 times the cost of amoxicillin. When, however, that same 300 mg dose, four times per day, is given as one generic 300 mg capsule four times a day, the cost is $79.99 per week, 6.67 times the cost of amoxicillin, over 50% greater than when the same 300 mg dose is given as two capsules, instead of one. Therefore, when cost is a primary concern, the 300 mg dose can be given as two 150 mg capsules instead of one 300 mg capsule. The cost savings may be offset, however, by a decrease in compliance (the patient's actually taking the medication as prescribed) due to the increased number of capsules per dose.

The newer antibiotics tend to be more expensive than older ones. For example, generic amoxicillin/clavulanate (brand name Augmentin®), 875 mg given twice per day, costs $69.99 per week, 5.84 times the cost of amoxicillin, yet its clinical effectiveness is not significantly different than penicillin V, when appropriate dental treatment is performed (Lewis et al. 1993). Moxifloxacin is over nine times the cost of amoxicillin,

Table 15.11 Costs of oral antibiotic therapy

Antibiotic	Usual Dose (mg)	Usual Interval (h)	1-week retail Cost 2017	Amoxicillin Cost ratio
Penicillins				
Amoxicillin	500	8	$11.99	1.00
Penicillin V	500	6	$18.59	1.55
Augmentin	875	12	$48.99	4.09
Augmentin XR (1000 mg X2)	2000	12	$119.99	10.01
Amoxicillin/clavulanate XR generic(1 g X2)	2000	12	$178.99	14.93
Dicloxacillin	500	6	$39.59	3.30
Cephalosporins (generation)				
Cephalexin caps (first)	500	6	$17.99	1.50
Cefadroxil (first)	500	12	$35.29	2.94
Cefuroxime (second)	500	8	$82.99	6.92
Cefaclor ER (generic)	500	12	$264.99	22.10
Cefdinir (third) (300 mg X2)	600	24	$61.59	5.14
Erythromycins				
Erythromycin base	500	6	$464.99	38.78
Clarithromycin (Biaxin XL)	500	24	$34.99	2.92
Azithromycin (Zithromax)	250	12	$74.99	6.25
Fidaxomicin (Dificid)	200	12	$3034.99	253.13
Antianaerobic				
Clindamycin (generic)	150	6	$27.69	2.31
Clindamycin (2 T generic)	300	6	$52.59	4.39
Clindamycin (generic)	300	6	$79.99	6.67
Metronidazole	500	6	$29.69	2.48
Others				
Trimethoprim/Sulfamethoxazole	160/800	12	$11.99	1.00
Vancomycin	125	6	$376.99	31.44
Ciprofloxacin	500	12	$17.19	1.43
Moxifloxacin (Avelox)	400	24	$102.99	8.59
Doxycycline	100	12	$50.59	4.22
Linezolid (Zyvox)	600	12	$2223.99	185.49

Notes: Usual doses and intervals are for moderate infections and are not to be considered prescriptive. Amoxicillin cost ratio = retail cost of antibiotic for 1 week/retail cost of amoxicillin for 1 week

yet it is not more effective than amoxicillin/clavulanate (Al-Nawas et al. 2009). Doxycycline (Vibramycin®), a broader-spectrum drug than amoxicillin, is 3.54 times the cost of amoxicillin. Well-done clinical trials failed to demonstrate any significant advantage of these newer, broader-spectrum drugs over the older narrow-spectrum penicillin family antibiotics, such as penicillin V or amoxicillin (Flynn 2011).

15.1.9 Use Prophylactic Antibiotics Only When Proved Effective or According to Professional Guidelines

Antibiotics can be used to prevent systemic complications of dental procedures, such as endocarditis and late prosthetic joint infection, and to prevent surgical site

infection (SSI) in the oral wound left by an oral surgical procedure. Prophylactic antibiotics are given to prevent infection; therapeutic antibiotics are given to treat an established infection.

The use of prophylactic antibiotics to prevent distant infections after routine dental procedures, such as scaling and root planing or endodontic therapy, is discussed in Sect. 15.1.10. Prophylactic antibiotics to prevent SSI (wound infection) are discussed here.

There is no evidence to support the use of prophylactic antibiotics for extraction of erupted teeth. Expert recommendations exist to support this practice in immunocompromised patients, such as in patients undergoing cancer chemotherapy or taking immunosuppressive drugs (Tong and Rothwell 2000).

A mounting body of reliable evidence supports the use of prophylactic antibiotics for the removal of impacted mandibular third molars. One randomized clinical trial (Halpern and Dodson 2007) compared one intravenous dose of antibiotic before third molar surgery and found a significant reduction in SSI and alveolar osteitis (dry socket). Several meta-analyses have also found a significant reduction in SSI and alveolar osteitis when an antibiotic is administered 2 h or less preoperatively and some additional benefit when the antibiotic is continued for 3–4 days postoperatively (Ren and Malmstrom 2007; Lodi et al. 2012; Moreno-Drada and García-Perdomo 2016; Marcussen et al. 2016).

The value of using prophylactic antibiotics in third molar surgery may be questioned, however, because in these studies it was found that the number needed to treat (the number of third molar patients that must be given an antibiotic in order to prevent one infection) ranged from 12 to 40. The number needed to treat raises concerns of adverse or allergic reactions, expense, and increased antibiotic resistance. On the other hand, the costs, morbidity, and professional liability of postoperative infection and its treatment can be considerable, especially when hospitalization becomes necessary.

In periodontal surgery, adjunctive antibiotic therapy with tetracycline or metronidazole provides marginal improvement in attachment levels, according to a meta-analysis by Haffajee et al. (2003).

Even though many dental implant manufacturers recommend prophylactic antibiotic therapy before dental implant placement, a recent meta-analysis of randomized clinical trials on this topic found no significant risk reduction of SSI following dental implant surgery when prophylactic antibiotics were used (Moreno-Drada and García-Perdomo 2016). In addition, these authors found no benefit of prophylactic antibiotics in endodontic surgery.

In summary, there is high-quality evidence to support the use of prophylactic antibiotics for prevention of SSI in otherwise healthy patients for removal of impacted mandibular third molars and for improved results in periodontal surgery, but not for other common dental procedures, such as routine extractions, dental implant placement, or periapical surgery. Concerns about adverse reaction to prophylactic antibiotics, costs, and antibiotic resistance remain, even when prophylactic antibiotics show benefit in reduction of SSI.

15.1.10 Follow the Guidance of Evidence-Based Recommendations and Professional Guidelines When They Are Available

When conclusive evidence-based guidelines are not feasible, whether due to lack of available high-quality evidence or to ethical considerations that preclude clinical trials directly testing alternative treatments, professional associations, such as the American Dental Association, the American Heart Association, the American Academy of Orthopaedic Surgeons, and the Infectious Diseases Society of America, join forces to convene expert panels charged with providing guidelines for clinicians. Their guidelines are periodically reevaluated, based on new basic research and studies of clinical outcomes, resulting in revisions. Such has been the history of guidelines for the prevention of endocarditis and late prosthetic joint infections following dental procedures.

Bacteremia following dental procedures, often caused by *Streptococcus viridans*, an oral streptococcus, has been suspected as the cause of some cases of subacute bacterial endocarditis since the 1930s (Weiss 1934). Bacteremia occurs in up to 100% of dental extractions, 70% of root planing, and 20% of root canal procedures (Li et al. 2000). Prophylactic antibiotics, administered before tooth extraction, can prevent bacteremia, according to the meta-analysis by Moreno-Drada and García-Perdomo (2016), by up to 80% in one trial (Vergis et al. 2001). A reasonable strategy, therefore, would be to use antibiotics to prevent bacteremia and its resultant endocarditis or late prosthetic joint infection. Since the 1950s, the antibiotic regimens for preventing endocarditis have ranged from intramuscular penicillin administered for 5 days, including 2 days before and after the procedure, to a large dose of amoxicillin given shortly before surgery, with no follow-up dose (Wilson et al. 2008). The regimens have evolved as our understanding of the oral flora, the timing of bacteremias, the effectiveness of antibiotics in preventing bacteremias, the antibiotic sensitivities of the oral flora, and the actual risk posed by the predisposing conditions has evolved. We can expect continued evolution of our understanding of these factors and accordingly updated antibiotic regimens.

The most recent revision of the endocarditis guidelines was published in 2008 (Wilson et al. 2008). The committee took into account recent information that only a very small proportion of cases of endocarditis might be prevented by the use of antibiotic prophylaxis before dental procedures, even if the antibiotic were 100% effective. The committee recommended prophylaxis only for those patients with cardiac conditions with the highest risk of adverse outcomes, and not for all patients having an increased lifetime risk of endocarditis. The dental procedures for which antibiotic prophylaxis is recommended are "All dental procedures that involve manipulation of gingival tissue or the periapical region of teeth or perforation of the oral mucosa." Specifically excluded procedures, however, include local anesthetic injections through uninfected tissue, taking dental radiographs, placement of removable orthodontic or prosthodontic appliances, adjustment of orthodontic appliances, and bleeding from trauma to the lips or oral mucosa. The 2008 recommended antibiotic regimens are shown in Table 15.12.

Antibiotic prophylaxis for the prevention of late prosthetic joint infection has been much more controversial than for endocarditis. In 1994, a survey of orthopedic

surgery and general dentistry program directors found that the majority of both groups felt that dental diseases can affect joint prostheses and that antibiotic prophylaxis should be used in such patients before dental procedures (Shrout et al. 1994). In 2003, the American Dental Association and the American Academy of Orthopaedic Surgeons published updated guidelines recommending cephalexin, cefazolin, amoxicillin, or clindamycin for antibiotic prophylaxis before dental procedures in prosthetic joint patients with certain risk factors, such as recent placement of the prosthetic joint, immunocompromised patients, or those with comorbidities, such as type 1 diabetes or a history of prosthetic joint infection (American Dental Association and the American Academy of Orthopaedic Surgeons 2003).

However, in 2009, the American Academy of Orthopaedic Surgeons unilaterally published online a guideline that recommended antibiotic prophylaxis for all patients with prosthetic joint replacements before indicated dental procedures. After considerable debate in the literature among orthopedic surgeons, dentists, infectious disease specialists, and others, the American Dental Association and the American Academy of Orthopaedic Surgeons published a joint clinical practice guideline

Table 15.12 Antibiotic prophylaxis regimens for prevention of endocarditis following dental procedures

Situation	Agent	Single dose: 30–60 minutes before procedure
Oral	Amoxicillin	Adults, 2 g; children, 50 mg/kg
Unable to take oral medications	Ampicillin	Adults, 2 g IM or IV; children, 50 mg/kg IM or IV
	OR	
	Cefazolin	Adults, 1 g IM or IV; children, 50 mg/kg IM or IV
	OR	
	Ceftriaxone	Adults, 1 g IM or IV; children, 50 mg/kg IM or IV
Allergic to penicillin	Clindamycin	Adults, 600 mg; children, 20 mg/kg
	OR	
	Cephalexin[a]	Adults, 2 g; children, 50 mg/kg
	OR	
	Azithromycin or clarithromycin	Adults, 500 mg; children, 15 mg/kg
Allergic to penicillin and unable to take oral medications	Clindamycin	Adults, 600 mg; children, 20 mg/kg IV
	OR	
	Cefazolin[a] or ceftriaxone[a]	Adults, 1 g IM or IV; children, 50 mg/kg IM or IV

Total children's dose should not exceed adult dose
IM intramuscular, *IV* intravenous
From: Flynn TR (2008) Principles of management and prevention of odontogenic infections. In: Ellis E, Hupp JR, Tucker MR (eds) Contemporary oral and maxillofacial surgery, fifth edition. Mosby, St. Louis, MO. p. 315. Used with permission
[a]Cephalosporins should not be used in an individual with a history of anaphylaxis, angioedema, or urticaria with penicillins or ampicillin

acknowledging the lack of evidence to support the use of antibiotics to prevent late prosthetic joint infection following dental procedures and recommended in general against antibiotic prophylaxis for this purpose. However, the guideline also recommended that practitioners consult their best judgment and give the patient a say in whether antibiotic prophylaxis is used (American Academy of Orthopaedic Surgeons and American Dental Association 2012).

Most recently, in 2015, the American Dental Association's Council on Scientific Affairs published an evidence-based guideline for dentists on the use of prophylactic antibiotics. The expert panel convened by the Council on Scientific Affairs judged that the current best evidence failed to demonstrate an association between dental procedures and late prosthetic joint infection. The panel cited evidence that antibiotic prophylaxis is not effective in preventing prosthetic joint infections. Because of mounting concerns about antibiotic resistance, adverse drug reactions, opportunistic infections, and costs associated with prophylaxis, the panel did not recommend antibiotic prophylaxis prior to dental procedures for this purpose. In fact, the panel judged that the benefits of antibiotic prophylaxis may not exceed the harms for most patients. The panel did allow that special clinical circumstances may present significant risk in providing care without antibiotic prophylaxis, which may require the dentist to use his or her professional judgment, in consultation with the patient and the orthopedic surgeon. If antibiotics are deemed necessary, the panel stated that it is most appropriate for the orthopedic surgeon to choose the regimen and write the prescription (Sollecito et al. 2015).

15.2 Empiric Antibiotics of Choice for Odontogenic Infections

The evidence presented thus far in this chapter can be integrated to allow evidence-based selection of the empiric antibiotics for odontogenic infections that require antibiotic therapy, in addition to appropriate dental treatment.

Table 15.13 lists the empiric antibiotics of choice for outpatient odontogenic infections.

The antibiotics usually chosen for odontogenic infections are not significantly different in their clinical effectiveness when appropriate dental treatment is given (see Table 15.3). Therefore, empiric antibiotics can be chosen based on their

Table 15.13 Empiric antibiotics of choice for outpatient orofacial infections

Antibiotic of choice	
	Amoxicillin
	Clindamycin
	Azithromycin
Penicillin allergy	Clindamycin
	Azithromycin
	Moxifloxacin

pharmacologic safety, the patient's medical history (such as allergy or interaction with concurrent medications), and cost.

In the absence of penicillin allergy, amoxicillin is the antibiotic of first choice for odontogenic infections. The penicillins are among the least toxic of antibiotics and have few drug interactions. Besides hypersensitivity reactions, antibiotic-associated colitis, suppression of hematopoietic tissues, hepatitis, cholestatic jaundice, and seizures are rare adverse reactions to amoxicillin. As shown in Table 15.11, amoxicillin is the least expensive among the antibiotics dentists may have occasion to use, nowadays even cheaper than penicillin V.

Clindamycin has been used effectively by dentists for decades. However, recent overuse may be the cause of an alarming rise in the carriage of clindamycin-resistant pathogens among patients with odontogenic infections. A recent study found that 32% of strains isolated from severe odontogenic infections were clindamycin resistant (Kim et al. 2017). Further, clindamycin's major adverse reaction is antibiotic-associated colitis caused by *Clostridium difficile*. The treatment of *C. difficile* colitis has become more challenging in recent years due to increasing resistance to the usual antibiotic management, resulting in common recurrence of the condition. Fidaxomicin is a new member of the macrolide family that is effective against *C. difficile*, but it is extremely expensive. Other adverse reactions of clindamycin include gastrointestinal intolerance, metallic taste, hypersensitivity reactions including Stevens-Johnson syndrome, erythema multiforme, and toxic epidermal necrolysis, as well as suppression of the blood-forming tissues. Clindamycin can interfere with the effectiveness of contraceptive pills and may prolong the effect of non-depolarizing muscle relaxants used during general anesthesia. Its cost is 4.39 times that of amoxicillin.

Among the macrolide family of antibiotics, azithromycin has the best safety profile because, unlike the other macrolides, it is not metabolized by CYP3A4, the liver microsomal enzyme responsible for a large proportion of known drug interactions. This avoids the interaction between clarithromycin, for example, and the statin drugs commonly used to treat hyperlipidemia, resulting in increased breakdown of skeletal muscle due to elevated statin levels. A similar reaction between most macrolides and the warfarin anticoagulants, which results in unwanted bleeding, is avoided with azithromycin. Azithromycin does have a life-threatening interaction with the psychiatric drug, Orap® (pimozide), which can result in a form of ventricular fibrillation called torsades de pointes. Adverse reactions include hypersensitivity reactions, hepatotoxicity, pancreatitis, prolongation of the QT electrocardiographic interval, and exacerbation of myasthenia gravis. While the other macrolides carry pregnancy risk category C (toxicity in animals; human studies insufficient data), azithromycin has been assigned pregnancy risk category B (no toxicity in animals; human studies insufficient data). The cost of azithromycin is 6.25 times that of amoxicillin.

Moxifloxacin is a fourth-generation fluoroquinolone with increased effectiveness against oral streptococci and anaerobes, as compared to ciprofloxacin. The toxicities of moxifloxacin are considerable, however. Like other fluoroquinolones, it is toxic to growing cartilage and is therefore contraindicated in pregnancy and in children younger than 18 years. Its adverse reactions include hypersensitivity reactions, phototoxicity, seizures, mental clouding and fatigue, nephrotoxicity,

hepatotoxicity, suppression of hematopoietic tissue, exacerbation of myasthenia gravis, and tendon rupture. Achilles tendon rupture, especially in individuals older than 60 years, has occurred. *C. difficile*-associated colitis can also occur. Further, moxifloxacin prolongs the QT interval, and when combined with other drugs that prolong the QT interval, it can result in torsades de pointes and death. Some of those drugs are methadone, tramadol, amitriptyline, trazodone, macrolide antibiotics, antiretroviral drugs, and halogenated inhalation anesthetics (Box 15.4). Moxifloxacin is 8.59 times the cost of amoxicillin.

15.3 Conclusion

The available evidence strongly supports the primacy of appropriate dental treatment interventions, such as tooth extraction, gingival curettage and scaling, root canal therapy, and incision and drainage in the management of odontogenic infections. The modern era of antibiotic therapy is characterized by increasing antibiotic resistance, drug interactions, toxicities, and cost. Well-performed studies, however, indicate that older antibiotics, when combined with appropriate dental treatment, are equally as effective as the newer ones, with increased safety and lower cost. Figure 15.3 is an algorithm for the use of antibiotics in dentistry.

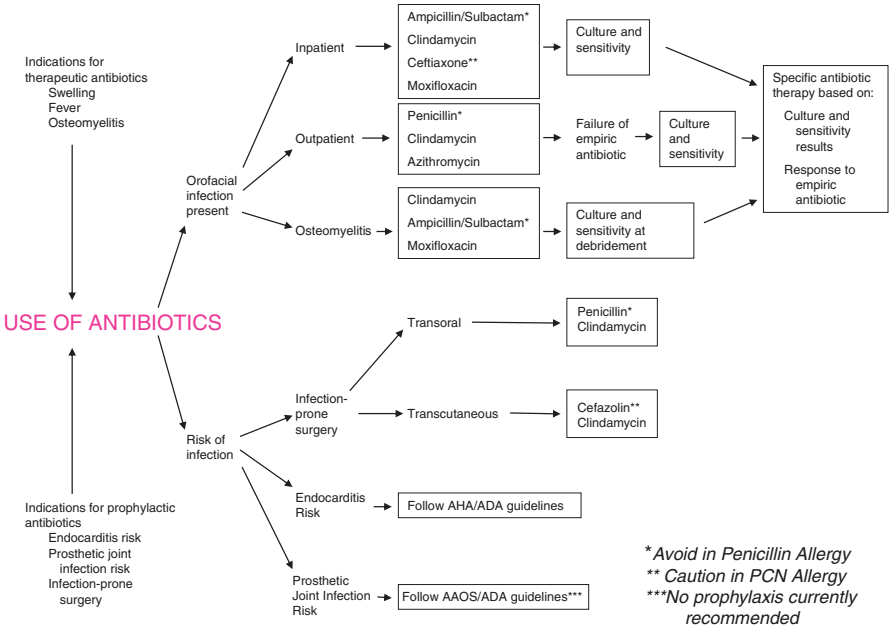

Fig. 15.3 Algorithm for the use of antibiotics in dentistry. *PCN* penicillin, *AAOS* American Academy of Orthopaedic Surgeons, *ADA* American Dental Association, *AHA* American Heart Association. Adapted from: Flynn TR (2007) Use of antibiotics. In: Laskin DM, Abubaker AO, eds. Decision making in oral and maxillofacial surgery. Chicago, Quintessence

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Preprosthetic Surgery

16

Riccardo I. Ambrogio and Daniel Beauvais

"I will compress the story as far as may be done without omitting anything vital to the case."
Sherlock Holmes in—The Crooked Man

Abstract

Proper performance of preprosthetic surgery entails a systematic and detailed review of the patient's medical and dental history, appropriate imaging, preoperative models, and a thorough understanding of the patient's goals for prosthetic treatment. This chapter will provide an overview of preprosthetic surgery. Surgical techniques will be reviewed and complications will be discussed.

16.1 Introduction

The primary goal of preprosthetic surgery is to establish a functional and healthy platform for support and retention of prosthetic devices. Preprosthetic surgery performed by the general dentist is a service that can be comfortably and efficiently provided to the dental patient. It alleviates patient scheduling and traveling to another practitioner's office and allows continuity of care with the primary dental provider. When prostheses are to be delivered at time of surgery, this allows for immediate adjustments of the removable or fixed prosthetics at time of delivery. As the prevalence of edentulism among American adults is noted to be as high as 16.3% (rural settings), with predictions that 8.6 million Americans will be edentulous in

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2050, the current and future needs for preprosthetic surgery continue to exist (Miloro et al. 2011; Vargas et al. 2002; Slade et al. 2014).

Radiographic imaging may guide the practitioner with treatment planning and surgical options. The panoramic radiograph serves as the best initial image for evaluation of hard tissue and any existing pathology. This initial radiograph can serve as a tool for making measurements for potential bony reduction, identifying anatomic variants, evaluating of the maxillary sinuses, locating root tips or impacted teeth, and identifying the location of the inferior alveolar canal and mental foramina. The use of cephalometric analysis used in conjunction with mounted models serves as a tool for aiding the practitioner in establishing an appropriate path of insertion for prostheses and identifying interarch relationships that may complicate the prosthetic treatment plan. Additionally, computed tomography (CT) radiographs may be used for some cases where detailed evaluation of bone quality and contour, precise neurovascular location, and sinus anatomy are of interest.

Preoperative models not only assist in treatment planning, e.g., for the reduction of a soft tissue tuberosity, but can also be used for model surgery, e.g., for the fabrication of clear stents to be used either postoperatively or to judge appropriate reduction of the surgical site.

Paramount to preprosthetic surgery is a thorough evaluation of the hard and soft tissue form in the maxilla and mandible. The practitioner should carefully visualize, palpate, and examine the soft tissue overlying the alveolar ridges and the associated muscle attachments. Ideally, the maxilla and mandible should be in a normal relationship. The alveolar processes should be as large as possible without the presence of protuberances or undercuts. The arches should be broad and U-shaped, the width of the maxilla should be as similar to that of the mandible as possible to provide good stability, and the jaws should be oriented in a dental Class I position Starshak and Sanders (1980). Bone and soft tissue should be free of disease, with uniform gingival thickness and consistency. The vestibules should be free from scar tissue or pathology. The tongue should be freely moveable without disease or a restricting frenum. Adequate salivary gland function must be intact so as to keep the mouth, and subsequent prostheses, moist and lubricated. All of these characteristics must be noted prior to the initiation of preprosthetic surgery. A thorough initial examination will help the practitioner create a clear and concise plan for subsequent surgery.

It also must be stressed that successful surgery involves appropriate expectations from the patient. Proper preoperative discussion of goals, including risks and benefits of the preprosthetic procedure, will ultimately assist with patient understanding of successful surgery.

16.2 Factors to Consider When Performing Preprosthetic Surgery

16.2.1 Local Anesthesia

The practitioner should be thoroughly knowledgeable in the administration of local anesthesia, as discussed in Chap. 7. The principles of administering local anesthesia for preprosthetic procedures are the same as for other routine dental procedures;

profound analgesia is best obtained by nerve block technique, and soft tissue hemostasis is best achieved by using the local anesthetic with a vasoconstrictor applied locally to the surgical site El-Kholey (2013). It is important to take into account the distorting effect of local anesthesia on soft tissues when performing preprosthetic surgery. Applying direct pressure to the site and waiting for several minutes after administration will help minimize this tissue distortion while maximizing the effect of the vasoconstrictor. As a simple technique, soft tissue preprosthetic surgery tends to be performed with administration of local anesthesia directly in the surgical field, whereas bony surgery frequently relies on nerve block anesthesia with some local infiltration to assist in dissection and/or hemostasis.

16.2.2 Surgical Technique

When creating access for hard or soft tissue surgery, full-thickness flaps are the preferred method of access in most bony surgery, especially in simple preprosthetic surgery. Partial thickness flaps are used in more advanced and specific surgical techniques, which are not covered in this chapter.

Proper flap technique allows for adequate blood flow to the entirety of the flap, thereby decreasing the incidence of flap necrosis. Flap access to the surgical site should offer adequate exposure, whether with a direct flap or with the addition of releasing incisions. Flaps should be kept moist, noting the longer the flap is open, the more likely the chance of injury to the flap, suboptimal healing, or infection.

When performing bony preprosthetic surgery, consider trimming any redundant mucosal tissue and/or using a surgical splint to reinforce any areas of potential dead space. If a properly relieved postoperative stent is available, this will help protect the wound from direct trauma and decrease the chance of hematoma formation. Clear (transparent) stents are recommended so that the wound site is visible in the postoperative period.

16.3 Hard Tissue Removal

16.3.1 Alveoloplasty

Alveoloplasty is the recontouring of the bone in an area that previously was dentate, specifically involving the alveolar bone. The immediate goal in performing an alveoloplasty is to provide adequate ridge contour in order to facilitate fabrication of a well-fitting and esthetic prosthetic device. In evaluating alveolar ridges for alveoloplasty, the practitioner should aim to leave the ridges as broad as possible to distribute masticatory load. Undercuts should be identified and removed if their presence would hinder in denture retention. Sharp edges should be rounded, and the mucosa overlying the alveolus should be uniform in thickness and compressibility for even transmission of masticatory forces. Care must be taken not to over-reduce the alveolus, as resorption occurs over time. Furthermore, if implants are being considered for restoring the alveolar ridge, alveoloplasty should be performed judiciously to allow for a broad site with adequate bone height for implant placement.

Alveoloplasty may be performed at the time of dental extractions or anytime following exodontia. For efficiency and patient comfort, alveoloplasty should be ideally performed immediately following exodontia in most cases. There are scenarios, however, in which delayed alveoloplasty is indicated. If the immediate removal of the bone will result in a narrow, V-shaped ridge, it is advisable to wait for the bone to fill the extraction sockets prior to performing alveoloplasty (4–6 weeks). Additionally, in cases of advanced periodontitis with severe resorption of the alveolar and interradicular bone, allowing for bony healing prior to performing alveoloplasty will prevent over-reduction of the alveolus.

16.3.2 Technique

During exodontia, the full-thickness mucoperiosteal flap must be maintained, and consideration should then be given to extending the flap or performing releasing incisions to fully expose the surgical site. The practitioner must be cognizant of areas of anatomy to avoid when creating the flap, e.g., mental foramina. Releasing incisions should avoid neurovascular structures, and in the edentulous, possibly atrophic mandible, the mental foramina may be on or close to the alveolar ridge, and the incisive papilla may also be positioned in a similar fashion. Preoperative radiographs can aid in locating the mental foramina. A bone file, irrigated rotary bur, or rongeur forceps are then used to reduce the areas of the irregular bone. The surgical site is then inspected with the gingiva reflected back into place and palpated with a gloved finger to evaluate any irregularities or sharp edges. When satisfactory reduction is complete, the wound is closed primarily with silk or resorbable sutures.

For alveoloplasty performed at a later date than the exodontia, a full-thickness flap is initiated at the occlusal aspect of the alveolar ridge. Proper exposure may involve elongating the incision and/or adding releasing incisions. Once the bone is properly exposed, a bone file, irrigated rotary bur, and/or rongeur forceps are used to shape the areas of the irregular bone. The surgical site should then be inspected, palpated, and closed primarily as described above.

16.3.3 Palatal Torus

A palatal torus is a benign, slowly growing bony projection on the maxilla that is prevalent in the adult population. Palatal tori have a dense cortical surface with a cancellous core, and they vary in shape and size. A palatal torus can be comfortably removed in the office with local anesthesia. The anxious patient may require some anxiolytic intervention, and the patient with a strong gag reflex might require nitrous oxide supplementation or sedation.

Palatal tori serve no useful purpose, yet they do not need to be routinely removed. Indications for removal of a palatal torus include interference with the tongue, speech and/or mastication, chronic trauma, biopsy or evaluation for pathology, a source of autogenous bone for grafts, or preparation for delivery of dental prosthesis.

Preparation for any preprosthetic surgery entails appropriate review of medical and dental history and evaluation of radiographs for bone-related surgery. Radiographs for soft tissue surgery are not always necessary but are recommended for bone-related surgery. Preoperative models of the maxilla are very helpful in planning torus surgery. The torus can be conservatively reduced on the models, and an interim thermoplastic splint can be fabricated from the model surgery. This splint will act as a guide, assisting in evaluating the amount of bony reduction sought surgically.

16.3.4 Technique

Local anesthesia is recommended via bilateral greater palatine block, nasopalatine block, and infiltration. The infiltration should be attempted in a subperiosteal fashion in an attempt to freely elevate the soft tissue off of the torus. This aids the dentist in flap dissection and decreases the chance of flap perforation. A "Y" or "double Y" (−< or >−<) incision is made over the torus. Careful incisions are made in an attempt to avoid the palatine vasculature. Once the flap is reflected and the torus is exposed in its entirety, surgical removal can commence (Fig. 16.1).

A fissure bur with saline irrigation can be used to score the torus. Once scored, a chisel or elevator can be used to remove the bony fragments. A round bur and bone file are then used to smooth the surface of the palate. If the palatal torus is small, it can be removed via chisel, reduced with round bur, and filed with a bone file or any combination thereof. Copious irrigation is recommended throughout the procedure. Once the torus is completely removed, the soft tissue flap edges should be approximated, and the surgical site should be evaluated for bony irregularities or redundant soft tissue.

If a bony irregularity can be felt, a bone file can be used to file the rough edges. Failure to do this may contribute to wound dehiscence. It is also important to ensure not to over-reduce the bony torus. A good strategy for proper reduction without over-reduction is to intentionally leave a miniscule amount, e.g., less than half a millimeter, of bony torus during reduction, and then complete the remainder of the reduction with a bone file.

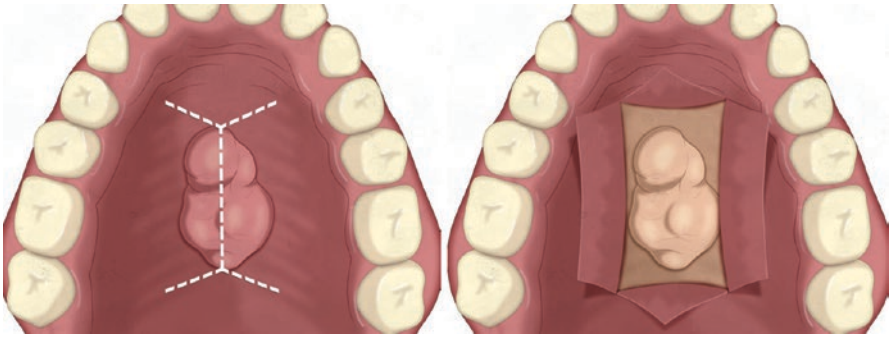

Fig. 16.1 Double "Y" flap design for removal of a palatal torus

If the torus is large, there may be a significant amount of redundant soft tissue remaining following bony reduction. This tissue has a large area of potential dead space, which can lead to hematoma formation under the flap. It is recommended to conservatively trim excessive mucosa, while still maintaining a primary, linear closure. Once the wound is closed, the dentist may consider placing a clear denture type stent for wound protection. The stent should be relieved so as not to place pressure on the wound. If not properly relieved, this can lead to pressure necrosis.

The patient should begin a soft diet postoperatively and advance the diet slowly as tolerated.

16.3.5 Complications

Despite appropriate patient selection, the practitioner may experience the occasional patient that cannot commence with surgery once they have a completely anesthetized palate. Anxiety, gagging, and or nausea may be so profound that the surgery may require rescheduling and/or pharmacologic assistance.

Infection is relatively rare, but clean incisions and dissection assist in wound healing. Inadequate cooling/irrigation while using rotary instruments can cause bone necrosis, thus increasing possibility of wound dehiscence or infection.

Perforation into the nasal or maxillary sinus, or fracture of bone in these regions, is a potential unexpected outcome. A small perforation can be managed by applying firm pressure with gauze in order to achieve hemostasis. In rare cases, it may be necessary to pack the nasal cavity with gauze strips to achieve hemostasis.

Hemorrhage is a potential complication that can be avoided by clean incisions that avoid the greater palatine and nasopalatine vasculature. In the event of persistent bleeding, injecting a small amount of local anesthetic with vasoconstrictor and application of firm pressure usually resolve the bleeding. In instances of persistent bleeding, electrocautery may be required to achieve hemostasis.

Wound dehiscence can occur from many ways, including flap dissection with tears, a palatal splint with excessive pressure on the mucosa, or attempted removal of a torus with improper access. If dehiscence does occur, the wound should be covered with a temporary stent to facilitate application of tissue conditioner until wound healing has occurred.

16.3.6 Mandibular Tori and Maxillary/Mandibular Exostoses

A mandibular torus is a benign bony growth of the mandible that usually occurs bilaterally on the medial (lingual) surface of the body and alveolar process of the mandible. Like palatal tori, the overlying mucosa is typically very thin. Indications for mandibular tori removal include interference with speech, interference with comfortable chewing, ulceration and poor healing of the overlying mucosa, and facilitation of removable denture construction.

Buccal exostoses occur on the buccal aspect of the either the maxilla or mandible. They occur near the crest of the alveolar process, most commonly in posterior areas. Exostoses typically present problems for the prosthetic patient, as they can interfere with retention and stability, and they may pose difficulty in obtaining accurate impressions.

16.3.7 Principles of Torus and Exostosis Removal

A full-thickness mucoperiosteal flap offers proper wound protection at closure and is the recommended approach to removing bony growths of the jaws. Consider releasing incisions if appropriate for exposure and to avoid encroaching on neurovascular structures.

Lingual mandibular flaps or releasing incisions can create additional morbidity to the patient, and caution should be used in deciding to attempt surgery on the lingual aspect of the mandible for multiple reasons. The abundance of salivary glands and ductal structures are at risk for direct and indirect damage. The lingual nerve and artery vary in anatomic location in all patients, and in part this is related to changes in alveolar architecture in the edentulous alveolar segment as well as muscle pull caused by tongue movement. Lingual flaps have greater potential for injury to the mylohyoid muscle and lingual nerve and artery. In the third molar region, variants in the course of the lingual nerve are not uncommon, and studies have noted the presence of the lingual nerve at the height of the mandibular third molar in a significant percentage of patients. Therefore, surgical access in this location, including lingual releasing incisions, is not advised (Pogrel et al. 1995).

In the edentulous mandible, the location of the mental foramina migrates superiorly, and exiting mental nerve branches may limit the extent of soft tissue surgery. In the edentulous patient, the mylohyoid muscle and lingual nerve also move superiorly. Careful clinical and radiographic examination can assist the dentist in evaluating these parameters.

16.3.8 Technique

A full-thickness mucoperiosteal flap is the access of choice for bony growths of the mandible and maxilla. Keeping in mind key anatomic areas to avoid, the bony growth is fully exposed, by linear ridge incision in the edentulous patient or an intrasulcular flap in the dentate patient (Fig. 16.2). Releasing incisions are recommended if the linear/intrasulcular incision is of adequate length, but exposure is still inadequate (Fig. 16.3).

Lingual releasing incisions of the mandible are not advocated for reasons previously discussed. The flap is reflected and protected with a retractor of the practitioner's preference (Fig. 16.4).

The retractor will keep the surgical field exposed and also act as a protective barrier to the surrounding anatomical structures. A combination of one or many devices can

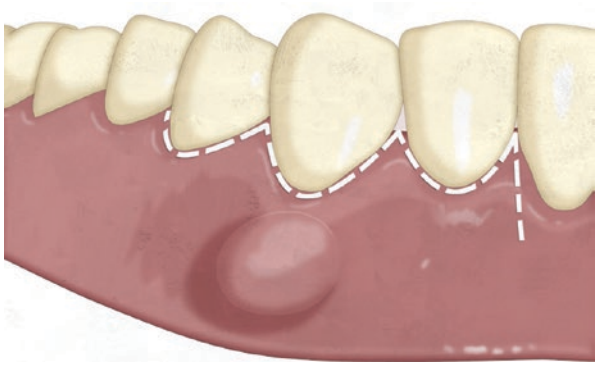

Fig. 16.2 Sulcular incision with small anterior releasing incision (Avoid splitting the papilla at the junction of the release. This diagram has the release too close to the papilla)

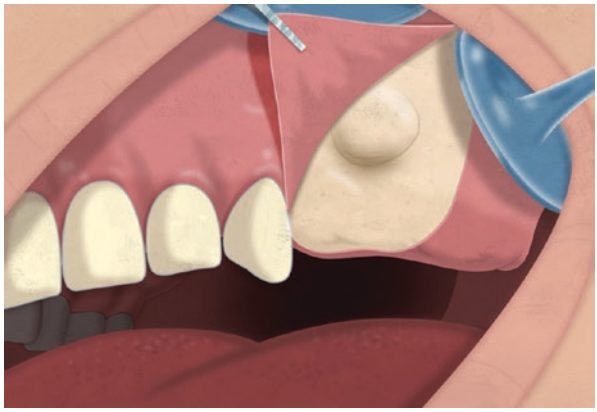

Fig. 16.3 Large posterior relaxing incision in an edentulous area

be used to remove the exostosis/torus. A fissure bur can be used to score the growth, followed by removal by chisel or elevator. With the lingual torus, the fissure bur can be used to create a linear channel into the cancellous region of the bony growth, at the interface of the alveolus and the torus. This linear channel, placed mesial to distal, will allow the placement of a chisel or elevator to chip off/elevate the exostosis. If the exostosis is small, a round bur or bone file can be used to physically reduce and remove the growth, rather than creating the channel. It is important to note that copious sterile saline irrigation is recommended when using rotary instruments to alter bony structures. Excessive heat will create postoperative bone necrosis, increase the risk of infection, and contribute to increased postoperative discomfort for the patient. Once the bony growth is removed, the surgical site should be inspected and palpated to feel for any sharp edges or bony excess. With mandibular tori, the practitioner will frequently need to file a small step at the inferior-most aspect of the wound. One must be very careful to protect adjacent soft tissues when working in this anatomic area, as soft tissue injury here may be very dangerous. Hemorrhage, glandular obstruction, nerve injury, and airway embarrassment are some of the potential complications that could occur with soft tissue injury at the floor of the mouth.

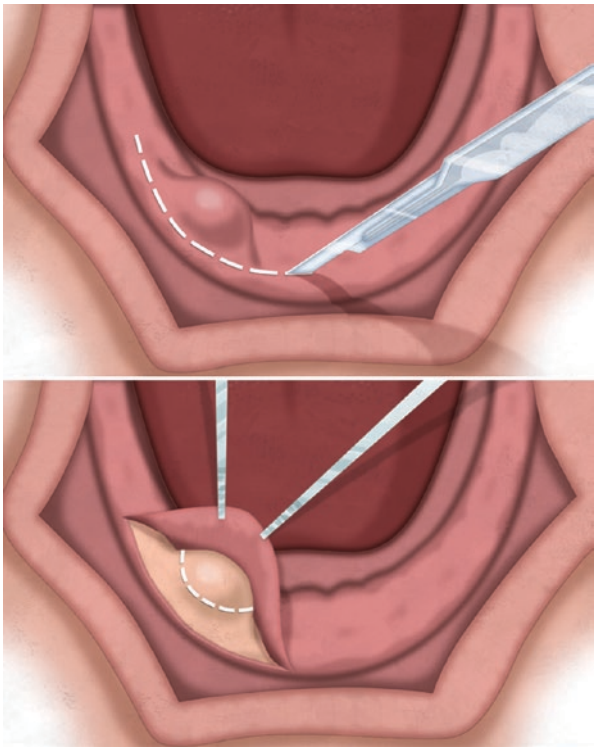

Fig. 16.4 Lingual flap for removal of torus using a crestal incision and no relaxing incisions

As with most bone-related preprosthetic surgery, care should be taken to not over-reduce the bony protuberance. Once the surgery is completed, the underlying bone will continue to undergo some degree of bone resorption and remodeling. One technique for completing bony reduction involves using a bone file: this allows for tactile sensation while smoothing off rough edges and clinically visualizing proper bone reduction. If the majority of a bony prominence is removed via handpiece, the remaining finishing touches can be performed with the bone file.

Primary closure with either silk or resorbable sutures is recommended. Postoperative thermoplastic splint protection is not necessary for these procedures, but fabricating a clear surgical stent as a surgical guide may be helpful.

Removal of exostoses of the maxilla and mandible will create some postoperative discomfort for the patient. This tends to be localized and well-tolerated. Removal of lingual tori tends to be locally painful in the postoperative period and may also cause some discomfort with swallowing. Diet may be more affected with the lingual tori patient, and bruising of the neck, and later dependent bruising discoloration to the chest, will usually be more evident. In light of these postoperative findings, proper preoperative patient teaching will better prepare the patient for a better postoperative recuperation.

16.4 Soft Tissue Removal

Following tooth loss, muscle and frenum attachments may interfere with prosthetic fit, esthetics, and function. It is therefore necessary to carefully evaluate soft tissue interferences prior to fabricating prostheses. It is important to remember, however, that hard tissue remodeling must be performed prior to removal of soft tissue. Soft tissue is often used to aid in grafting and augmentation procedures, so preservation of soft tissue should be attempted when possible.

16.4.1 Frenectomy

Frenum attachments consist of thin mucosa overlying fibrous tissue bands, which extend from the buccal, labial, or lingual mucosa to the alveolar periosteum. Following tooth removal, frenum attachments commonly become more prominent and may interfere with the fit of removable prostheses.

There are multiple techniques available for performing frenotomy, including simple excision and Z-plasty for narrow frenum attachments, and vestibuloplasty for wider frenum attachments.

The following technique describes the surgical removal of the maxillary midline frenum (Fig. 16.5). Other modalities include laser and electrosurgery, which are not discussed in this chapter.

16.4.2 Technique

One must consider the tissue distorting effects of local anesthetics prior to injecting the soft tissue. Regional anesthesia has the benefit of avoiding tissue distortion at the site of excision. However, local infiltration affords the benefit of hemostasis. When administering local anesthesia via infiltration, gentle direct pressure with gauze should be placed on the frenum and lip for several minutes so as to help dissipate the soft tissue distortion. The upper lip is then everted to allow for

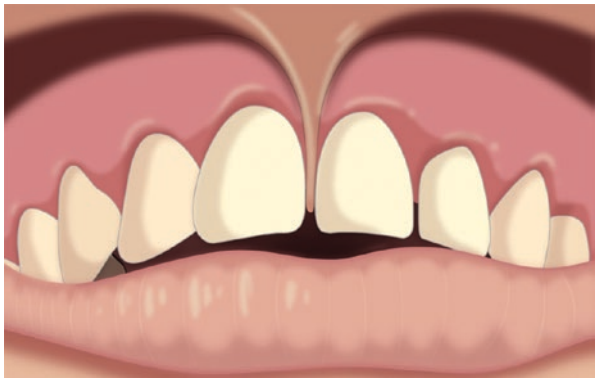

Fig. 16.5 Maxillary midline frenum

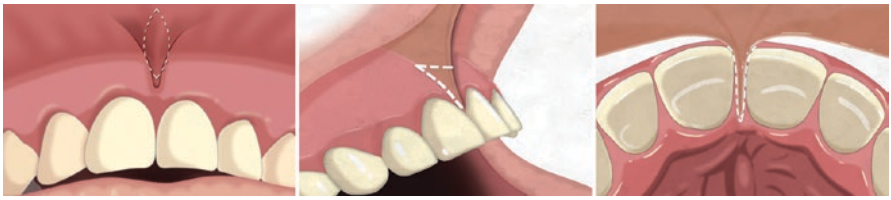

Fig. 16.6 Remove triangular wedge from the maxillary frenum

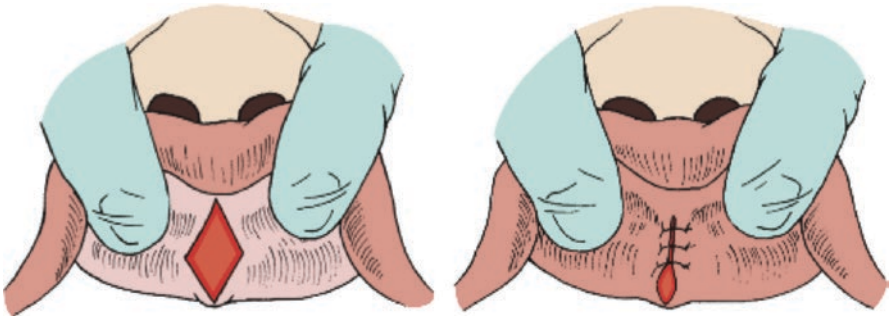

Fig. 16.7 After removal of tissue from the maxillary frenum, with underlying periosteum. Closure with simple interrupted sutures. With permission: Hupp JR, et al. "Preprosthetic Surgery." Contemporary Oral and Maxillofacial Surgery, 5th ed., Mosby Elsevier, 2008

adequate visualization. A hemostat can be used to hold tension on the frenum, while an elliptical incision is made around the frenum in a supraperiosteal fashion. Sharp dissection is then performed, ensuring that the underlying mucosa and connective are removed, while preserving the periosteum (Fig. 16.6). Upon removing the hemostat with the excised frenum still engaged, one will notice a triangular- or diamond-shaped wound, as the elastic fibers will pull the mucosal edges apart. At this time, the wound edges should be inspected to determine if adequate soft tissue has been removed. If there is a superior edge of puckered frenum mucosa, this triangular tissue can be excised with a scissor. Occasionally, dense, fibrous, mucosal tissue will be remaining at the alveolar ridge. This soft tissue will also require excision, noting that it is removed while leaving the underlying periosteum intact on the alveolar ridge. The incisive papilla should not be involved in the palatal-most extent of the dissection.

Following complete dissection of the frenum and underlying connective tissue, there are two methods of achieving primary closure. If wound edges are approximated and vestibular depth is adequate, simple closure can be performed with resorbable sutures in an interrupted fashion (Fig. 16.7). It is important to note that the sutures should encounter the periosteum in order to preserve alveolar ridge height and anatomy Hupp et al. (2008).

If there is concern for shallow vestibular depth, Z-plasty can be performed. Two releasing incisions are made: one from the superior-most point of the wound, angled

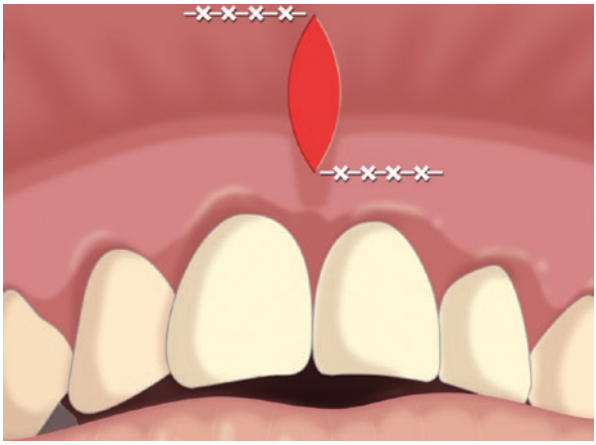

Fig. 16.8 Horizontal releasing incisions for Z-plasty in labial frenum repair

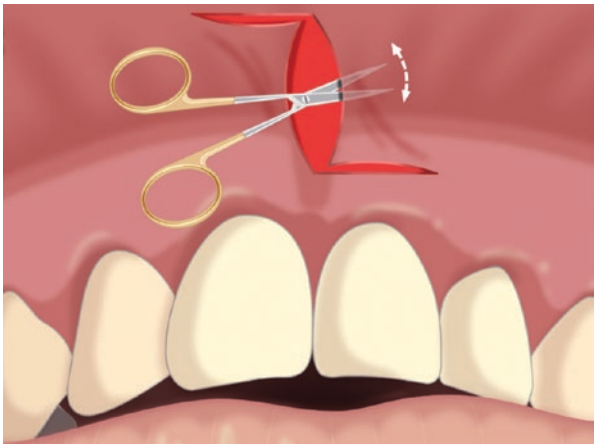

Fig. 16.9 The mucosa underlying the flap margins is freed to relieve tension

laterally and inferiorly, and the other from the inferior-most point of the wound, angled in the opposite lateral direction and superiorly (Fig. 16.8). The mucosa under each side of the flap should be freed with either sharp scissors or a periosteal elevator to relieve tension on the flaps (Fig. 16.9). The resulting two flaps are then rotated, creating a Z-shape, which allows for horizontal closure of the vertical wound (Fig. 16.10).

Localized vestibuloplasty can be performed for broad-based frenum attachments. An incision is made along the superior aspect of the frenum attachment, and dissection is made to expose the underlying periosteum. The mucosa is then repositioned more apically and sutured to the underlying periosteum. Healing occurs via secondary intention.

Lingual frenum attachments are unique in that they may interfere with speech or tongue range of motion. Like labial frenum attachments, they often interfere with denture stability. Local anesthesia for a lingual frenectomy can be achieved through bilateral lingual nerve blocks and local infiltration. The tongue can be retracted

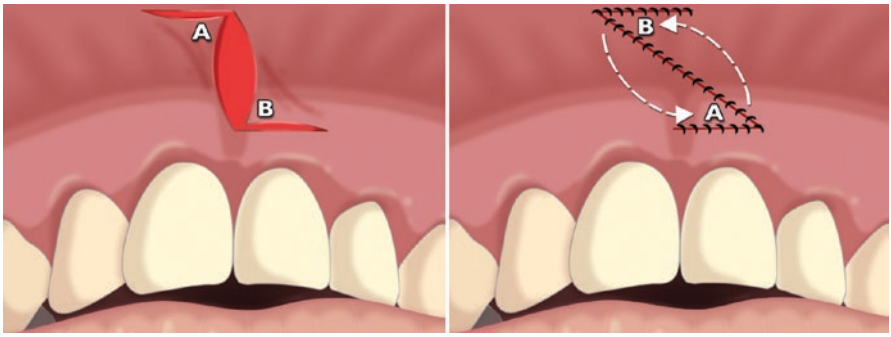

Fig. 16.10 Incision following a labial frenectomy with horizontal releasing incisions, prior to closure. The flap margins (marked A and B) are rotated inferiorly and superiorly, respectively, closing the soft tissue. The resulting Z-shaped incision can then be closed primarily with sutures

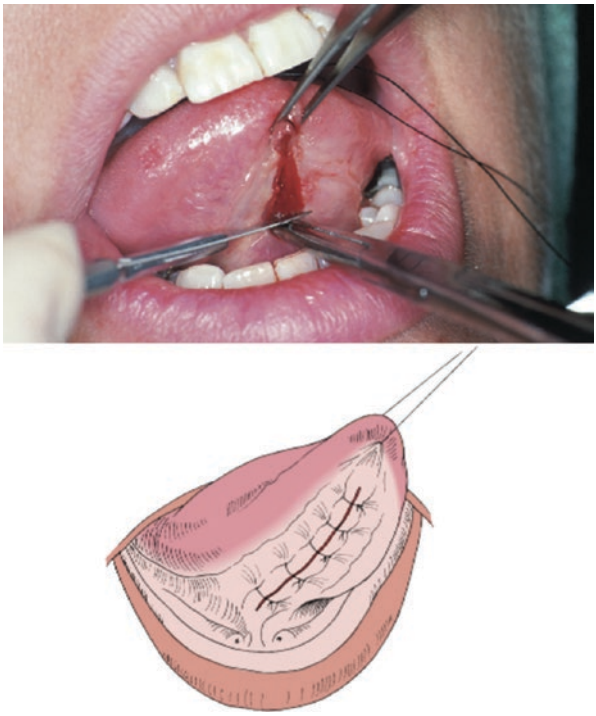

Fig. 16.11 Incision of lingual frenum attachment with scalpel blade, followed by closure with simple interrupted sutures. With permission: Hupp JR, et al. "Preprosthetic Surgery." Contemporary Oral and Maxillofacial Surgery, fifth ed., Mosby Elsevier, 2008

either via a suture through the tip of the tongue or by manual retraction with gauze. A linear incision is then made transversely through the frenum at the base of the tongue, releasing the connective tissue attachments. Closure is performed in a linear direction, thereby releasing the ventral aspect of the tongue from the alveolar ridge Hupp et al. (2008). Care must be taken to avoid Wharton's ducts and superficial vessels on the floor of the mouth (Fig. 16.11).

The patient should be instructed to maintain a soft diet for several days to minimize strain on the wound and also should be advised that some swelling will be noticeable for a few days. Ice packs in the postoperative period will aid in patient comfort and may decrease swelling.

16.4.3 Soft Tissue Tuberosity of the Maxilla

Tuberosity reduction tends to be more often a soft tissue procedure than a hard tissue endeavor. Preoperative radiographic evaluation will assist in initial treatment planning. A quality panoramic radiograph may be sufficient to evaluate the soft and hard tissue in the area of surgery. Mounted models of the maxilla and mandible are invaluable planning aids for tuberosity reduction, both for hard and soft tissue surgery. The goal is to achieve adequate interarch distance between the maxillary and mandibular denture, while not reducing the entire tuberosity.

The mounted models can be manipulated so as to reduce the tuberosity on stone via model surgery. The altered model of the maxilla can then be used to create a clear thermoplastic surgical guide to assist the surgeon intraoperatively. This will guide the surgeon with appropriate reduction of the tuberosity.

The objective of the soft tissue surgery is to decrease the occlusal height of the tuberosity without disrupting the distal hamular notch region. It is important to preserve landmarks that make up part of the denture borders. An elliptical incision is made in the fibrous tuberosity, starting just anterior to the hamular notch (not involving the notch). The incisions are extended anteriorly in an elliptical shape, meeting at a point on the center of the alveolar ridge just anterior to the area of the intended reduction (Fig. 16.12). It is important that the initial incision is full thickness. In order to achieve optimal wound approximation and minimize soft tissue injury, it is prudent to aim the

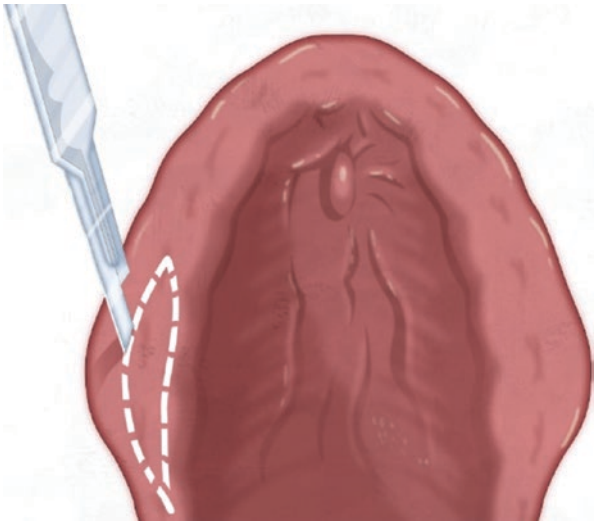

Fig. 16.12 Elliptical incision over the alveolar ridge for soft tissue tuberosity reduction

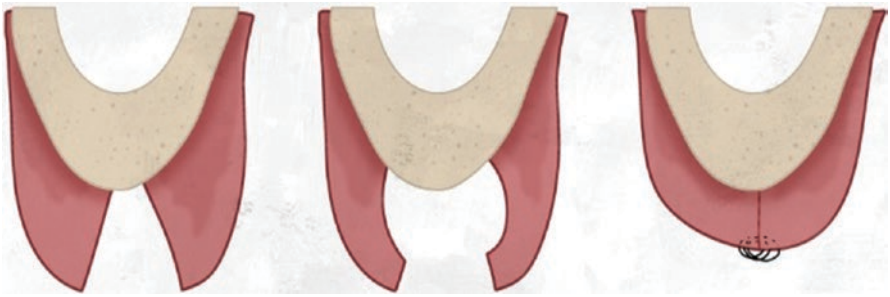

Fig. 16.13 Undermining of the soft tissue following tissue removal to facilitate wound edge approximation. Closure with simple interrupted sutures

scalpel with a slight bevel toward the center of the alveolar ridge. Once the elliptical incision is completed, a periosteal elevator or curette is used to free the underlying periosteum of the elliptical wedge and remove the wedge. Once the wedge is removed, the wound is inspected for any soft tissue tears or fragments. A periosteal elevator is then used to undermine the periosteum bordering the wedge defect so as to mobilize soft tissue. This will aid in bringing wound edges together. The wound edges are suture closed, and the interocclusal clearance is then inspected (Fig. 16.13). A surgical stent/guide would be used at this time to evaluate amount of reduction. In some instances, the practitioner will find adequate reduction but will be unable to get complete primary closure of the wound edges. The edges should be sutured as close as possible to each other without tension on the edges. This will granulate and close with time.

16.4.4 Complications

Potential complications of soft tissue tuberosity reduction include perforation of palatine vessels and oral-antral communication. Palatine vessels can be avoided by keeping the incision within the tuberosity and beveling the scalpel toward the center of the alveolar ridge. This will also help keep the shape of the tuberosity, a vital landmark in denture fabrication. If excessive pressure or aggressive reduction takes place on the underlying alveolar bone, it is possible to perforate the bone and expose the maxillary sinus. This iatrogenic oral-antral communication may require further treatment.

16.5 Conclusion

Preprosthetic surgery is a service that the general dentist can provide to their patients to facilitate the transition to removable and/or fixed prostheses. Reduction of both hard and soft tissues can be performed in the office setting and, when appropriate, can minimize trips to other providers for additional procedures. It is essential to appreciate the patient's medical and dental history, utilize appropriate imaging, and consider the use of preoperative models for predictable surgical planning.

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Soft Tissue Oral Pathology

17

Easwar Natarajan and Michael T. Goupil

"We balance probabilities and choose the most likely. It is the scientific use of the imagination."
Sherlock Holmes in—The Hound of the Baskervilles

Abstract

Once a complete oral exam has been completed, coupled with an appropriate patient history, then a systematic approach should be utilized to develop a differential diagnosis for any abnormalities noted during the exam. This chapter provides a framework to obtain a focus patient history, accomplish an appropriate oral examination, and develop a differential diagnosis and recommendations for the management of specific entities using simple algorithms.

17.1 Introduction

Diagnostic science relies on the ability of the practitioner to obtain a detailed focus history and to accurately describe the oral pathologic condition of concern. This history and clinical examination must include both positive and negative findings. Once the complete history and examination have been obtained, and then and only then, a differential diagnosis is developed and a provisional diagnosis made.

This purpose of this chapter is to provide a systematic method to obtain a complete focused history and a descriptive framework that will allow the clinician to develop a system-based differential diagnosis. This systematic method will be demonstrated

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in the oral pathologic conditions most likely to be encountered by the general dental practitioner. Once a provisional diagnosis is made, further laboratory tests, including some form of biopsy, may be required to confirm the diagnosis. Appropriate directed care can only be provided when a definitive diagnosis is obtained.

17.2 Focused History

Time Line—A focused history should be obtained in the form of chronological events related to the present pathological condition of concern. When was the condition first noted? Was there an obvious cause at the time? What is the growth rate? Unfortunately, the patient is frequently unaware of the condition until it has been identified by the dental provider and thus may only be able to provide limited historical data.

Medical History—Both current and past medical histories including medications that may be relative. Certain medications may produce allergic-type reactions and mucosal alteration. A variety of chronic diseases, especially dermatologic conditions such as lichen planus, have oral manifestations. A review of systems is an excellent way to ensure that all pertinent medical information has been collected (see Chap. 3).

Habits—The use of alcohol and tobacco products is an obvious question as part of the focused history, and this information can be easily obtained through a questionnaire. But questions concerning hobbies, holding objects in the mouth, chewing on pencils, etc. can be equally as important.

Related Information—If the patient has been aware of the condition, then more specific information can be obtained. What makes it better? Worse? Has it changed over time? What treatments have been attempted including complementary and alternative medicine? Have any dental procedures been performed prior to the onset of the current problem?

17.3 Focused Examination

General—When conducting an examination, keep in mind that the findings will need to be recorded in the patient record, and these findings will need to be communicated as part of a consultation referral. The description should convey a description so complete that the reader should be able to mentally visualize the pathologic condition. Taking photographs is another excellent way of accurately documenting an area of concern. Most mobile phones can be used for this purpose.

Location—It is very important to be very specific as to the location of the condition of interest. White lesions on the floor of the mouth may be of greater significance than those along the occlusal line. Multifocal bilateral mucosal alterations may be suggestive of an autoimmune process or merely a patient-specific normal variation. The location of the lesion is an important consideration for performing a biopsy. If the lesion is close to vital structures, i.e., salivary gland duct orifices, it may be prudent to refer the patient to a specialist.

Size—The size of the lesion should be measured. There may be a tendency to over- or underestimate the size of the lesion depending on other characteristics. A periodontal probe is a very convenient way to accomplish this and is usually very readily available.

Texture—Is the lesion flat or raised? Is it rough or smooth? Is the mucosal intact? Ulcerated? Is there a lack of adherence of the mucosa? In the case of a nodule is it firm? Soft? Dough-like? Feel like a water balloon?

Color—Does the lesion have a distinct color change from the surrounding or "normal" mucosa? Red, velvety lesions may carry a higher index of suspicion. Are there color changes noted throughout the oral cavity, and might they represent normal, ethnic variation?

Borders—Are the edges of the lesion very distinct and demarcated from the surrounding normal tissue? Or do the edges merely blend in to more appearing tissue making an accurate measure difficult?

Surrounding Effect—Is the lesion having an effect of surrounding tissue? In the case of bony lesions, are teeth being moved or eroded? Is the body attempting to wall off the pathologic condition? This, walling off, may be represented by a sclerotic border in bony conditions or a firm nodule in the case of soft tissue lesion. Has salivary flow, amount or consistency changed?

Related Information—In the case of white lesions, it is important to note whether the lesion is wipeable or not. Are there radiographs already available that may provide information? In the case of bony lesions, this may have been the first presenting sign. Old radiographs should be obtained and compared to help determine length of duration. Rapidly growing lesions causing tooth destruction are usually of greater concern than slow-growing lesions that move teeth.

17.4 Differential Diagnosis

The development of a differential diagnosis should be done in a systematic and orderly fashion and not merely a list of best guesses. One way to approach this task is to consider potential diagnoses within specific diagnostic groups.

1. Congenital/developmental
2. Reactive/inflammatory
3. Infection
   (a) Bacterial
   (b) Viral
   (c) Fungal
4. Immune mediated
   (a) Localized
   (b) Systemic
5. Neoplastic
6. Oral manifestations of systemic disease

The use of these diagnostic groups should result in a list of the more probable diagnoses that the area of interest might be. This should also help reinforce the fundamentals of oral pathology. The resulting list of diagnoses can then be ranked ordered using information from the history and clinical examination. This rank ordered list can then be used to decide on how to best manage the area of concern. Certain conditions, such as geographic tongue, will not require any management other than informing the patient and reassuring them that nothing needs to be done.

Other conditions, such as an ulcer, may be followed for a brief period of time to see if it heals or may need to be biopsied especially if there is any suspicion of a malignant condition.

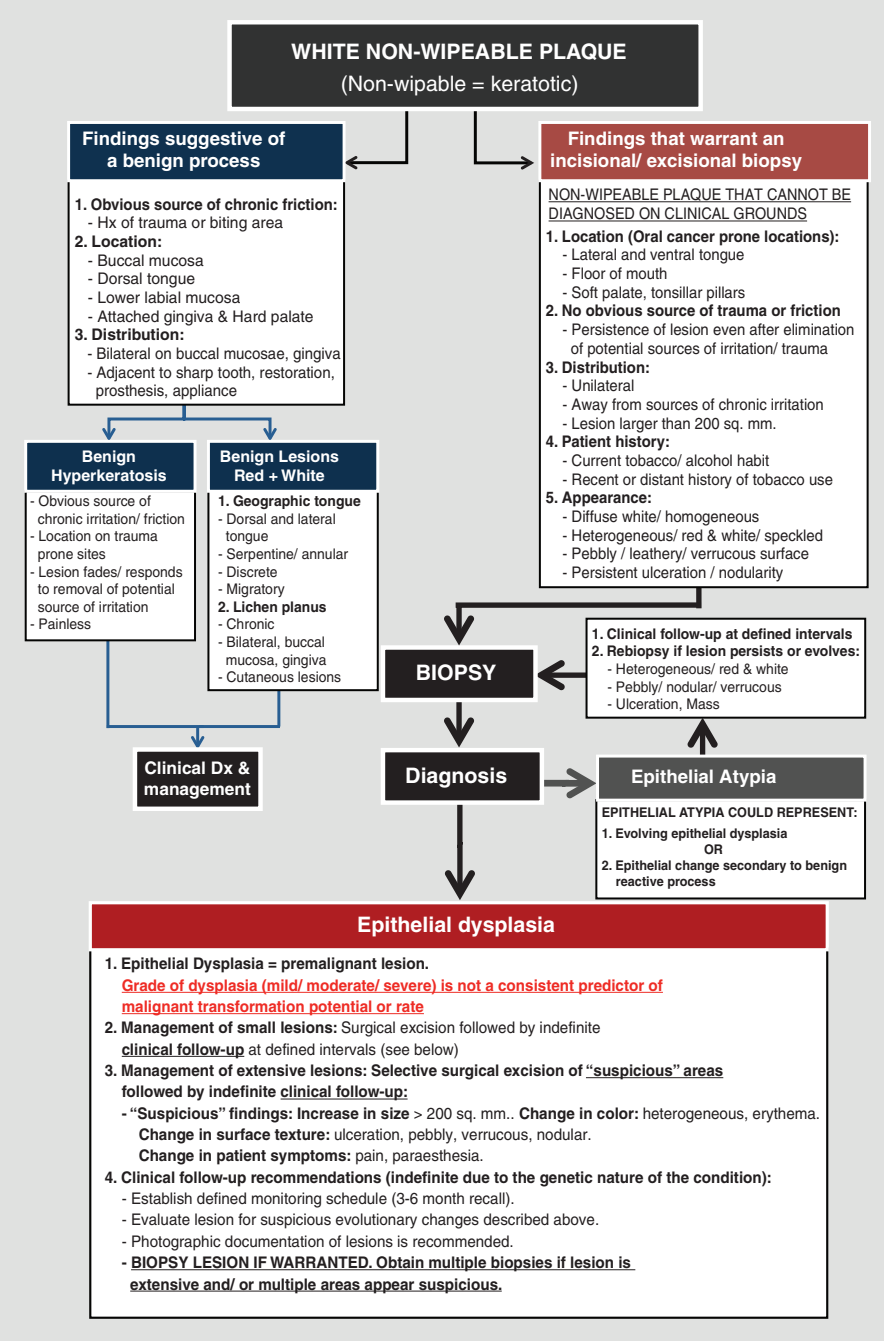
17.5 White Lesions

In daily practice, the discovery of a white oral lesion often raises concern and in many cases can present the clinician with a diagnostic dilemma. Encountering a white lesion may bring a planned dental appointment to a grinding halt. Clinicians are understandably concerned about potential epithelial dysplasia (premalignant change) or oral squamous cell carcinoma. While this concern is justified, the fact is that the vast majority of white lesions that occur on oral mucosal surfaces are benign. The diagnosis of white lesions, or any other oral/extraoral lesion, should always be approached in a disciplined and logical manner. The clinician should gather all relevant data regarding the finding, including history, symptoms, location/distribution, and clinical features, and then proceed to build a differential diagnostic list based on his/her understanding of pathological processes. White lesions, as with all other pathological lesions, can be categorized by pathological process as shown in Table 17.1.

Given that white oral lesions represent a range of pathological processes, it is essential that clinicians approach the diagnostic process in a stepwise manner as it is discussed below and as shown in the accompanying diagnostic flow diagram (Flowchart 17.1).

Table 17.1 White lesions of the oral cavity. Pathological processes and selected examples

1. **Variants of normal/physiological** • Linea alba • Geographic tongue
2. **Reactive** • Frictional/reactive hyperkeratosis • Cheek/tongue chewing (morsicatio) • Ridge keratosis
3. **Infectious diseases** (viral, fungal) • Candidiasis—pseudomembranous, hyperplastic • Oral hairy leukoplakia (EBV)
4. **Immune-mediated conditions** • Lichen planus
5. **Neoplastic** • Benign—verruca vulgaris/squamous papilloma • Premalignant—epithelial dysplasia, actinic cheilitis/actinic keratosis • Malignant—squamous cell carcinoma
6. **Developmental/Genetic** • White sponge nevus • Hereditary benign intraepithelial dyskeratosis



Flowchart 17.1 White non-wipeable plaque. A step-by-step approach to the diagnosis of a clinically indeterminate non-wipeable white plaque

17.5.1 Diagnosis of White Lesions: History of the Presenting Lesion

The diagnostic process must always begin with a patient's presenting complaint and relevant history taking. Most patients who present with white oral lesions are unaware of these findings until they are discovered incidentally, either by themselves or by a healthcare provider at a routine visit: hygienist, dentist, or physician. Lesions that present on the buccal mucosa, dorsal and lateral tongue, labial mucosa, and gingivae are generally discovered by patients as these areas are easily accessible and illuminated. However, white lesions on the ventral tongue, floor of the mouth, retromolar pad, vestibules, and palatal mucosa are discovered by healthcare providers who are able to examine these areas with better illumination and instruments and after having dried these areas appropriately. When a white lesion is reported or discovered, it is essential for clinicians to gather additional data by asking pointed questions to flesh out the history of the presenting complaint as listed below:

1. *Duration*:
   (a) When did you/your provider discover this lesion/lesions?
   (b) How long have you been aware of this lesion?
2. *Discovery*: How did you discover this lesion?
3. *Distribution*:
   (a) Focal/unilateral
   (b) Multifocal—intraoral and/or extraoral sites
4. *Stimuli/triggers*:
   (a) Do you recall a history of trauma?
   (b) Do you have a habit of grinding your teeth/biting your tongue/cheek/lip?
5. *Symptoms*: Do you have pain or discomfort associated with this lesion?
   (a) *Character of symptoms*: persistent/intermittent
   (b) *Quality of symptoms*: intense pain, burning, scales of pain
6. *Progression*:
   (a) Has the lesion grown in size or reduced in size since discovery?
   (b) Has it spread to other oral sites or is it localized?
   (c) Do the lesions move around?
7. *Factors that alleviate symptoms or make the lesions change in character*

17.5.2 Examination: Wipeable and Non-wipeable White Plaques

Oral examination should always be preceded by a thorough neck, extraoral and perioral exam. Intraoral examination should be conducted with appropriate illumination, instruments, and gauze sponges to properly dry oral surfaces. Examination is followed by thorough visualization and palpation of all of the oral surfaces.

A plaque is a lesion that is characterized by a broad, raised thickening of the surface epidermis or mucosa. During examination, if a white plaque is detected, the clinician should attempt to wipe or scrape it away with gauze or a tongue depressor.

If the white plaque is wipeable, it likely comprises surface debris and is not the result of epithelial proliferation, hyperkeratosis, or maturational irregularity. On the other hand, if the white plaque is non-wipeable, it represents an increase in thickness of the oral surface epithelium with or without attendant hyperkeratinization, i.e., epithelial hyperplasia. Non-wipeable white plaques may also represent hyperkeratosis of the surface epithelium resulting increased keratinization (para- or orthokeratinization). In addition to hyperplasia and hyperkeratosis, non-wipeable white plaques may demonstrate epithelial maturational irregularities.

17.5.3 Wipeable White Plaques

Clinicians must always try to wipe or scrape away detected white plaques with a gauze sponge or tongue blade. As a general rule, wipeable white lesions are overwhelmingly suggestive of a benign process. They are generally representative of surface debris. They can include accretions of food debris, fungal microorganisms, desquamated keratin, the fibrinopurulent pseudomembrane that covers an ulcer base, and necrotic tissue resulting from a chemical burn or a collapsed bulla. Scraping away necrotic tissue or debris that covers an ulcer base often causes pain. If possible, any white material that wipes away should be examined under the microscope in order to identify it. The salient features of selected common and clinically significant entities are discussed below:

(a) *Hairy tongue/coated tongue*: Hairy tongue/hairy coated tongue manifests as a thick, hairy/matted white/yellow/pigmented change on the dorsal surface of the tongue. It is characterized by the accumulation of keratin and food debris likely resulting from the elongation of filiform papillae (Fig. 17.1). Although the specific cause of hairy tongue is uncertain, possible factors that result in hairy tongue include oral dryness, poor oral hygiene, lack of filiform clearing in the setting of other painful oral conditions (lack of debridement), aggressive tongue scraping/brushing, or general debilitation. Although hairy tongue does not

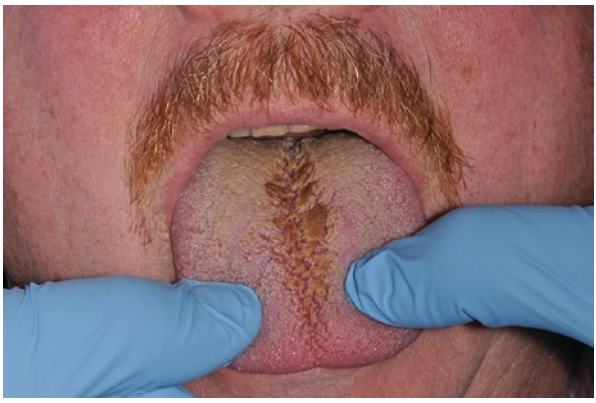


Fig. 17.1 Hairy tongue/coated tongue. A result of filiform papillary hyperplasia often the result of aggressive tongue brushing and not the result of candidal infection

present as a white "plaque," the clinical presentation can be quite striking and alarming to patients. The keratin debris that builds up on the tongue can be wiped or scraped off with a tongue blade or gauze. Patients may complain of a bad taste in the mouth. It is important for clinicians to recognize that this is a benign condition and not the result of oral candidiasis. Proper oral hygiene and addressing the predisposing factors listed above often address this benign clinical finding. No diagnostic tests or biopsies are indicated.

(b) *Pseudomembranous candidiasis* (*thrush*): Candidiasis is an opportunistic fungal infection that can manifest itself on the oral mucosal surfaces of patients with certain predisposing factors (e.g., dry mouth, poor appliance hygiene, anticholinergic use, asthma inhalers, antibiotic use, immunosuppression/depletion, etc.). Clinically, oral candidiasis is characterized by a wide distribution of lesions. Patients may present with the various clinical forms of candidiasis including the erythematous (atrophic) form, angular cheilitis (commissures), hyperplastic (non-wipeable/candidal leukoplakia), and the abovementioned pseudomembranous form simultaneously. It is the pseudomembranous form, commonly referred to as *thrush*, that presents with wipeable curd-like accretions on an atrophic mucosal background (Fig. 17.2). Patients presenting with oral candidiasis are typically asymptomatic or may complain of mild discomfort, and they seldom report pain. Oral candidiasis is typically diagnosed based on a patient's clinical history and presentation. In selected cases lab tests may be required: cytological smears to demonstrate fungal organisms, fungal cultures, or biopsies. Oral candidiasis can be managed with antifungal agents. Additionally, it is essential for clinicians to investigate and address the underlying systemic factors leading to this opportunistic infection.

(c) *Other wipeable white lesions*: Food debris, fibrinopurulent ulcer membranes, and necrotic oral mucosal tissue may also present as wipeable white plaques. In each case, clinical correlation with patient history, symptoms, and oral mucosal findings will enable clinicians to arrive at a diagnosis.

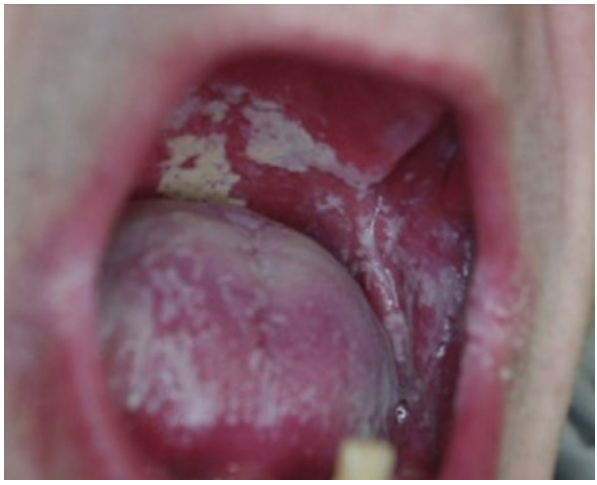


Fig. 17.2 Pseudomembranous candidiasis. Wipeable curd-like white patches on an atrophic, erythematous background. Note the widespread distribution

17.5.4 Non-wipeable White Plaques: Findings Suggestive of a Benign Process

(a) *Benign reactive hyperkeratoses*: White plaques located along oral mucosal sites that are subject to chronic friction or trauma are most likely a result of reactive hyperplasia and hyperkeratosis and are termed *benign reactive hyperkeratosis* (Flowchart 17.1). This is a common benign response to local irritation and is equivalent to calluses seen on palms and soles resulting from chronic friction. Typically, these plaques appear as rough-surfaced, asymptomatic lesions and arise directly opposite the source of friction or irritation. The most common locations include the buccal mucosa, dorsolateral tongue, labial mucosa, gingival mucosae, and hard palate. In most cases, if the presumptive source of irritation is eradicated, then these epithelial changes will resolve within a few weeks. If the irritant persists or reintroduced, the white plaque can return. Regardless, reactive hyperkeratoses are fundamentally benign mucosal lesions; they are not predisposed to malignant transformation. In the oral cavity, benign reactive hyperkeratoses are most commonly seen in the following forms:
   - *Linea alba*: Linea alba or "white line" corresponds to asymptomatic, bilateral linear white plaques seen exclusively on the buccal mucosa along the occlusal plane at the site of dental intercuspation. This white oral finding is extremely common, benign, and is considered a variant of normal (Fig. 17.3). It is a result of physiological hyperplasia and keratosis of the buccal mucosal epithelium in response to daily function and intercuspation. It is widely recognized and requires no further diagnostic testing.
   - *Cheek and tongue chewing/biting (Morsicatio)*: Patients who have a history of chronic cheek and/or tongue chewing/biting or other parafunctional habit that results in chronic friction/irritation of the buccal mucosa and dorsolateral surfaces of the tongue present with bilaterally distributed, painless, diffuse and ill-defined, rough, or shaggy-surfaced white plaques

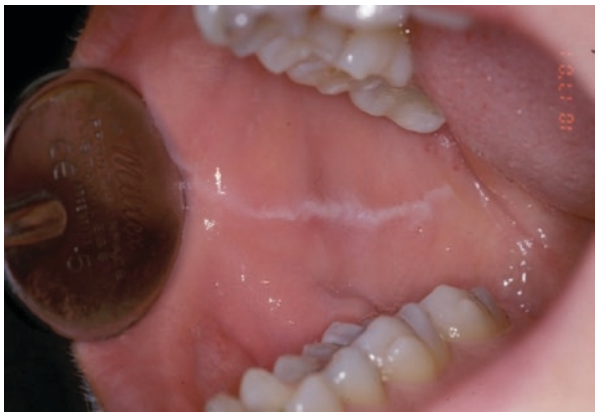


Fig. 17.3 Linea Alba. A common finding noted on the buccal mucosa along the interocclusal plane

(Fig. 17.4a, b). These plaques are typically directly opposite the source of irritation and may extend superiorly or inferiorly depending on the individual patient's chewing habit. Some patients may present with intervening areas of erythema or atrophy that correspond to areas of trauma. In rare instances, focal areas within the plaque corresponding to frayed surface keratin may be wipeable leaving behind intact mucosae. The diagnosis of "Morsicatio" is established based on a patient's history and the typically bilateral distribution of shaggy white plaques on the buccal mucosa and dorsolateral tongue. There is no need for further diagnostic testing, including tissue biopsies.

– *Alveolar ridge/gingival keratosis*: Areas along the attached gingival surfaces, palate, and partially/completely edentulous alveolar ridges that are subject to chronic friction can present with epithelial hyperplasia and hyperkeratosis. Clinically, these lesions appear as asymptomatic non-wipeable white plaques that typically have a corrugated/rough surface texture and correspond to a local/specific source of friction. The most common causes of gingival keratoses include aggressive toothbrushing techniques, appliance clasps, or parafunctional habits, while the most common cause of

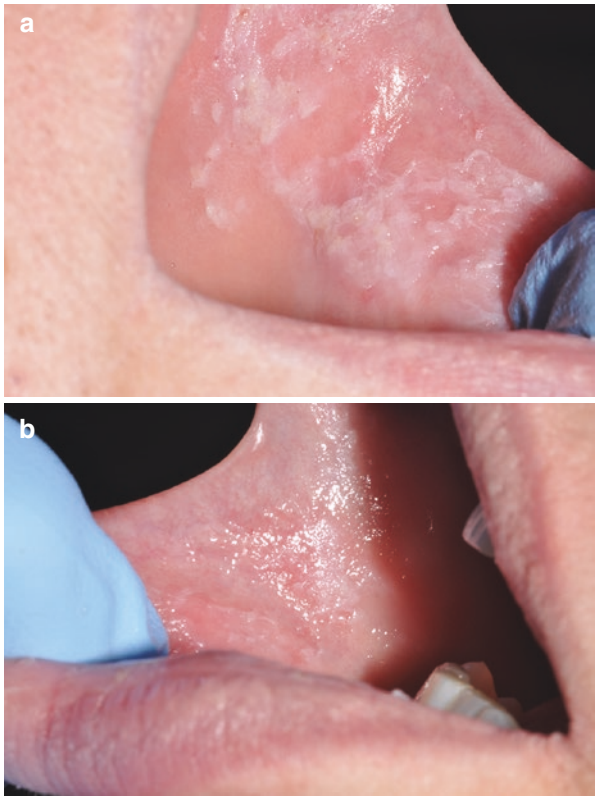


Fig. 17.4 (**a**, **b**) Cheek chewing (morsicatio). Benign reactive hyperkeratosis that is a result of habitual cheek chewing/biting. Note the bilateral distribution with foci of erythema

hyperkeratosis along edentulous alveolar ridges is friction from mastication. The borders of these white lesions can be either discrete or ill-defined. The diagnosis is typically made by correlating patient history, distribution and location of the plaque, and identification of specific irritant. If these lesions do not correspond to a specific physical irritant then a biopsy/ biopsies may be warranted, especially as there is no specific stimulus.

(b) *White and Red Lesions*

– *Erythema migrans/benign migratory glossitis*: This is a benign condition that is typically seen on the tongue (geographic tongue). It is an extremely common finding (1–3% of the population) that is thought to be a variant of normal. The lesions are clinically asymptomatic and are frequently discovered incidentally by the patient or on routine clinical examination. The clinical presentation of erythema migrans/geographic tongue is characterized by multiple, well-demarcated areas of erythema surrounded by serpiginous/annular/scalloping yellow-white linear plaques on the dorsal and lateral borders of the tongue (Fig. 17.5a, b). Erythematous areas on the dorsolateral tongue correspond to areas of filiform papillary atrophy. Geographic tongue often occurs in the background of the fissured tongue. Patients are generally asymptomatic; a few

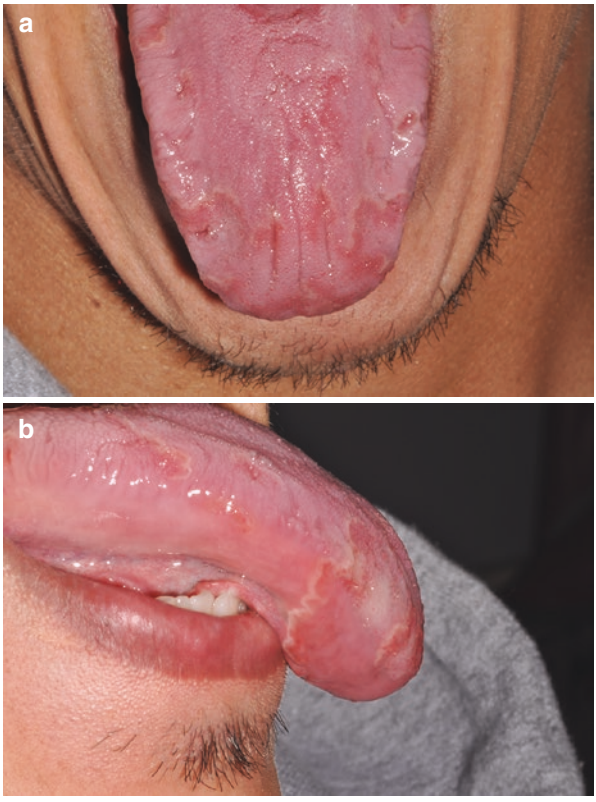


Fig. 17.5 (**a**, **b**) Benign migratory glossitis (geographic tongue). Well demarcated, serpiginous, annular areas of mucosal atrophy rimmed by yellow-white linear mucosal changes with a history of migration. Fissuring of the dorsal-lateral tongue is a common finding in these patients

patients may report sensitivity to hot/spicy foods. In some patients, the lesions of erythema migrans may be seen in other oral sites including the buccal mucosa, ventral tongue, floor of the mouth, and other sites. Although its appearance can be clinically alarming, erythema migrans/geographic tongue should be recognized for what it is—a benign, noninfectious, non-cancerous condition that requires no further management or diagnostic tests.

– *Lichen planus*: Is a benign cell-mediated autoimmune disease characterized by multifocal, symmetrical, papulosquamous dermatosis and mucosal lesions. Lichen planus is the result of a T lymphocyte-mediated cytotoxic destruction of basal keratinocytes that results in compensatory surface hyperkeratosis (Cheng et al. 2016). Clinically, the lesions of classic reticular oral lichen planus are characterized by papules, plaques, and delicate lacy white striations distributed bilaterally within the oral cavity (Fig. 17.6a, b). The buccal mucosa is affected in >80–90% of patients followed by the gingiva, tongue, and lip surfaces (mucosa and vermilion). Patients with the reticular form of lichen planus are generally asymptomatic. Patients may present with intervening areas of erythema and erosion in areas where cytotoxic basal cell destruction has not been sufficiently compensated with surface hyperkeratosis. Patients

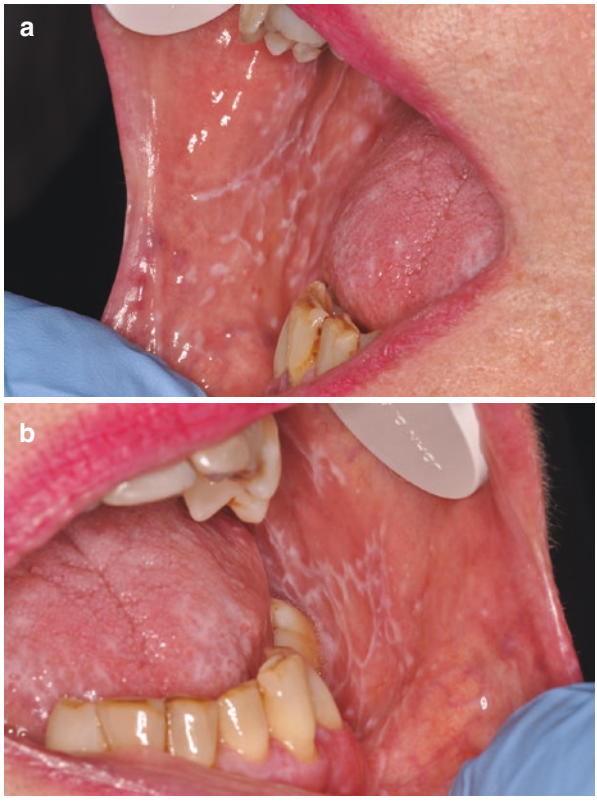


Fig. 17.6 (**a**, **b**) Oral lichen planus. Classic bilateral, multifocal distribution of reticular white striations with intervening areas of erythema. This patient was asymptomatic given the lack of erosions/ulceration

with erosive lichen planus may present with symptoms of sensitivity and/or pain. The diagnosis of lichen planus and lichenoid stomatitis should be made ONLY if specific *clinical* (i.e., multifocality, symmetric distribution of cutaneous/mucosal lesions) and *microscopic* criteria (i.e., normal epithelial maturation, basal cell liquefaction, lymphocytic infiltration of the stroma) are satisfied (Cheng et al. 2016). Lesions that appear red and white and clinically lichenoid that are unilateral or in cancer-prone locations (ventral tongue, floor of the mouth, lateral tongue, soft palate, etc.) must be biopsied to rule out epithelial maturational irregularities.

17.5.5 Non-wipeable White Plaques: Findings That Warrant Biopsy/Biopsies

Before the emergence of an oral squamous cell carcinoma (oral cancer; malignant neoplasm of oral squamous epithelium), clinically visible precancerous oral mucosal surface changes precede the appearance of a tumor (Fig. 17.7). These findings present as white non-wipeable plaques and are often the first signs of cancer development (Natarajan and Eisenberg 2011). Given that the oral mucosal surfaces are readily accessible to exam and visualization, clinicians can detect these lesions during a thorough oral examination. *White non-wipeable plaques that meet one or more of the following criteria must be biopsied*:

1. *White plaques in oral locations that are relatively protected from friction or trauma*—floor of the mouth, lingual mandibular vestibules, ventral-lateral tongue, soft palate, uvula, and tonsillar pillars. These locations are referred to as the oral cancer-prone locations (Natarajan and Eisenberg 2011).
2. *White plaques for which there is no identifiable inciting agent* and for which a presumptive clinical diagnosis cannot be made with confidence (i.e., no obvious inciting agent, no history of trauma, no features characteristic of other specific keratotic diseases).

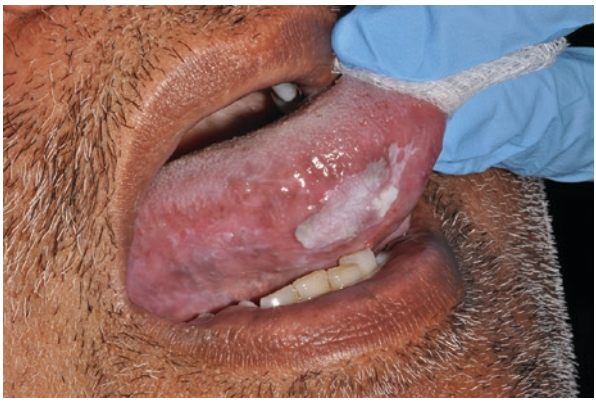


Fig. 17.7 Non-wipeable white plaque that warrants multiple biopsies. A large white plaque on the right ventral tongue. Note the leathery surface texture on the anterior portion and the diffuse milky white surface changes extending to the posterior ventral tongue

3. *White plaques in trauma protected locations that are unilateral* and *are larger than 200 sq. mm*. Large lesions (200 sq. mm. or more) require multiple biopsies (Natarajan and Eisenberg 2011; Holmstrup et al 2006; Arduino 2009; Ho et al. 2012; Ho et al. 2013).
4. *White plaques in patients with a current or past history of tobacco use* (smoking/smokeless) or heavy alcohol use. Plaques in patients with a distant history of smoking must not be dismissed and should be evaluated similarly.
5. *White plaques with the following surface changes must be regarded with suspicion* and biopsies obtained—diffuse borders, heterogenous (red + white)/speckled surface changes, pebbly/leathery/verrucous surface changes, and areas of ulceration/nodularity/induration (Natarajan and Eisenberg 2011; Holmstrup et al 2006; Arduino 2009; Ho et al. 2012; Ho et al. 2013).
6. *White plaques with surface nodularity/ulceration/erythema accompanied by patient symptoms of pain/paresthesia or bleeding must be biopsied* (Natarajan and Eisenberg 2011).

Full thickness tissue biopsies of non-wipeable white plaques are required to establish a definitive biopsy. Only an incisional (scalpel) or punch biopsy will permit proper evaluation of the full thickness of the epithelium and its relationship to the underlying connective tissue. While a majority of the clinically indeterminate white lesions demonstrate benign features on biopsy, a small but significant subset of white lesions that demonstrate one or more of the above clinical characteristics demonstrate histopathological evidence of epithelial maturational disturbance (epithelial atypia/epithelial dysplasia) or squamous cell carcinoma.

(a) *Squamous cell carcinoma*: Oral squamous cell carcinoma is a malignant neoplasm arising from the oral mucosal lining. It is a disease of protracted genetic deregulation within the stratified squamous epithelial cells of the oral cavity. While these mutations typically occur in the setting of genetic predisposition, it is well known that this deregulatory process can be accelerated by chemical carcinogens (risk factors), primarily smoking tobacco. The resulting genetic mutations cause an uncoordinated and unregulated proliferation of squamous cells. This cellular proliferation and maturational disturbance causes epithelial thickening and manifests clinically as a white, non-wipeable mucosal plaque defining the evolutionary process of epithelial dysplasia during carcinogenesis. The altered epithelial cells acquire additional mutations and eventually alter the homeostatic equilibrium between the epithelium, the basement membrane, and the underlying stromal tissue. Genetically "rogue" epithelial cells acquire the ability to breach the basement membrane and infiltrate the underlying stromal tissue—this violation of natural tissue barriers manifests itself clinically as an irregular, ulcerated, indurated, red, and white mass and defines a squamous cell carcinoma (Natarajan and Eisenberg 2011). For the clinician, it is important to understand that the cumulative mutations leading to oral cancer affect all epithelial cells within a field within the oral cavity—this accounts for the known risk for recurrence of oral cancer but also accounts for new primary tumors elsewhere within the oral cavity.

Classically, oral squamous cell carcinomas present as ulcerated, white, and red masses (Fig. 17.8) usually with a variegated surface appearance (i.e., corrugation, verrucous, speckled, lobulated, pebbly) on classic cancer-prone locations (e.g., floor of the mouth, ventral-lateral tongue, soft palate, etc.). The tumors are typically indurated (hard) on palpation and tend to tether down the affected tissues. Patients may report being aware of the tumor growing over weeks to months and may report symptoms of pain and paresthesia. Tumor infiltration of the surrounding jawbones may result in bone destruction and manifest as tooth mobility. The ulcerated tumor masses are frequently surrounded by non-wipeable white plaques that exhibit microscopically diagnosable epithelial dysplasia. This is consistent with the genetically devolutionary process of carcinogenesis (Natarajan and Eisenberg 2011). When clinicians discover a non-wipeable white plaque in an oral cancer-prone location, it is important for them to recognize and characterize the surface changes (e.g., ulceration, variegation, pebbly texture) and lesion characteristics (e.g., nodularity, induration, mass lesion) that make it suspicious for squamous cell carcinoma (see Flowchart 17.1). It is essential that any lesion that exhibits the above characteristics be biopsied (multiple biopsies if necessary) and submitted for histopathological examination.

Patients diagnosed with oral squamous cell carcinoma should be referred to an appropriate specialist for further staging and appropriate management.

(b) *Epithelial dysplasia*: Epithelial dysplasia is a potentially malignant (premalignant/precancerous) mucosal lesion that usually precedes the emergence of oral squamous cell carcinoma. Epithelial dysplasia typically presents clinically at a relatively late stage in the evolutionary process of carcinogenesis and is representative of the protracted accumulation of genetic defects within the oral squamous epithelium (Natarajan and Eisenberg 2011). As described above, the unregulated epithelial proliferation in oral mucosal fields susceptible to chemical carcinogens manifests itself as a non-wipeable white plaque on oral cancer-prone mucosal surfaces (Fig. 17.9). These mucosal alterations are often described using the clinical descriptor "leukoplakia." It is important for clinicians to understand that not all lesions described as "leukoplakia" exhibit

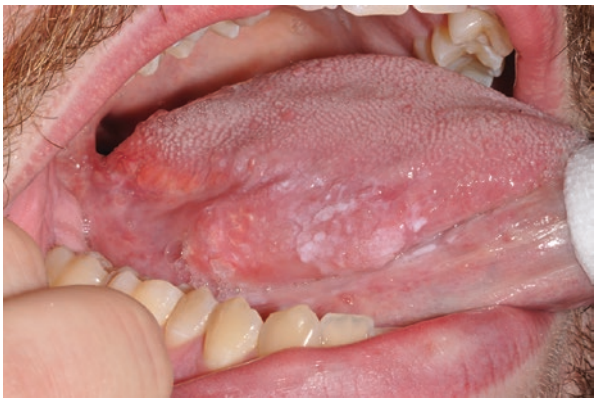


Fig. 17.8 Oral squamous cell carcinoma. A heterogeneous ulcerated mucosal mass on the posterior ventral tongue. Note the location, surface irregularity and the white leathery non-wipeable plaque anterior to the mass

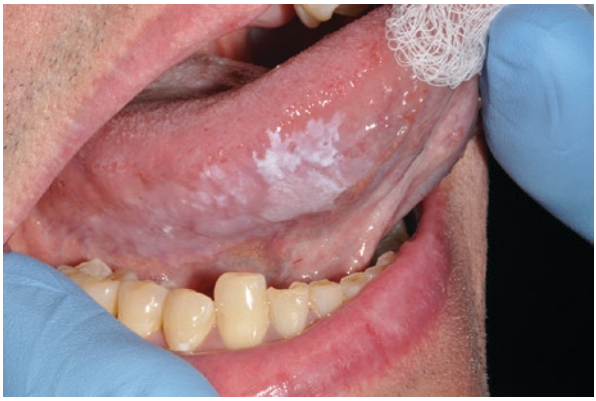


Fig. 17.9 Epithelial dysplasia, clinical features. A large white plaque on the right ventral tongue. The anterior portion of the lesion is milky white with a leathery surface quality. The posterior portion extent of the lesion on the ventral tongue is diffuse and indescernable

features diagnostic for epithelial dysplasia, i.e., "leukoplakia" is not synonymous with epithelial dysplasia (Natarajan and Eisenberg 2011). Epithelial dysplasia as a diagnosis refers to a composite of architectural, maturational, and cytomorphological changes noted in biopsies of clinically detected white plaques. Pathologists require a specimen that captures the full thickness of the epithelium and some underlying connective tissue to arrive at this diagnosis; detection of cytological abnormalities by themselves is not sufficient to make this diagnosis. By definition, lesions diagnosed with epithelial dysplasia exhibit maturational irregularities confined within the stratified squamous epithelium and above the basement membrane (i.e., there is no infiltration beyond the basement membrane). Pathologists grade oral dysplastic lesions as being mild (subtle basal cell changes), moderate, severe, or carcinoma in situ (top-bottom epithelial change) based on the extent of maturational abnormality as it presents from the basal cell layer to the surface of the oral epithelium. Grading oral epithelial dysplasia enables pathologists to categorize lesions by degree of microscopic severity. However, it is important for clinicians to understand multiple studies have demonstrated that the grade of microscopic dysplasia does not necessarily predict or correlate with the likelihood of progression to squamous cell carcinoma (Holmstrup et al 2006; Arduino 2009; Ho et al. 2012; Ho et al. 2013; Arnaoutakis et al. 2013; Mehanna et al. 2009). It is important to understand that microscopic findings do not provide objective information on the specific genetic defects harbored by cells within the dysplastic epithelium, nor does it predict its stage in carcinogenic evolution. Irrespective of degree, it is important for clinicians to recognize the significance of epithelial dysplasia. A diagnosis of epithelial dysplasia constitutes a risk for progression to squamous cell carcinoma. Patients diagnosed with epithelial dysplasia must be appropriately educated about the genetic basis of the disease and must be monitored/managed in an ongoing, indefinite manner.

(c) *Epithelial atypia*: Epithelial atypia is a term used by pathologists to describe deviations from normal observed in epithelial architecture or cytomorphology that indicate disturbances in epithelial maturation (Flowchart 17.1). In comparison to epithelial dysplasia which is clearly precancerous, the findings seen in epithelial atypia do not meet all the criteria for epithelial dysplasia (Natarajan

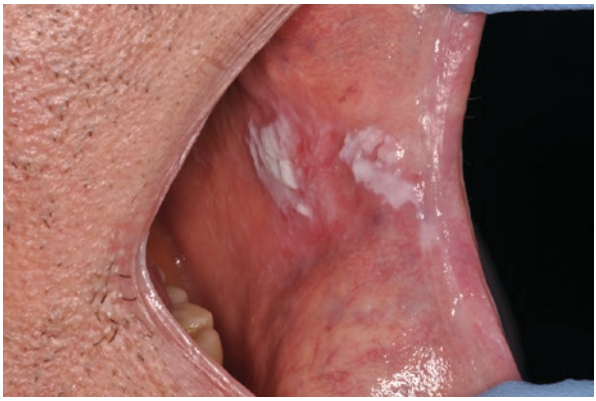


Fig. 17.10 Non-wipeable white plaque, epithelial atypia. Large white plaque on the left buccal mucosa with intervening area of pebbly erythema/erosion. The plaque exhibits a verrucous texture. Given the patient's smoking history, multiple biopsies were obtained revealing epithelial atypia and recommendation for continued monitoring

and Eisenberg 2011). The maturational disturbances of epithelial proliferation, architecture, and differentiation may represent unusual epithelial responses to local inflammatory or physical insults (chronic friction) and infectious or other unspecified stimulus. For instance, the margins of healing ulcers or epithelial tissues with candidal infection can demonstrate significant epithelial atypia. It is important for clinicians to recognize that in some instances, epithelial atypia may be seen in an evolving dysplastic lesion. Given that there are no predictive genetic biomarkers to distinguish between "benign" atypias and "evolving precancerous" atypias, the pathologist uses the term atypia to alert the clinician about microscopic findings that are deviant from normal epithelium. When pathologists diagnose a non-wipeable plaque as "epithelial atypia," they typically include a comment that alerts the clinician to the diagnosis, recommending further clinical correlation (rule out local reactive/inflammatory factors) and continued monitoring of the lesion (Fig. 17.10). Clinical follow-up of atypical lesions is mandatory. On follow-up examination visits, any clinical evidence of persistence, increase in the size of the lesion, progressive heterogeneity in surface character (pebbly change, corrugation, ulceration, erythema, nodularity, change in symptoms), or evolution of the lesion should trigger a biopsy (see Flowchart 17.1).

(d) Management of patients diagnosed with epithelial dysplasia:

- Patient education: Patients diagnosed with epithelial dysplasia, irrespective of histopathological grade, must be educated about the potentially cancerous nature of the lesion and about the underlying acquired genetic deregulatory basis of the disease. From the outset, and given the lack of genetic biomarkers that predict progression to squamous cell carcinoma, clinicians must strongly emphasize the need for continued clinical follow-up at regular intervals (Natarajan and Eisenberg 2011; Smith et al. 2009). Patients must also be educated about the "field effect" of genetic change that is likely present in normal-appearing oral mucosal tissues that surround the clinically detectable white plaque. Patients may be offered surgical management options including excision of visible lesions. However, clinicians must advise patients that excision of all clinically abnormal tissue will neither eliminate nor predictably "cure" a disease characterized by underlying

genetic deregulation further emphasizing the need for ongoing clinical vigilance (Holmstrup et al 2006; Ho et al. 2012; Ho et al. 2013; Arnaoutakis et al. 2013; Mehanna et al. 2009; Warnakulasuriya et al. 2008; Field et al. 2015).

- Surgical management (see Flowchart 17.1): Complete surgical excision is recommended for small dysplastic lesions measuring <200 sq. mm. in area followed by clinical follow-up at defined 3–6 months of intervals. For large and extensive dysplastic lesions measuring >200 sq. mm., multiple biopsies are recommended from the outset. Complete surgical excision of all clinically visible areas in extensive dysplastic lesions can pose a surgical and clinical challenge. In these patients, clinicians may elect to follow a conservative and selective approach. One recommendation based on findings in the literature includes complete surgical excision of clinically "suspicious" areas followed by indefinite follow-up (Holmstrup et al 2006; Ho et al. 2012; Ho et al. 2013; Smith et al. 2009; Field et al. 2015). *Clinically "suspicious" findings that warrant full surgical excision include areas within a white plaque that exhibit the following features*:
  - *Increase in size* > 200 sq. mm. between clinical visits.
  - *Color*—erythema, variegation of color, change in color between visits.
  - *Surface texture*—pebbly (red + white), verrucous, nodular, ulceration, induration (palpation), or changes between visits.
  - *Patient symptoms*—discomfort, pain, paresthesia, increase in size.
- Clinical follow-up recommendations: Ongoing and indefinite clinical follow-up must be emphasized at every patient visit given the genetic basis of epithelial dysplasia and squamous cell carcinoma (Natarajan and Eisenberg 2011). Patients diagnosed with epithelial dysplasia must be monitored following a defined schedule (every 3–6 months)—a general dentist can examine these patients along with their hygiene team every 6 months. At these visits, it is important to evaluate the lesion for the presence/absence of the clinically suspicious findings described above. Photographic documentation of the lesion, original biopsy site, and the surrounding tissues is strongly recommended (Natarajan and Eisenberg 2011; Field et al. 2015; Kanatas et al. 2011). If a clinically suspicious finding is detected at these monitoring visits, selective biopsies/re-biopsies are recommended. If multiple evolutionary changes are noted, then multiple biopsies are recommended.

17.6 Oral Ulcers

Oral ulcerative conditions are common. Patients suffering from oral ulcers present with much pain, discomfort, and functional compromise. On initial presentation, oral ulcers resulting from a wide array of pathological conditions can look alike and pose a clinical diagnostic challenge. Regardless of pathological process, number, distribution, or size of the ulcers, patients who suffer from these lesions experience significant pain and are understandably concerned. Fortunately, the majority of oral

ulcerative conditions, solitary or otherwise, are benign and can be diagnosed using specific criteria.

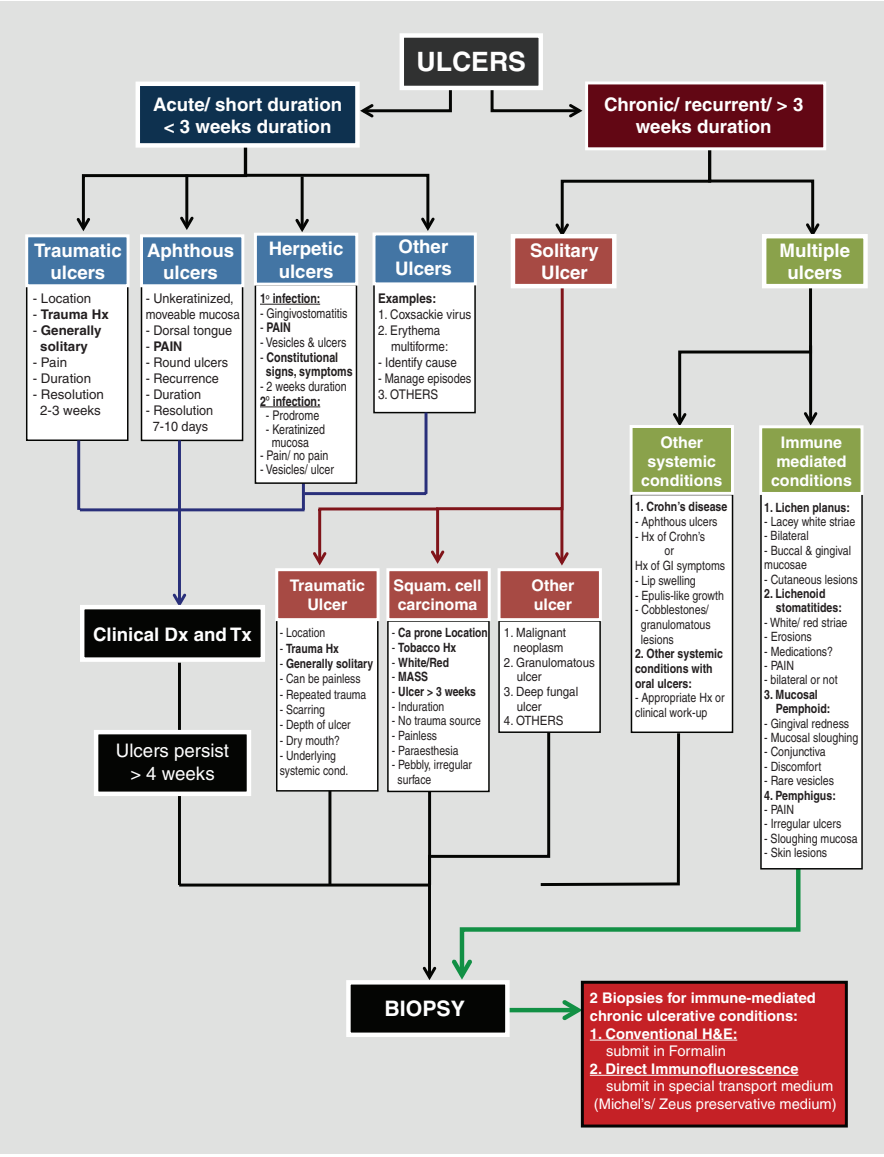
17.6.1 Oral Ulcerative Lesions: The Diagnostic Process

The diagnostic approach to oral ulcerative lesions should be disciplined and must begin with a thorough clinical history, followed by examination of extraoral and oral surfaces. Oral ulcerative conditions can be categorized as being either acute (<2–3 weeks of duration) or chronic (> 2–3 weeks of duration). While obtaining a history of the presenting complaint, clinicians must address the factors listed in Table 17.1 in order to determine the type of pathological process causing the ulcers. There is a range of pathological processes associated with oral ulceration, including ulcerations due to reactive physical/chemical (e.g., traumatic ulcers), infectious diseases (e.g., herpes), local immune dysregulation, manifestations of systemic immune-mediated conditions, and malignant neoplasia. Although there is a range of oral ulcerative lesions, it is important for clinicians to recognize that ulcers caused by direct physical trauma (*traumatic ulcers*) are the most common of all oral ulcerations. The salient features of each type of pathological process and examples of ulcerative conditions are listed in Table 17.2.

Table 17.2 Oral ulcers, blisters and desquamation. Questions to guide the clinical diagnostic process

Onset/Duration – Acute (<2 weeks) – Chronic (>2 weeks)
Number of lesions – Solitary ulcers – Multiple
Distribution – Localized (unilateral/bilateral/multifocal) – Oral mucosal distribution: keratinized (attached gingiva, hard palate, vermilion) vs. unkeratinized surfaces (ventral tongue, buccal mucosa, labial mucosa) – Extraoral: cutaneous lesions, mucosal lesions (conjunctiva, genital, nasal mucosae)
Local factors – Trauma: restorations, sharp teeth, appliances, foreign objects – Dry mouth – Chemical agents, medications etc.
Frequency – Single episode – Persistence/progression – Recurrent/overlapping episodes/previous hx of similar lesions
Systemic factors – Cutaneous lesions/mucosal lesions—rashes, hives, pruritic, scaly, vesiculo-bullous lesions – gastrointestinal symptoms—cramping, diarrhea, gluten sensitivity, blood in stools, Hx of IBS – general health—anemia, fatigue

Given the range of pathological processes associated with oral ulcerative lesions, clinicians must approach the diagnostic process in a stepwise manner as discussed below and in Flowchart 17.2. The first step in the diagnostic process is to establish whether a patient's ulcerative lesions/condition is acute or chronic, and the second step is to establish the number/distribution of the ulcerative lesions. Additional information on local/systemic precipitants, frequency, and systemic/extraoral



Flowchart 17.2 Oral ulcers. A step-by-step approach to the diagnosis of clinically indeterminate oral ulcers, blisters and desquamation with selected examples

manifestations guides a clinician's diagnostic work-up. As seen in Flowchart 17.2, determining whether an ulcerative condition is acute or chronic is the single most important step as it immediately guides clinicians' differential diagnostic considerations. Clinicians can use their knowledge about salient features of ulcerative entities as shown in Table 17.3 to guide this diagnostic process.

Table 17.3 Oral ulcers. Pathological process, general features and selected examples

Pathological process and clinical features	Examples
1. *Reactive* – Local factors—restorations, margins, sharp teeth, irritant – Generally acute/patient recalls specific cause – Heal within 10–14 days – Can be chronic if irritant/agent persists – Generally painful – Heal if irritant is removed/scarring with chronic ulcers – Predisposing factors—oral dryness	1. Traumatic ulcers 2. Chemical burns (pizza burn, aspirin burn)
2. *Infectious diseases* (viral,[a] fungal,[a] bacterial infection) – Children – Primary and recurrent episodes – Acute onset—last 10–14 days – Multiple ulcers; distribution depends on type of infection – Pain – Constitutional signs/symptoms: fever, malaise, lymphadenopathy – Recurrences	1. Herpetic infection (primary or secondary) 2. Coxsackie virus infection
3. *Local immune-dysregulation/immune-reaction pattern* – Acute onset – Duration—10–14 days – Pain – Multiple ulcers – Distribution—oral mucosal (aphthous); oral + extraoral (E.M.) – Recurrent episodes (aphthous; E.M. if trigger persists)	1. Recurrent aphthous stomatitis 2. Erythema multiforme (E.M)
4. *Immune-mediated conditions (systemic)* – Adults – Chronic and progressive – Multiple ulcers—unrelated to local physical factors – Distribution—oral + extraoral (skin, conjunctiva, genital etc.) – Persistent ulcers; recurring and overlapping episodes – Hx of underlying systemic condition	1. Erosive lichen planus 2. Mucosal pemphigoid 3. Pemphigus vulgaris 4. Irritable Bowel Syndrome
5. *Neoplastic—Malignant* – Clinically obvious mass/tumor – Solitary ulceration; persistent; chronic ulceration (>3–4 weeks) – Unrelated to local physical factors – *Cancer prone oral locations—ventral/lateral tongue, floor of mouth, soft palate* – Pain, paresthesia	1. Squamous cell carcinoma 2. Malignant salivary gland neoplasms

*Benign neoplasms are generally non-ulcerated, unless secondarily traumatized

**Ulcers due to underlying developmental/genetic disorders are extremely uncommon

[a]Oral ulcers due to fungal and bacterial infections are extremely uncommon and generally associated with severe immune-depletion and tend to be solitary non-healing ulcers

17.6.2 Acute Ulcerative Conditions

(a) *Traumatic ulcer*: Traumatic ulcers are the most common oral ulcerations and typically present as acute, painful, focal/solitary ulcers. Classically, patients report a history of recent trauma to the oral mucosa. The traumatic insults range from self-inflicted cheek/tongue bite, denture irritation, irregular teeth/restorations, oral appliances, pizza burn, iatrogenic injury, or other traumas. The majority of traumatic ulcers occur in so-called trauma-prone sites, i.e., the buccal mucosa, lower labial mucosa, lateral and dorsal tongue, and gingival surfaces. It is unusual to see traumatic ulcers on the floor of the mouth, ventral tongue, and soft palatal surfaces as they are naturally protected from direct trauma (so-called cancer-prone sites). Traumatic ulcers are typically painful and solitary (unless there are multiple areas of physical trauma, e.g., denture flange) and appear as shallow yellow-white ulcers with irregular, erythematous borders (Fig. 17.11a, b). The vast majority of traumatic ulcers heal within 2–3 weeks of the initial injury. If the initial stimulus persists (e.g., overextended denture flanges, fractured tooth structure, improperly contoured/fractured restoration), then the ulcer can persist for longer than 3 weeks. In this setting,

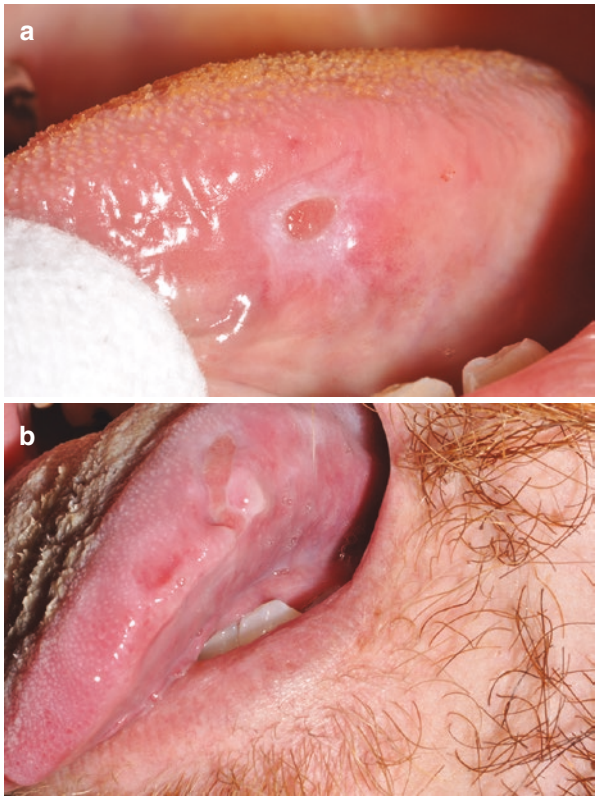


Fig. 17.11 Traumatic ulceration. (**a**) A shallow ulcer on the left lateral tongue in a patient with a history of recent trauma to the area. (**b**) A deep painful ulcer on the left lateral tongue. The patient reportedly inadvertently bit his tongue. Note the buildup of debris on the dorsal tongue secondary to oral pain

traumatic ulcers can be chronic in duration and present as deep ulcers with hyperplastic borders and appear clinically worrisome. It is essential for clinicians to determine the source of trauma and address the initial stimulus accordingly. Once the stimulus/source of trauma is addressed, the patient must be followed up in 2–4 weeks depending on the size of the initial traumatic ulcer. Solitary ulcers that persist beyond 2–4 weeks despite having addressed the source of physical trauma must be viewed with suspicion. These ulcers must be biopsied to rule out other diagnostic possibilities, including oral squamous cell carcinoma. Complete surgical excision may be required for large traumatic ulcers with surrounding hyperplastic tissue.

(b) *Recurrent aphthous stomatitis (RAS)*: Aphthous ulcers (RAS/"canker sores") are among the most common oral ulcerative conditions, second only to traumatic ulcers. RAS is an acute ulcerative disease of local immune dysregulation and the result of localized T lymphocyte-mediated vasculitis and epithelial necrosis. Transient deposition of cytokines like tumor necrosis factor alpha (TNF-α) and interferon γ (IFN-γ) is among the chemotactic factors within local blood vessel and epithelial basement membranes, and the subsequent oral epithelial necrosis results in clinical ulcers (Al-Samadi et al. 2015; Natah et al. 2000).

Clinically, patients with RAS present with painful ulcers almost exclusively on moveable, unkeratinized mucosal lining surfaces, i.e., buccal mucosa, labial mucosa, floor of the mouth, ventral tongue, soft palate, alveolar mucosa, vestibules, and the dorsal tongue (exception; heavily keratinized surface). Aphthous ulcers do not present on the attached gingiva, hard palate, and the labial vermilion. Given that RAS is an acute process, aphthous ulcers can present suddenly (no prodrome), typically running a 7- to 10-day course, with some patients aware of specific inciting triggers. Classic aphthous ulcers present as round-to-ovoid ulcers surfaced by a yellow-white fibrinonecrotic center and erythematous borders (Fig. 17.12a). Aphthous ulcers may be classified by size with minor aphthae measuring less than 1.0 cm in diameter. Major aphthae are 1.0 cm or greater in diameter and, because of their width and depth, could run a more protracted course in excess of 2 weeks (Fig. 17.12b). Herpetiform aphthae present as clusters of very small ulcers measuring 0.1 or 0.2 cm in diameter. Individual patients may have one or several types of aphthous ulcers in a single episode. Patients with aphthae may present with one or multiple ulcers within the oral cavity. Irrespective of lesion size, number, and distribution per episode, RAS is very painful and can cause significant morbidity, especially in patients presenting with major aphthae or with multiple overlapping episodes (Sciubba J.J. 2007; Staines & Greenwood 2015; Porter & Scully Cbe 2007). While the immunological basis of RAS is well established, the triggers that precipitate this localized immune dysregulation are not as clear. The best-characterized predisposing factors that have been implicated in the etiopathogenesis of RAS are (1) genetic susceptibility (~35–40% patients present with a +ve family history), (2) local factors (e.g., trauma, stress, exposure to certain foods/materials), (3) immune deficiency, and (4) systemic immune-mediated conditions (e.g., Behcet's disease, Crohn's disease, celiac disease, ulcerative colitis).

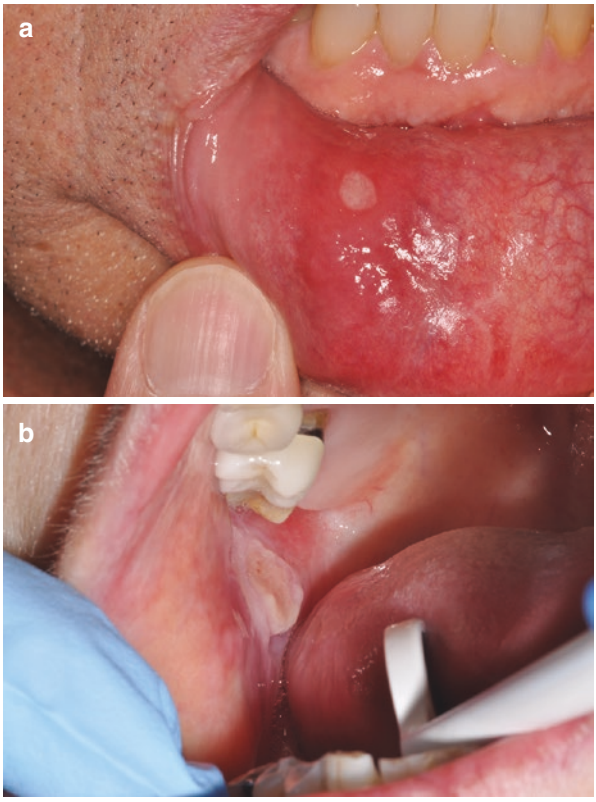


Fig. 17.12 (**a**) Aphthous ulcer, minor. A round 0.5 cm ulcer with a yellow-white central pseudomembrane surrounded by erythema on the lower labial mucosa (an unattached, unkeratinized surface). (**b**) Aphthous ulcer, major. A irregularly shaped >1 cm ulcer with yellow-white center and erythematous surrounding on the right posterior buccal mucosa (unattached, unkeratinized surface)

For clinicians, it is important to emphasize a critical concept: recurrent aphthous stomatitis is a disease of localized immune dysregulation. It is not the result of a viral infection (e.g., herpes, coxsackie), nor is it associated with specific dietary deficiencies (Sciubba J.J. 2007; Staines & Greenwood 2015; Porter & Scully Cbe 2007). The vast majority of patients (~95%) have recurrent aphthous stomatitis as an isolated oral mucosal disease, with no underlying systemic condition or predisposition. However, given that RAS is a potential feature of some systemic disorders (e.g., Crohn's disease, ulcerative colitis, Behcet's disease, celiac disease), it is important for clinicians to ask patients with RAS questions about potential gastrointestinal symptoms, extraoral mucosal involvement, and cutaneous lesions. A positive history of systemic signs/symptoms associated with an underlying systemic condition should trigger an appropriate referral and work-up (Sciubba J.J. 2007; Porter & Scully Cbe 2007).

It is essential for clinicians to understand that the diagnosis of recurrent aphthous stomatitis is based almost entirely on correlation of patient's history, the clinical course (acute), and the distribution and appearance of oral mucosal ulcerative lesions. Laboratory studies and biopsies are non-revelatory and tend to be diagnostically nonspecific. With regard to treatment options for aphthous stomatitis, it is important to understand that there is no "cure" for this condition.

The treatment objective should be to manage the localized underlying immune-mediated condition and individualize immunomodulatory therapy taking into consideration the following factors: (1) frequency of ulcerative episodes (single/overlapping), (2) number and distribution of ulcers/episodes, and (3) presence of underlying systemic complaints/conditions or triggers (Sciubba J.J. 2007; Staines & Greenwood 2015; Porter & Scully Cbe 2007; Montgomery-Cranny et al. 2015).

(c) *Herpes simplex infection (primary or reactivated/secondary)*
Herpes simplex infections (primary or reactivated) are attributable to herpes simplex viruses 1 and 2 (HSV-1 and HSV-2) which are part of the α group of human herpes viruses (large DNA viruses). As with most human herpes viruses, HSV-1 and HSV-2 exhibit the phenomenon of primary and latent infection whereby a virus has the ability to remain dormant in a host following the initial infection, with the potential for intermittent reactivation. Epithelial cells are the preferential primary target for HSV-1 and HSV-2 with local neurons/ganglia serving as the site for viral latency (Woo & Challacombe 2007; Westley et al. 2011).

– Primary herpes simplex virus infection in the orofacial region is often a clinically silent event that occurs fairly early on in life. Following viral entry into epithelial cells, the host's cell-mediated immune response abrogates viral replication and cell lysis and almost immediately sends the virus into a latent phase. Therefore, the vast majority of patients do not present with clinical manifestations of a viral syndrome (subclinical primary infection). In a small proportion of patients, HSV replication and epithelial cell lysis (acantholysis = vesicle formation) proceed unabated. These patients present with an acute vesiculoulcerative clinical syndrome. In the orofacial region, this presents as primary acute herpetic gingivostomatitis. The classic patient is a child or teenager who presents with constitutional signs of a viral infection—fever, lymphadenopathy, chills, nausea, anorexia, and malaise—which often precede visible oral lesions. Within a matter of hours to a day, patients present with an acute, painful, vesiculoulcerative eruption (blisters that quickly ulcerate) that involves multiple oral mucosal sites. The characteristic manifestation of primary HSV infection is generalized, extremely painful ulcerative gingivitis (Fig. 17.13a, b). In addition, ulcerative lesions may be seen involving the skin and vermilion of the lip and oral mucosal surfaces that are both keratinized (attached gingiva, hard palate, etc.) and unkeratinized (buccal mucosa, tongue, soft palate, labial mucosa, etc.). Due to severe pain, patients are often unable to eat or drink anything—children are especially at risk of hydration. In otherwise healthy individuals, the primary disease resolves within 2–3 weeks of onset. Following the primary infection, the virus goes into a latency phase within the local ganglion (trigeminal ganglion—oral infection) with the potential for future reactivation (Woo & Challacombe 2007; Westley et al. 2011). The ulcerative lesions of primary HSV infection of the oral cavity can mimic the presentation of recurrent aphthous stomatitis. However, they can be distinguished from aphthous stomatitis based on the history (constitutional signs of fever, etc.), the type of lesions (HSV presents as vesicles that

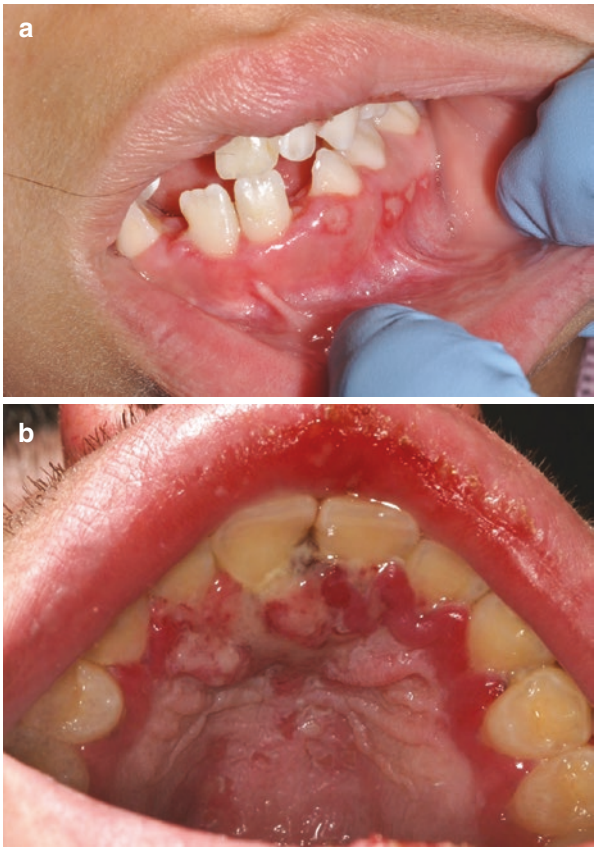


Fig. 17.13 Primary herpetic gingivostomatitis. (**a**) A young patient with multiple ulcerative lesions involving attached and unattached oral mucosal membranes. The patient reports acute onset and accompanying constitutional signs. (**b**) A young patient with widespread ulcerative lesions on attached and unattached oral mucosa with fever and lymphadenopathy. Note the generalized gingival erythema, ulceration and necrotic debris in the interdental papillae

ulcerate), and most importantly the distribution of lesions. Primary HSV lesions can be seen on both attached and moveable surfaces, whereas RAS is seen almost exclusively on moveable, unkeratinized surfaces.

– Secondary (recurrent) herpetic lesions represent the reactivation of latent HSV virus from the native ganglion (oral cavity = trigeminal ganglion) followed by viral replication and epithelial cell lysis (acantholysis). Reactivated orofacial HSV infection presents almost exclusively on keratinized/attached mucosal surfaces (i.e., vermilion/skin of the lip, attached gingiva, hard palate). The classic manifestation of reactivated (secondary/recurrent) HSV infection is herpes labialis ("cold sore"). This is characterized by an outbreak of localized cluster of small vesicles that ulcerate along the vermilion or skin of the lips. Lesions are localized, cause mild discomfort to pain, and last for around 10–14 days before they crust over and heal. Recurrent outbreaks are typically preceded by a prodrome (tingling, burning, pain) in the area where vesicles emerge. Recurrences can be precipitated by several triggers—stress, febrile illness (fever blister), immune dysregulation, intense heat/cold, menstruation, etc. Some patients can present with intraoral reactivated HSV infection which is seen almost exclusively on the attached gingiva or hard palate (keratinized surfaces) in a unilateral distribution (Fig. 17.14). In addition to

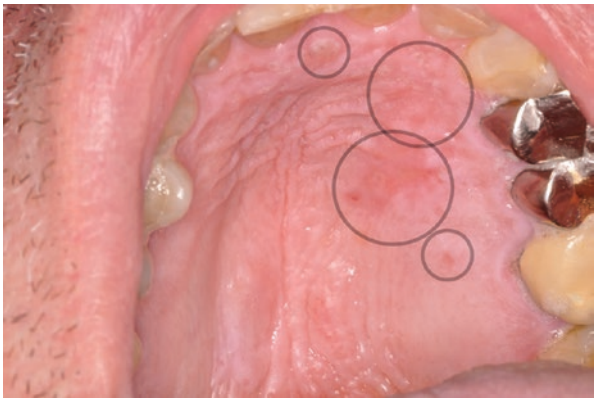


Fig. 17.14 Secondary/reactivated intraoral herpes. Painful 1–5 mm ulcerations on the left hard palate (attached mucosa). Note the clustered, unilateral distribution and lack of soft palatal involvement

some of the above triggers, intraoral HSV reactivation has also been precipitated by local anesthetic injections or dental procedures. The lesions are similar and present as small clusters of painful ulcers that heal within 2–3 weeks (Westley et al. 2011).

HSV infections (primary and reactivated) are acute, self-limiting viral infections that present with oral ulcerations and may be confused for RAS or coxsackie infection. The diagnosis of orofacial HSV infections is made almost exclusively on clinical grounds alone correlating a patient's history (constitutional signs, acute/short duration) and clinical presentation (distribution, appearance of ulcers). Laboratory tests and biopsies are of limited value and are diagnostically nonspecific. Cytological smears looking for virally modified epithelial cells (Tzanck cells) may be a useful adjunct in selected patients who present with intact ulcers; however, given that oral vesicles quickly rupture, the value of this test is limited. Diagnosis based on clinical manifestations as described above tends to be more reliable. Management of patients with HSV infections is conservative: analgesics-antipyretics, soft diet, and pain management with topical agents (viscous lidocaine). In selected patients with multiple, overlapping reactivated HSV infections, antiviral medications (systemic or topical) may be considered (e.g., acyclovir, valacyclovir, etc.).

(d) *Oral coxsackie viral infection (herpangina, lymphonodular pharyngitis, hand-foot-and-mouth disease)*: Oral coxsackie viral infections are attributable to group A coxsackieviruses which are typically spread via the fecal-oral route. The incubation period for coxsackieviruses is typically 1 week, and resulting viral syndrome is typically acute running a short 7–10 days of course. Coxsackie viral infections are usually seen in children, adolescents, and less often in adults. Patients with coxsackie viral infections typically present with constitutional signs of fever, lymphadenopathy, malaise, headache, nausea, and anorexia reflective of a self-limiting systemic viral infection. Orofacial lesions are seen in all three forms of coxsackie infection, i.e., herpangina (localized), lymphonodular pharyngitis, and hand-foot-and-mouth disease (systemic). Patients typically complain of pharyngitis, dysphagia, and a modest degree of oral mucosal pain. Coxsackievirus infections can be acquired multiple times in an individual patient but occur only once in a single season.

Clinically, the lesions of coxsackievirus infection present as widely distributed vesicles and ulcers. The ulcers are typically clustered and small, ranging from 1 to 3 mm. The classic distribution is around the posterior oral cavity and oropharynx (soft palate, tonsillar pillars, base of the tongue, etc.) with a few lesions seen toward the anterior oral cavity. Lesions may be seen on both keratinized and unkeratinized locations. In some instances, oral and oropharyngeal lesions may be accompanied by cutaneous vesicles located on the hands, feet, and other cutaneous sites (hand-foot-and-mouth disease).

Oral coxsackie infections are common and therefore are important for clinicians to recognize. Coxsackie infections are acute, self-limiting viral infections that present with oral ulcerations and may be confused for RAS or herpes infection. The diagnosis of oral coxsackie infections is made almost exclusively on clinical grounds alone correlating a patient's history (constitutional signs, acute/short duration) and clinical presentation (distribution, appearance of ulcers). Laboratory tests and biopsies are of limited value and are diagnostically nonspecific. Management of patients with coxsackie viral infections is conservative: analgesics-antipyretics, soft diet, and pain management with topical agents (viscous lidocaine).

(e) *Erythema multiforme*: Erythema multiforme (EM) is an acute, noninfectious, immunologic mucocutaneous reaction resulting from a T-cell-mediated vasculitis. The explosive clinical manifestation of EM is often the result of a precipitant to which a patient has become immunologically sensitized through prior exposure. Typical precipitants include medications (prescribed/over-the-counter), drugs (recreational), alcohol, or certain microbial infections (mycoplasma and herpes simplex viruses). The chemical or infectious agents have the potential to trigger a systemic Type-III (immune complex mediated) or Type-IV (delayed/cell-mediated) hypersensitivity reaction. It is essential for clinicians to recognize that this is not a true "allergic" response (Type-I hypersensitivity); it is not the result of mast cell-mediated histamine release. Patients sensitized to a specific precipitant have the potential to present with progressively more severe manifestations with subsequent exposures.

Clinically, EM can present involving multiple cutaneous and mucosal sites (e.g., oral, nasal, genital, conjunctival). On the skin, patients may present with lesions in multiple forms (multiforme): vesicles/bullae, maculopapular rashes, ulcers, urticaria, purpura, or classically described "target lesions." Although the lesions can affect any cutaneous surface, lesions are often seen involving the palms, soles, and the perioral cutaneous surfaces. Orofacial manifestation is seen in a significant number of patients (>60–70%) diagnosed with EM. Patients typically present with acute swelling, vesicles/bullae, ulcerations, and hemorrhagic crusting of the vermilion, skin, and mucosa of the upper and lower lips. Widely distributed intraoral ulcers may be seen. The ulcers are typically irregular and ragged, and they can mimic the clinical appearance of lesions seen in chronic conditions like pemphigus or pemphigoid. The extremely painful oral lesions may preclude a patient's ability to eat or drink fluids with potential for dehydration and morbidity.

The differential diagnosis for erythema multiforme includes acute primary herpes infection, pemphigus/pemphigoid, recurrent aphthous stomatitis, and herpangina. The diagnosis of EM is typically made on clinical grounds in recognition of its acute, self-limiting presentation (ruling out chronic conditions), correlating a patient's history (acute/explosive onset, pain, precipitants), and clinical presentation (distribution, appearance of lesions). The clinical presentation of erythema multiforme may trigger biopsy studies with conventional and direct immunofluorescence (DIF) analyses; histopathological and DIF analyses are diagnostically nonspecific. Although the clinical course of EM episodes is acute and self-limiting, it is essential that clinicians address this explosive, often debilitating immune-reaction syndrome. Immunomodulatory intervention (systemic/topical) may be indicated in addition to pain management. Additionally, and more importantly, clinicians must try and identify and address the inciting agents that cause EM in patients. A significant proportion of EM is associated with reactivated herpes simplex infection, providing the rationale for prophylactic antiviral therapy in those patients.

17.6.3 Chronic Ulcerative Conditions

17.6.3.1 Solitary Chronic Ulcers

(a) *Chronic traumatic ulcer*: As described in the section above (traumatic ulcers), traumatic ulcers typically heal within 1–2 weeks. If the initial stimulus that led to the ulcer persists (e.g., overextended denture flanges, fractured tooth structure, improperly contoured/fractured restoration), or if a patient has certain predisposing factors (e.g., extremely dry mouth, immunosuppression/depletion), then a traumatic ulcer can persist for longer than 3 weeks. In this setting, traumatic ulcers can be chronic in duration. These lesions are clinically worrisome and present as deep ulcers with areas of hyperplasia, underlying scarring, symptoms, and surrounding white and red changes (Fig. 17.15a, b). The ulcers may present with areas of induration as a result of underlying scar tissue. Chronic, long-standing traumatic ulcers may present with pain or in some patients be painless or associated with persistent discomfort. Just as with self-limiting traumatic ulcers, it is essential for clinicians to determine the source of trauma and address the inciting stimulus accordingly. Solitary chronic ulcers that persist beyond 2–4 weeks despite having addressed the source of physical trauma must be viewed with suspicion. These ulcers must be biopsied to rule out the possibility of oral squamous cell carcinoma (see Flowchart 17.2). Complete surgical excision may be indicated for chronic traumatic ulcers with surrounding hyperplastic tissue in an attempt to achieve healing/repair by primary intention.

(b) *Squamous cell carcinoma*: Oral squamous cell carcinoma (OSCC) is a malignant neoplasm arising from the oral mucosal lining and is the result of protracted genetic deregulation within the stratified squamous epithelium (Natarajan and Eisenberg 2011). The most common clinical presentation of OSCC is as a solitary, progressive, chronic, ulcerated mass in classically

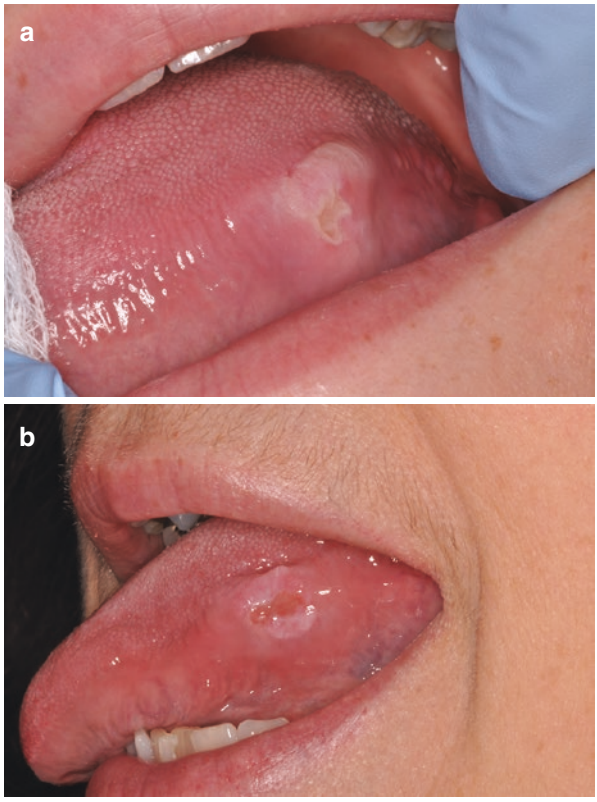


Fig. 17.15 (**a**, **b**) Traumatic ulcers, chronic. Longstanding (>1 month) ulcers on the left lateral-ventral tongue. These patients reported a history of trauma. If these ulcers do not show signs of healing 2–3 weeks after addressing local traumatic factors, a biopsy is indicated

cancer-prone locations (e.g., lateral tongue, ventral tongue, floor of mouth, soft palate, etc.) and in locations in contact with tobacco and tobacco products (e.g., buccal vestibules). Patients are often aware of a "sore" or "lump" in these locations for several weeks or months and may report progressive growth. The ulcer is often painless but in some patients can present with symptoms of severe pain and paresthesia (i.e., numbness, tingling, burning). The growth rate of the ulcer and/or mass is variable but is relatively rapid when compared to benign processes. As described previously in the section on "White Lesions," the ulcerated masses exhibit prominent red and white plaques with a variegated surface appearance (i.e., corrugation, verrucous/papillary, speckled, lobulated, pebbly) (Figs. 17.16 and 17.8). The ulcerated tumors are typically indurated (hard) on palpation and tend to tether down affected tissues (tumor infiltration, desmoplastic scarring). The surrounding white plaques exhibit microscopically diagnosable epithelial dysplasia. In addition to oral changes, patients with OSCC may present with palpable regional lymphadenopathy at the time of presentation. As with the tumor, these nodes are typically indurated and tethered/matted to adjacent tissues (Natarajan and Eisenberg 2011).

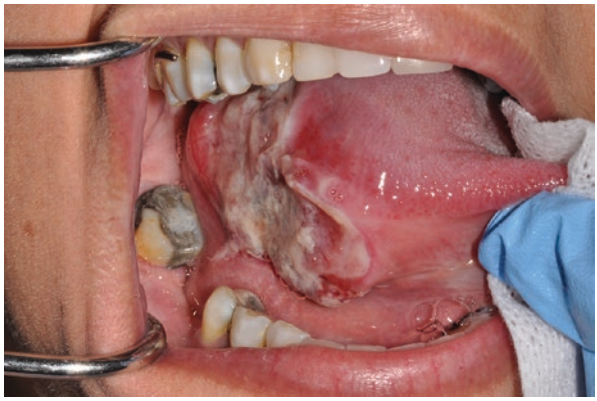


Fig. 17.16 Squamous cell carcinoma. A large painful, ulcerated, indurated (hard) mass on the right ventral tongue surrounded by white surface changes

As a general rule, any oral ulcerative lesion that is solitary in a cancer-prone location or otherwise that persists for more than 3–4 weeks despite having addressed potential traumatic stimuli must be biopsied. Multiple representative biopsies may be indicated for lesions that are large and heterogeneous in appearance.

(c) *Other solitary chronic ulcers*: Although trauma and OSCC account for the vast majority of solitary chronic ulcers of the oral cavity, there are chronic ulcers representative of the following pathological processes:
- Other malignant neoplasms—salivary gland malignancies (lateral palate), metastatic disease (bone + soft tissue), other primary malignancies (lymphoma, melanoma)
- Infections—granulomatous ulcers (e.g., tuberculosis, deep fungal infections, syphilis)
- Granulomatous ulcers—foreign body granulomas with ulceration

17.6.3.2 Multifocal Chronic Ulcers

Patients who present with a combination of chronic, multifocal oral ulcerations pose diagnostic challenge. Patients often present with pain, tissue fragility, and functional compromise. They are often the result of an underlying chronic immune-mediated mucocutaneous condition. As described above, the diagnostic process for such complaints must begin with a disciplined clinical history (Table 17.1), followed by thorough examination. In addition, clinicians may ask the following key questions that are pertinent to patients presenting with a potential immune-mediated condition:

1. Does the patient have any scaly, pruritic, popular, vesicular, or ulcerative cutaneous lesions anywhere on the skin surfaces?
2. Does the patient experience any discomfort, pain, redness, stinging/irritation, or gritty sensations involving the eyelids? History of nasal epistaxis? Genital mucosal, pharyngeal, or esophageal discomfort/pain?

3. Does the patient experience any gastric discomfort, diarrhea, bloating, flatulence, hematochezia (blood in the stools)?
4. Is there a temporal relationship between the onset of lesions and introduction of new medications (prescriptions/over-the-counter)/supplements?

(a) *Erosive lichen planus*: As described in the section on "White Lesions," oral lichen planus (OLP) is a benign cell-mediated autoimmune disease characterized by multifocal, symmetrical, papulosquamous dermatosis and mucosal lesions. Lichen planus is the result of a T lymphocyte-mediated cytotoxic destruction of basal keratinocytes that results in compensatory surface hyperkeratosis resulting in the classically described reticular white striations, papules, and plaques (Cheng et al. 2016). Foci of erosion/ulceration of the epidermis/mucosae correspond to areas where sustained cell-mediated destruction overwhelms or abrogates compensatory epithelial proliferation. Patients with the reticular form are generally asymptomatic. The erosive/ulcerative form of OLP, although less common, is clinically significant as patients are often symptomatic; the symptoms may include sensitivity (to acidic/abrasive food), discomfort, general soreness, pain, or combinations of the above (Cheng et al. 2016; Park et al. 2012). In addition to widely distributed chronic ulcerations/erosions, foci of erosive OLP are usually surrounded by characteristic non-wipeable white striations or papular lesions (Fig. 17.17a, b). Patients often present with progressively uncomfortable/painful oral mucosal surfaces. Gingival involvement is often a prominent feature of erosive lichen planus (Fig. 17.17c). In addition to widespread mucosal fragility, patients may report bleeding during professional manipulation and/or home oral hygiene care.

Additionally, lichenoid stomatitides (similar to lichenoid dermatoses), a large group of clinically and/or histologically diverse conditions, can have features similar to that of classic OLP. Since there is a range of clinical situations (clinical/histological) that mimic LP (e.g., direct contact hypersensitivity, drug-related lichenoid lesions, other autoimmune conditions, etc.), it is more appropriate to view them as chronic immune-mediated processes that share the pathogenetic mechanisms of chronic T-cell activation with degrees of basal cell and basement membrane complex destruction. This explains the spectrum and overlap in clinical presentation of lichenoid stomatitides. For that reason, lichenoid stomatitis should be considered as a diagnostic possibility in patients presenting with multifocal chronic oral ulcers (Park et al. 2012; Patel et al. 2016).

The clinical presentation of erosive lichenoid oral lesions can be indistinguishable from other chronic immune-mediated ulcerative/erosive mucocutaneous conditions like mucosal pemphigoid and pemphigus posing a diagnostic challenge. In this setting, biopsies are indicated to establish a definitive diagnosis (Patel et al. 2016). The recommended diagnostic work-up for chronic erosive/ulcerative immune-mediated mucocutaneous conditions is provided below.

(b) *Mucous membrane pemphigoid*: Mucous membrane pemphigoid/mucosal pemphigoid/cicatricial pemphigoid (MMP) is one among a number of chronic autoimmune vesiculobullous (blistering) conditions which can present with

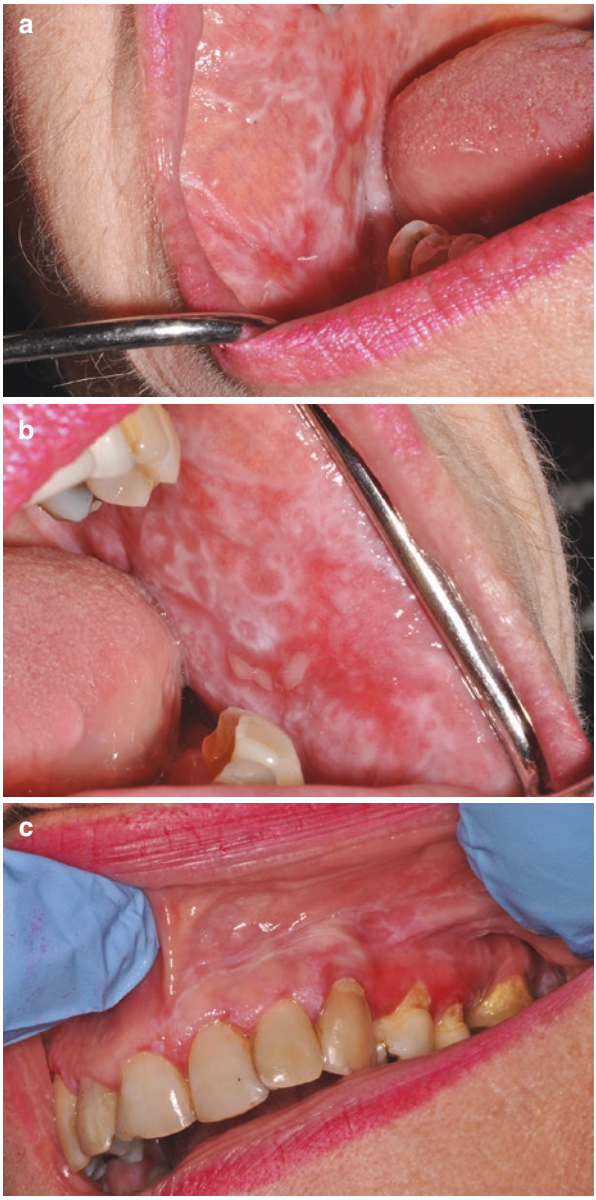


Fig. 17.17 (**a–c**) Oral lichen planus, erosive/ulcerative. Bilateral, multifocal distribution of reticular white striations with intervening areas of erosion and ulceration. Note the areas of ulceration on the buccal mucosae surrounded by radiating striations. Also, note the prominent gingival involvement—lichenoid striations on the interdental papillae and vestibule, and erosive changes along the posterior attached gingivae preventing oral hygiene maintenance

multifocal chronic oral ulcerations/erosions (Taylor et al. 2015). As the name indicates, there could be simultaneous involvement of multiple other mucous membranes, particularly conjunctival mucosa and nasal, genital, and esophageal mucosa. MMP is typically not accompanied by corresponding cutaneous involvement. MMP is the result of an autoimmune antibody-mediated destruction of the hemidesmosomal-basement membrane complex (BHMC). IgG and C3 mediated reaction against elements of the BHMC in the disruption of the

attachment which anchors the epithelium to the basement membrane zone (BMZ), resulting in separation and complete "lifting off" (desquamation) of the surface epithelium from the underlying lamina propria (Kasperkiewicz et al. 2012; Schmidt & Zillikens 2013; Jascholt et al. 2017). The separation of the basal epithelium from the underlying basement membrane complex is often described as being "clean" with intact basal epithelium seen along the roof of a blister. Therefore, MMP is among the mucocutaneous diseases characterized clinically by a positive Nikolsky sign: tactile-induced fragility and/or bulla formation which results in sloughing of the mucosal (or skin) surface. The Nikolsky sign is diagnostically nonspecific and is a clinical indicator of weakness in attachments between epithelial cells or the epithelial-stromal interface attachment.

MMP is often described as a disease that classically affects perimenopausal, middle-aged women. However, it must be noted that MMP is a chronic condition that can affect any adult, regardless of sex. Clinically, the most common initial presentation of patients with oral MMP is chronic, progressive gingival discomfort with notably "red gums" which are typically nonresponsive to professional and/or home oral hygiene measures (Fig. 17.18a). Patients often report a prolonged course with pain/discomfort that varies considerably over time and from patient to patient. The clinical manifestation of MMP is characterized by desquamative gingival lesions, erosions, ulcers, and tissue fragility; intact oral vesicles/bullae are rarely observed as they tend to rupture easily (Fig. 17.18b). Although the gingival involvement is most prominent, other oral mucosal sites can also be involved. Disease activity and degrees of discomfort vary considerably with every patient. Patients often report symptomatic exacerbations aggravated by the introduction of spicy/acidic or abrasive/sharp foods. The repeated, overlapping vesiculoulcerative lesions of MMP are associated with aberrant repair and scarring (cicatrix formation). In the oral cavity, repeated gingival/alveolar mucosal scarring may manifest as reduced vestibular depth.

This tendency for cyclical erosion and scarring is especially significant when other mucosal sites are involved, most of all the conjunctival surfaces. MMP involving the conjunctival mucosae can result in the formation of progressive band-like adhesions between the palpebral and bulbar conjunctiva (symblepharon) and potential inversion of the eyelid (entropion) (Kasperkiewicz et al. 2012; Schmidt & Zillikens 2013). Erosive and ulcerative lesions affecting other mucosal sites including the genital mucosa, nasal mucosa, and esophageal mucosa can cause significant morbidity. It is for this reason that clinicians must ask directed questions about extraoral mucosal and cutaneous involvement while documenting a patient's clinical history.

Bullous pemphigoid (BP) is an entity within the pemphigoid group of disorders and is similarly characterized by autoantibody-mediated destruction of elements of the BHMC (protein BP180) (Schmidt & Zillikens 2013). While the condition may bear some similarity to MMP, bullous pemphigoid is primarily a cutaneous condition with few patients exhibiting oral mucosal involvement. BP is considered a disease of older adults, typically 60 years of age or older. Cutaneous lesions on the trunk and extremities present as erythematous

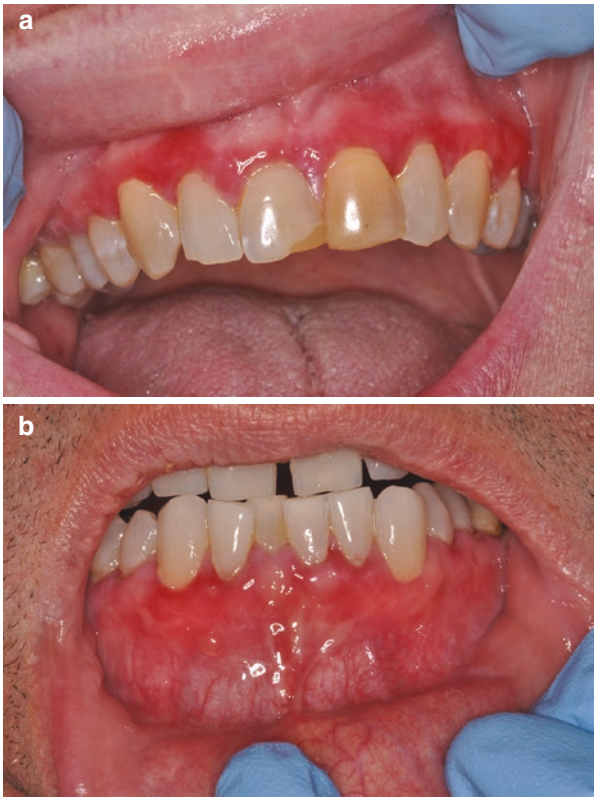


Fig. 17.18 (**a**) Mucous membrane pemphigoid, oral. Generalized gingival erythema and erosion involving the margins, attached gingiva and alveolar mucosal surfaces. Similar findings noted on the palatal aspect, and mandibular arch. The patient had concomitant conjunctival involvement. (**b**) Mucous membrane pemphigoid, vesicle. Generalized gingival erythema with desquamation. Note the intact vesicle on the gingival surface between teeth # 26 and 27

papules, tense bullae, and vesicles which rupture and ulcerate. The oral lesions of BP are indistinguishable from those seen in MMP, affecting the gingival tissues as well as other oral sites. Other mucosal sites may be involved in patients with BP.

As with erosive lichenoid stomatitides, MMP and BP can be indistinguishable from other chronic immune-mediated ulcerative/erosive mucocutaneous conditions (Patel et al. 2016). In this setting, biopsies are indicated to establish a definitive diagnosis. The recommended diagnostic work-up for chronic erosive/ulcerative immune-mediated mucocutaneous conditions is provided below (diagnostic work-up). Furthermore, patients diagnosed with MMP must be referred to appropriate specialists (e.g., ophthalmology, otolaryngology, dermatology, etc.) for further evaluation and management.

(c) *Pemphigus vulgaris*: Pemphigus is a group of chronic, antibody-mediated autoimmune mucocutaneous disorders characterized by acantholysis and vesiculobullous lesions (blistering) that can involve both cutaneous and mucosal tissues, including the oral cavity (Sultan et al. 2017; Feller et al. 2017). The pemphigus group of disorders consists of four subtypes of which pemphigus vulgaris is the most common. Pemphigus vulgaris is characterized by autoantibody-mediated destruction of cell-to-cell adhesion in the supra-basal keratinocyte layers (spinous cells). The sensitized immune system generates

antibodies (IgG) that target the desmosomes, specifically desmoglein 3, a glycoprotein cadherin linked to the intermediate filaments of epithelial cells. Destruction of desmosomes by IgG and resulting complement activity (C3) causes the spinous cells to separate from one another (acantholysis), compromising the integrity of the epithelium (Feller et al. 2017). In the clinical setting, acantholysis presents as cutaneous and/or mucosal blisters, mucosal/epidermal fragility, desquamation, and painful ulcerations. Untreated pemphigus can predispose patients to serious skin infections and can be a devastating and potentially fatal. Oral mucosal involvement can precede cutaneous involvement in some patients. Clinically, oral pemphigus is characterized by extremely painful ulcers involving any and all oral mucosal surfaces. Unlike the round, symmetrical appearance of aphthous ulcers, the oral ulcers seen in pemphigus are markedly irregular, ragged, and extremely friable (Fig. 17.19a–c) (Sultan et al. 2017). The surrounding mucosal surfaces are prone to sloughing on pressure (+Nikolsky sign). Intact vesicles/bullae are almost never seen within the oral cavity. Patients may be aware of or may report cutaneous lesions and/or other mucous membrane involvements (genital, nasal, etc.). A thorough history with relevant questions that address other areas of involvement as listed above should help guide a clinician toward an appropriate diagnostic work-up.

As with pemphigoid, biopsies with special immunofluorescence analysis are indicated to establish a definitive diagnosis. The recommended diagnostic work-up for chronic erosive/ulcerative immune-mediated mucocutaneous conditions is provided below (diagnostic work-up). Furthermore, patients diagnosed with pemphigus must be referred to appropriate specialists (e.g., dermatology, gynecology, etc.) for further evaluation and management as indicated below (management).

17.6.4 Diagnostic Work-Up for Oral Ulcerative Conditions

17.6.4.1 Acute Ulcerative Conditions

1. *Conditions/entities diagnosed on clinical grounds*: traumatic ulcers, aphthous ulcers, primary and/or reactive herpes simplex infections, coxsackievirus infections
2. *Conditions requiring biopsies*: large potentially traumatic ulcers that persist beyond 3–4 weeks
3. *Conditions potentially requiring additional diagnostic tests*:
   - Recurrent aphthous stomatitis with inflammatory bowel-related symptoms (Crohn's disease, celiac disease, ulcerative colitis)—gastroenterology evaluation
   - Recurrent aphthous stomatitis with mucocutaneous lesions (Behcet's disease)—rheumatology evaluation
   - Herpes simplex infections with intact vesicles—cytological smear to detect virally modified epithelial cells (Tzanck cells)

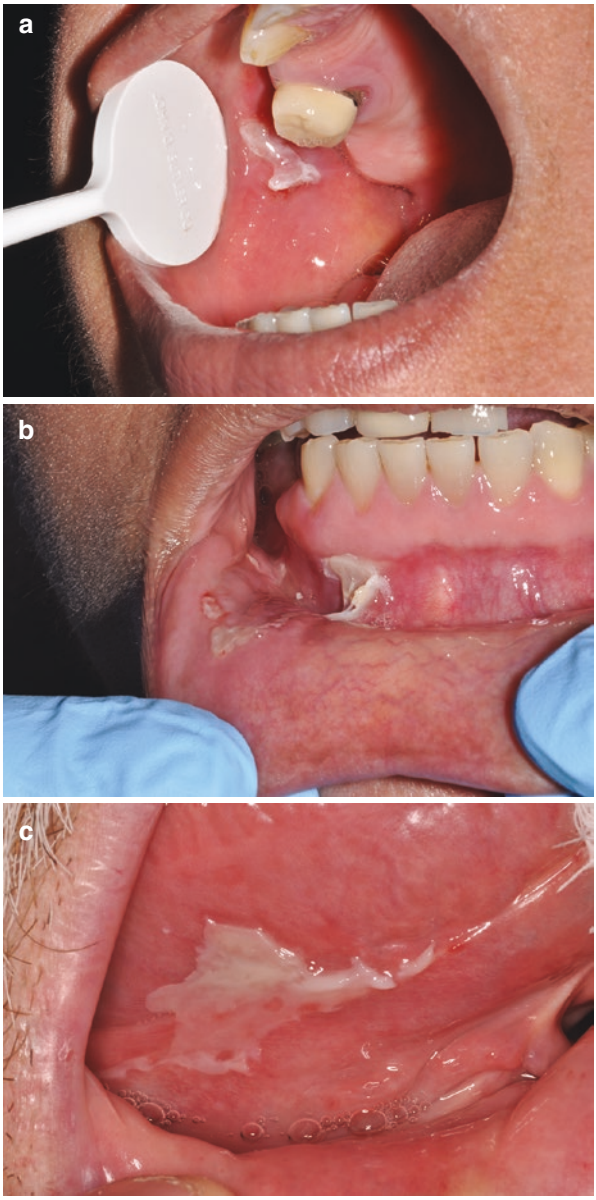


Fig. 17.19 (**a**) Pemphigus vulgaris, bulla. Patient with pemphigus vulgaris presents with an intact bulla on the right posterior buccal mucosa. This bulla ruptured shortly after this photograph was taken leaving behind a painful, ragged oral ulcer. (**b**) Pemphigus vulgaris, ruptured bulla. This is the same patient as (**a**) presenting with a ruptured bulla. Note the irregular, ragged appearance of the ulcer in the right lower vestibule and labial mucosa. (**c**) Pemphigus vulgaris, ulcer. Ragged appearing ulcers characteristic of pemphigus vulgaris

17.6.4.2 Chronic Ulcerative Conditions

1. *Conditions that require biopsies for specific diagnosis*—chronic/long-standing traumatic ulcers that have not healed/resolved after elimination of potential local sources of trauma/irritation. As discussed above, chronic solitary ulcers must be regarded with caution and must be biopsied to rule out the possibility of a malignant neoplasm or other pathology.

2. *Conditions/entities that require conventional biopsies and direct immunofluorescence analysis:* Long-standing/persistent multifocal oral ulcerative lesions that may or may not be accompanied by other mucosal and/or cutaneous involvement are generally suggestive of a chronic immune-mediated ulcerative mucocutaneous condition. In this setting, it is essential to analyze the affected and surrounding oral/cutaneous tissue under light microscopy and direct immunofluorescence (Suresh & Neiders 2012; Yih et al. 1998; Amber et al. 2016). Diagnostic confirmation of autoantibody-mediated immunological ulcerative conditions requires obtaining *two tissue specimens* during the same surgical procedure: (1) a representative tissue biopsy taken adjacent to an active mucosal lesions for conventional light microscopic examination submitted in 10% neutral buffered formalin and (2) a specimen from a relatively intact mucosal specimen which is adjacent to an active lesion for direct immunofluorescence (DIF) analysis. DIF analysis is essential for determining diagnostic specificity. It discloses (1) the presence or absence of immune reactants (e.g., antibody, antibody-antigen complexes, complement, fibrinogen, etc.); (2) the specific anatomic location of immune reactants within the epithelium, subepithelial zone, and perivascular regions; and (3) the specific immune reactants identified (e.g., IgG, C3, IgA, etc.). Specimens submitted for DIF analysis must be submitted in an appropriate transport medium (Zeus or Michel's preservative solution) to allow for analysis of immune reactants.

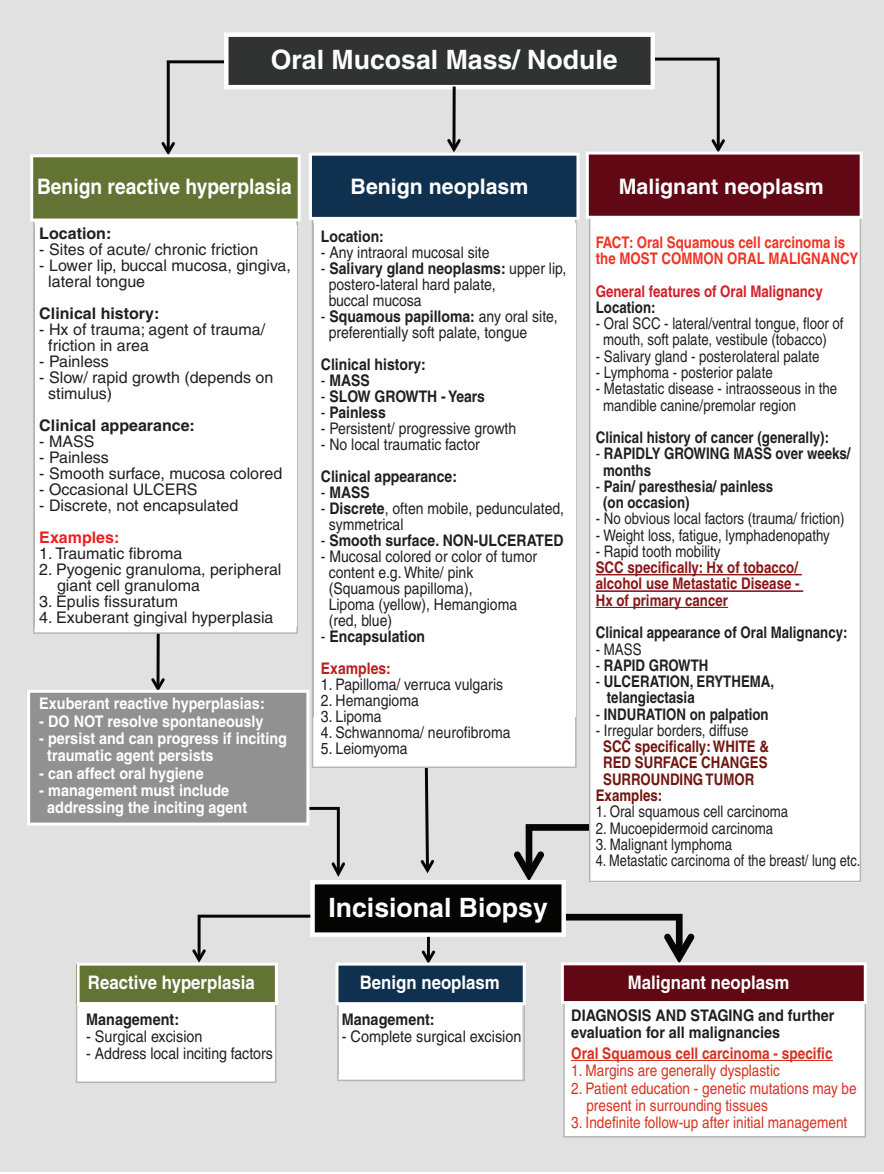
17.7 Oral Mucosal Masses/Tumors

The discovery of oral soft tissue masses can present clinicians with a diagnostic challenge, as they could be the result of epithelial and/or mesenchymal proliferation. These swellings can have varied clinical appearances, present in various oral locations, and represent a range of pathological processes: reactive/inflammatory, benign neoplasm, malignant neoplasms, developmental/genetic, or the manifestation of an underlying systemic condition. Fortunately, the vast majority of oral soft tissue masses are the result of the first three processes, namely:

1. Reactive/inflammatory—exuberant inflammatory and/or reactive hyperplastic lesions
2. Benign neoplasms—genetic mutations leading to benign proliferation of epithelial/mesenchymal tumor tissue
3. Malignant neoplasm—genetic mutations leading to malignant proliferation and infiltration of epithelial/mesenchymal tumor tissue

17.7.1 Oral Soft Tissue Masses/Nodules: The Diagnostic Process

When clinicians develop a differential diagnosis for a given oral soft tissue mass, clinicians must approach the diagnostic process in a stepwise manner as discussed below and as shown in Flowchart 17.3. As with any other abnormal finding, the



Flowchart 17.3 Oral mucosal mass/nodule. A step-by-step approach to the diagnosis of clinically indeterminate oral mucosal masses. Selected examples of reactive hyperplasias, benign and malignant neoplasms

diagnostic process must begin with a patient's presenting complaint and relevant history taking. Most patients who present with a mass are aware of it, often presenting with it being the chief complaint. Oral soft tissue growths can be alarming to patients, especially if they have grown rapidly and potentially associated with

symptoms of discomfort/pain/bleeding. On the other hand, patients with slow-growing, asymptomatic oral masses may be aware of them but overtly concerned. Regardless, clinicians should approach the diagnosis of masses/nodules by fleshing out the history of the presenting lesion.

1. *Duration*:
   (a) When did your provider discover this lesion/lesions?
   (b) How long have you been aware of this lesion?
2. *Discovery*: How did you discover this lesion?
3. *Stimuli/triggers*:
   (a) Do you recall a history of trauma?
   (b) Do you have a habit of grinding your teeth/biting your tongue/cheek/lip?
4. *Signs/symptoms*:
   (a) Do you have pain/discomfort/paresthesia associated with this lesion?
   - *Character of symptoms*: persistent/intermittent
   - *Quality of symptoms*: intense pain, burning, scales of pain

   (b) Any history of bleeding? Any discharge?
5. *Progression*:
   (a) Has the lesion grown in size or reduced in size since discovery?
   (b) Are you aware of any surface changes on this mass? Ulcer? Color change?
6. *Factors that alleviate/aggravate symptoms (if any)*

Each of the above parameters provides valuable information in developing a differential diagnosis. Among these, the following parameters are of paramount importance in determining whether a discovered mass represents a benign growth (exuberant hyperplasia or benign neoplasm) or a malignant neoplasm:

Location: certain pathological processes occur in specific locations.
Duration: benign growths are generally long-standing and painless. Malignant neoplasms tend to be more recent in history.
Rate of growth: benign growths typically grow slower than malignant neoplasms.
Surface characteristics: benign growths are typically non-ulcerated and smooth surfaced, while malignant tumors are often ulcerated.
Symptoms: benign growths tend to be painless. Malignant tumors are often associated with pain, paresthesia, and functional compromise.

Gathering the above information should help clinicians determine the appropriate diagnostic and management approach (see Flowchart 17.3).

17.7.2 Exuberant Reactive Hyperplasias

Nodules/masses that are reactive/inflammatory in origin are typically masses of submucosal (mesenchymal components) tissue that arise in response to a local inciting agent, inflammatory source, or chronic traumatic injury. Patients are generally aware of an underlying parafunctional habit or report a local traumatic agent. These

lesions tend to be painless and tend to grow very slowly over months to years. The surface mucosa is typically intact and the color of surrounding mucosa. Ulcerations and white surface plaques may be seen if these lesions are secondarily traumatized. Examples include traumatic fibromas (Fig. 17.20a, b) on the buccal or labial mucosa secondary to biting (Savage and Monsour 1985) and epulis fissuratum secondary to denture flange impingement. Exceptions to this slow growth rate include exuberant granulation tissue responses to local irritants. Examples include pyogenic granuloma (Fig. 17.21) in response to trauma/local plaque/ill-fitting restoration/extraction sockets and peripheral giant cell granulomas (PGCGs) on the gingiva secondary to plaque/rough restoration margins (Fig. 17.22) (Bhaskar & Jacoway 1966). Given their relatively rapid growth rate, pyogenic granulomas and PGCGs tend to present with ulcerated surfaces and occasional bleeding (Jafarzadeh et al. 2006; Katsikeris et al. 1988; Barker and Lucas 1967).

Although benign, it is important for clinicians to recognize that these lesions do not resolve spontaneously. These exuberant reactive hyperplastic nodules frequently require surgical excision as they can persist and progress to grow if a local inciting agent persists. Furthermore, it is essential that clinicians attempt to address the inciting agent. Failing to do so can result in these masses reappearing/recurring in

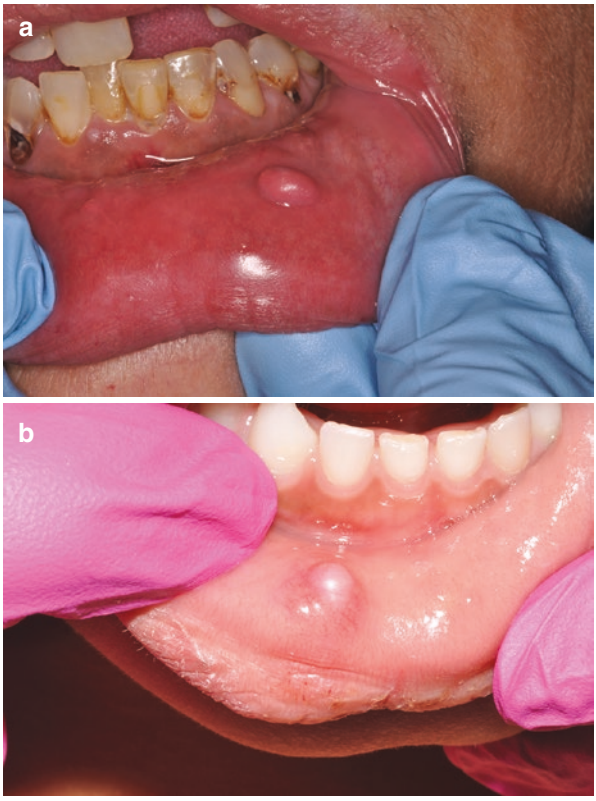


Fig. 17.20 (**a**, **b**) Traumatic fibroma. Painless, longstanding, discrete, sessile, smooth surfaced and mucosa-colored nodules on the lower labial mucosa (trauma prone location)

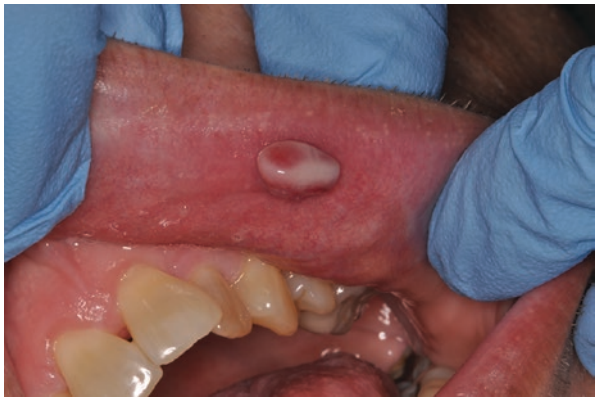


Fig. 17.21 Pyogenic granuloma. Painless, exophytic, ulcerated nodule on the upper labial mucosa. Note that pyogenic granulomas can occur on locations other than gingiva. Also, this is an older gentleman—PGs are not exclusive to pregnant women

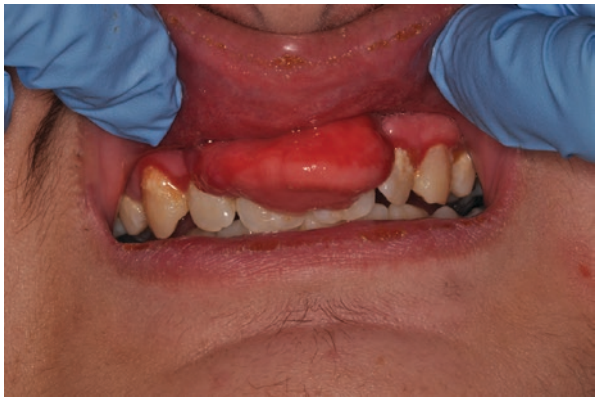


Fig. 17.22 Peripheral giant cell granuloma. Painless, longstanding, firm, focally ulcerated nodule on the maxillary anterior attached and marginal gingiva. PGCGs are comprised of hyperplastic granulation tissue with giant cells and occur exclusively on the gingival tissues

the same location. For instance, pyogenic granulomas on the gingiva tend to recur if the local plaque/calculus that stimulated the exuberant granulation tissue hyperplasia is not addressed. Such patients may require additional scaling/root planing in addition to surgical excision of the pyogenic granuloma.

Excised specimens must be submitted for histopathological examination and specific diagnosis.

17.7.3 Benign Neoplasms

Benign neoplasms are caused by genetic mutations (acquired/germ line) that result in a benign, often clonal proliferation of the affected tissue (epithelial/mesenchymal). Unlike exuberant reactive hyperplasias, benign neoplasms can arise in any oral mucosal location and are not associated with a specific traumatic insult/chronic irritant. Benign neoplasms present as slow-growing, painless masses with intact surface mucosal tissue. Patients are often aware of a slow-growing mass for several months to years and report no symptoms associated with them.

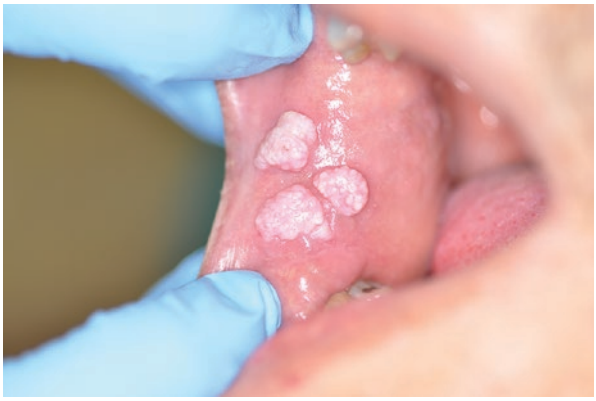


Fig. 17.23 Verruca vulgaris, multiple. Painless, discrete, exophytic, white, rough-surfaced/verrucous nodules on the right anterior buccal mucosa. Benign oral warts can present as solitary masses or can be multiple

Clinically, benign neoplasms are discrete, often mobile (encapsulation), and may be pedunculated (stalk). They tend to be symmetrical and smooth surfaced. Benign neoplasms may be ulcerated if patients have secondarily traumatized them. Depending on the tumor cell composition, benign neoplasms can range from being mucosal colored (e.g., leiomyoma, true fibroma, neurofibromas), or white/pink (e.g., HPV-associated squamous papilloma/verruca vulgaris) (Fig. 17.23), or yellow (e.g., lipoma, lymphoid proliferation), or red/blue (e.g., hemangioma), or other colors depending on the underlying proliferative component (Ethunandan & Mellor 2006; Fregnani et al. 2003; Friedman et al. 1987; Gonsalves et al. 2007; Kaban and Mulliken 1986; Toida et al. 2003).

As with exuberant reactive hyperplasias, these lesions must be completely surgically excised. They often lend themselves to easy excision given their discrete, often encapsulated nature.

17.7.4 Malignant Neoplasms

Malignant neoplastic processes are the result of cumulative genetic defects over years/decades. As described in the section on squamous cell carcinoma, the cumulative genetic deregulation within cells and tissues is often driven/accelerated by the presence of risk factors. There is a wide range of malignant neoplasms that can present as soft tissue masses on the oral mucosa, including squamous cell carcinomas, salivary gland malignancies (e.g., mucoepidermoid carcinoma, adenoid cystic carcinoma), malignant lymphoma, and oral manifestation of metastatic disease. With this in mind, it must be emphasized that the most common oral malignancy is squamous cell carcinoma (OSCC) that arises from the mucosal lining that lines the oral cavity. OSCC comprises more than 95% of all oral malignancies.

Regardless of the individual entity, malignant neoplasms of the oral cavity share certain general clinical features that are important for clinicians to recognize and act on. Almost all oral malignant neoplasms present as masses that grow fairly rapidly. Due to their rapid and infiltrative character, tumors are often ulcerated and exhibit

varying degrees of erythema and/or necrosis on the surface (Fig. 17.24a, b). Malignant tumors are frequently ill-defined and asymmetrical and have a lobulated/lumpy-bumpy character. Various surface changes that may be noted include prominent white/red plaques surrounding the masses (as seen in OSCC), bluish hue with secretions (as seen in mucoepidermoid carcinoma), or vascular surface marking/surface bleeding (resulting from the underlying angiogenesis and desmoplastic stroma associated with malignancies). Malignant tumors are frequently hard/indurated on palpation. Patients may present with symptoms of pain/paresthesia (i.e., numbness, tingling, burning), weight loss, lymphadenopathy, rapid tooth mobility, and difficulty swallowing. They may also report unintentional weight loss and fatigue, which may be an indication of systemic disease (metastatic spread). When clinicians encounter ulcerated masses on oral mucosal surfaces, it is essential to gather information on the duration of the lesion and to rule out local inciting factors. It is also important to ask patients if they have a history of other primary cancers currently or in the past. If an ulcerated mass has persisted longer than 3–4 weeks and the surface exhibits changes that are suspicious, representative incisional biopsy/biopsies must be obtained. Based on the specific diagnosis, patients diagnosed with malignant neoplasms must be referred to specialty teams for further evaluation, staging, and management. Furthermore, patients diagnosed with malignant neoplasms of the oral cavity must be followed up indefinitely following management.

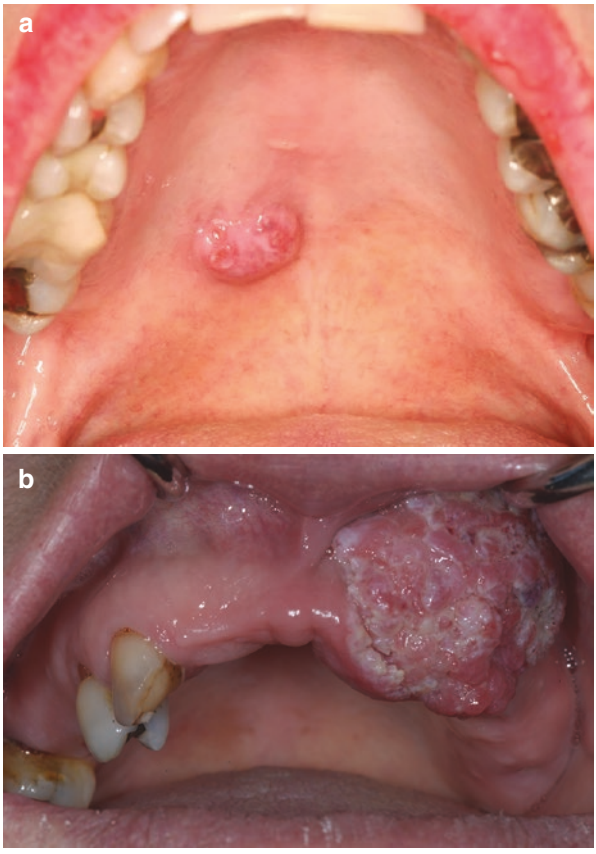


Fig. 17.24 Oral mass suspicious for malignancy, salivary gland malignancy. (**a**) This ulcerated mass on the right posterior hard-soft palate junction warrants biopsies. The biopsy revealed a mucoepidermoid carcinoma which is typical for this location. (**b**) A painful, fungating, ulcerated mass on the left anterior maxillary alveolar ridge with ill-defined radiographic destruction of the underlying bone. Biopsies revealed a squamous cell carcinoma that infiltrated the floor of the maxillary sinus and surrounding gnathic structures

17.8 Biopsy Considerations

Several decisions need to be made by the dentist prior to performing a biopsy. First and foremost, does a biopsy even need to be performed? The primary reason to perform a biopsy is to obtain tissue to establish a diagnosis once the differential diagnosis has been developed. Not infrequently the area of concern may be a normal anatomical variation, or the history and clinical exam may be so characteristic or pathognomonic that the diagnosis is obvious, and no further investigation is warranted. Even in these situations, a biopsy may be warranted to satisfy the patient's concern.

The next obvious question is who should perform the biopsy? Can the biopsy be performed by the general dentist or would a specialist be preferred? The author's (MG) preference is that if there is a high probability that the condition is malignant, then the biopsy may be better performed by the practitioner that most likely will be providing the definitive care. Other considerations in answering this question include comfort level of the dentist, location of the lesion within the oral cavity, and even the dental practice location. For example, lesions located on the tonsil pillar are much more difficult to biopsy than ones on the lip. Specialty referral may be more difficult for the patient when the patient is treated in a very rural practice as opposed to an office in a medical arts building.

Once the practitioner has decided to perform the biopsy, the next decision is what kind of biopsy? There are two primary biopsy types, an excisional biopsy where the entire area of concern is removed and an incisional biopsy where a representative sample is obtained. An excisional biopsy in most cases should be reserved for well-demarcated lesions 1 cm or less in the greatest diameter and not closely related to other significant anatomical entities, i.e., the lip commissure region. Incisional biopsy probably should not be considered for vascular lesions due to the potential difficulty in obtaining hemostasis. In the past one may have been advised not to incisional biopsy pigmented lesions that have a high probability of being a melanoma. Phlugfelder et al. state that "incisional biopsies of malignant melanoma do not negatively influence prognosis (Pflugfelder et al. 2010)."

There are a few subcategories within incisional biopsy. A fine needle aspirate (FNA) involves using a large bore needle on a syringe with the goal of aspirating diagnostic cells from within a nodule. This is frequently used for deep-seated nodules and is best performed by a specialist. A brush biopsy is used to obtain cells from the surface of a lesion. This technique has been recommended as part of a routine dental examination but is of questionable value and may lead to a false sense of security (Bhoopathi & Mascarenhas 2011; Bhoopathi et al. 2009). A punch biopsy is a special technique for an incisional biopsy that can be performed quite easily by most dental providers. Biopsy specimens should be obtained using sharp instruments. The soft tissue must be handled carefully to avoid distortion. This includes methods that may cause thermal damage.

A final consideration to be made is the transportation of the biopsy specimen to the pathologist. Biopsy specimens are usually transported in 10% buffered formalin. There is *one significant exception* to this and supports the importance of developing a differential diagnosis. In the case of vesicular-bullous lesions, where an underlying immune process is highly probable, different tissue preservation techniques are required. When performing a biopsy on an immunological based process,

a minimum of two biopsy specimens are required. One specimen is placed in the standard formalin solution and will undergo routine H&E examination. The other specimen is placed in saline gauze for quick freezing and can then be used for specialized immunofluorescent studies. An alternative to performing two biopsies is to take a slightly larger specimen and divide it in two.

Specimens can be delivered to the local hospital for histological evaluation which most likely will be conducted by a general pathologist who may not be knowledgeable in the nuances of oral pathological conditions. The alternative is to mail the specimens to an oral pathologist, but special precautions are required as formalin is a hazardous chemical.

17.8.1 Excisional Biopsy Technique

Local anesthesia should be obtained with regional anesthesia and not directly into the area of the lesions. Injecting directly in the lesion can distort the tissue and make it difficult for the pathologist to make an accurate diagnosis. The standard incision for an excisional biopsy is an ellipse that is approximately three times longer in length than width. The incision is "V" shaped from the superior aspect to the base of the lesion. There must always be an adequate border of normal tissues in all directions surrounding the pathologic condition. This normal tissue boarder can vary from a couple of millimeters for a benign condition to a centimeter or more for a malignant condition. The need for adequate margins reinforces the suggestion for referral to a specialist when the condition in question is most likely malignant.

The rationale behind the use of the elliptical incision is to allow tension-free closure. Since this technique is being recommended for lesions of 1 cm or less, the adjacent mucosa does not need to be undermined. The tissue is placed immediately in the transport medium.

17.8.2 Incisional Biopsy Technique

An incisional biopsy is indicated for larger lesions and/or where more than one representable sample is required. The basic principles are the same as for an excisional biopsy, whereas the specimen is elliptical in nature and undermining is not required (Fig. 17.25). Local anesthesia is the same as for an excisional biopsy. The sample should include both normal and abnormal tissues as this interface is important for the pathologist to make an accurate diagnosis. Multiple representative samples are taken especially for larger diffuse conditions, different textures, and/or color differences, i.e., red vs. white. The one disadvantage to an incisional biopsy is that a diagnosis can only be made on the tissue submitted. Therefore, it is very important to choose representative samples. Also, when multiple samples are taken, the biopsy lab requisition must be specific about where each specimen was obtained and only one specimen is placed in each bottle.

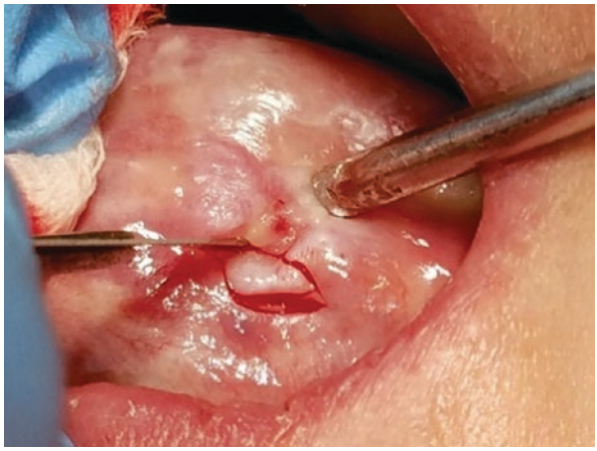


Fig. 17.25 An elliptical incision is made to remove all or a portion of a suspicious area. The length should be approximately three times the width which allows primary closure

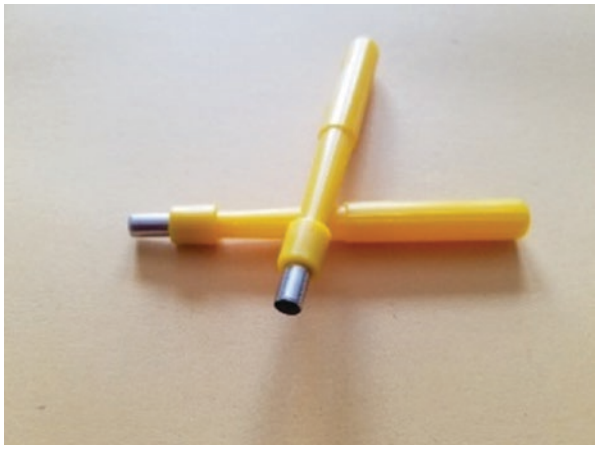


Fig. 17.26 4- and 5-mm biopsy punches

A punch biopsy is a specialized type of incisional biopsy that uses a circular cutting blade as opposed to a conventional scalpel. The incision is circular as opposed to the more ideal elliptical incision, but since the diameter of the incision is small and is being performed on mucosa, closure of the wound is not difficult and heals well. Punch biopsy blades come in a variety of diameters with a 4- or 5-mm-diameter punch being very adequate (Fig. 17.26).

A circular cut is made with the circle encompassing both normal and abnormal tissues (Fig. 17.27a, b). The depth of the cut in most cases needs to be only a few millimeters unless an excisional biopsy is being performed. The tissue core can then be picked up gently with a tissue forceps and cut off at the base with a sharp scalpel or tissue scissors. Closure can usually be accomplished with one or two sutures.

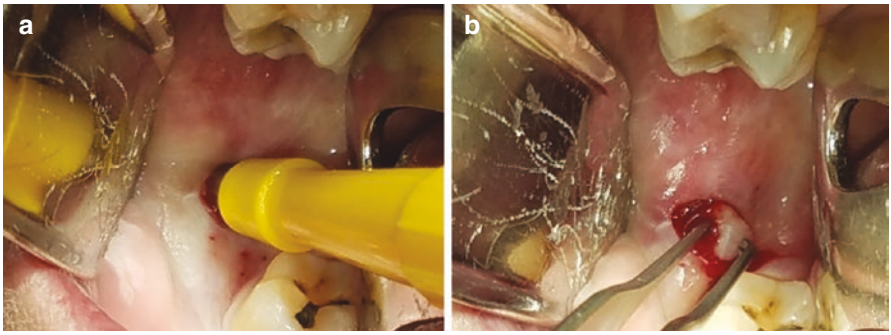


Fig. 17.27 (**a**) Making the circular "punch" incision. (**b**) The resultant "punch" biopsy specimen

17.9 Conclusion

The need for accurate diagnosis of oral pathologic conditions cannot be overemphasized. Common oral lesions can frequently be diagnosed and managed. A systematic approach to data collection and development of an appropriate differential diagnosis is the responsibility of very general dentist.

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Dentoalveolar Trauma

18

Richard T. Zhu, Frank Paletta, and Douglas L. Johnson

"In solving a problem of this sort, the grand thing is to reason backward. That is a very useful accomplishment, and a very easy one, but people do not practice it much."

—A Study in Scarlet

Abstract

Dentoalveolar injuries occur commonly in pediatric and adult populations and account for up to 5% of all traumatic injuries for which people seek medical treatment. These injuries present a significant challenge to dental practitioners and require proper diagnosis, treatment planning, and follow-up to ensure a favorable outcome. Dentoalveolar injuries span the full clinical spectrum from luxation injuries in primary dentition to tooth avulsions in permanent dentition. Guidelines have emerged to formulate a systematic approach for the appropriate and urgent care of these injuries and associated complications. This chapter focuses on the common causes, patient evaluation, classification system, and the medical, dental, and surgical management of dentoalveolar injuries.

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18.1 Introduction

The growing patient population with dentoalveolar injuries presents the dental practitioner with a series of thought-provoking challenges and opportunities to enhance diagnostic and treatment strategies. Dentoalveolar injuries are especially important to understand because of the potential complications related to aspiration risk, tooth eruption, alveolar stability, malocclusion, infection, bleeding, and facial asymmetry. The evaluation and management of dentoalveolar injuries differ among children and adults as commensurate with the different developmental stages of dentition. Timely diagnosis, classification, and appropriate management are critical to ensure salvage of the teeth and surrounding tissues to improve patients' overall masticatory function and quality of life. In this chapter, we discuss the common causes of dentoalveolar trauma, outline the key aspects of focused history and physical exam, delineate the indications for radiographic studies, discuss appropriate classification system, and highlight evidence-based treatment strategies for injuries to the teeth, alveolus, and surrounding soft tissues.

18.2 Causes

Traumatic dentoalveolar injuries are not uncommon and can occur from various causes that differ between adults and children. Among adults, these injuries are frequently the result of motor vehicle and motorcycle accidents as well as physical assaults, contact sports, and work-related accidents (Leathers and Gowans 2013). Iatrogenic injuries to dentoalveolar structures are potential complications of intraoral procedures such as dental and maxillofacial surgery and endotracheal intubation (Ozcelik et al. 2005). On the contrary, among younger children and toddlers, dentoalveolar injuries are most often caused by falls, especially during the first few years of life. The general prevalence of dentoalveolar injuries among children with primary dentition is approximately 30% and among children with mixed and permanent dentition is 5–20% (Leathers and Gowans 2013). Among adolescents with sport-related trauma, the incidence of dentoalveolar injuries is reported to be 36%. Among children, boys are affected almost twice as often as girls with a peak incidence at 2–4 years and 8–10 years (Leathers and Gowans 2013). Another cause of dentoalveolar injuries among children can result from child abuse. In fact, more than 50% of all physical injury associated with child abuse occurs in the head and neck region, of which roughly 7% of injuries involve the oral cavity (Cairns et al. 2005). Among children of school age, dentoalveolar injuries occur mostly in the playgrounds and from accidents related to bicycles, tricycles, and scooters (Hall et al. 2016). At the teenage years, these injuries are most often caused by contact sports, motor vehicle accidents, and relationship violence (Nesiama and Sinn 2010). Violent teeth grinding during seizures has also been documented to cause dentoalveolar injury in both children and adults (Lagunju et al. 2016). Finally, certain medical conditions and comorbidities may predispose one to dentoalveolar

trauma, such as radiation-induced osteonecrosis, osteoporosis, vitamin D deficiency, oral cavity cancer, and odontogenic infections.

18.3 Patient Evaluation

Meticulous and systematic diagnostic evaluation is critical to ensuring timely and appropriate management of dentoalveolar injuries. The pivotal importance of a focused history and physical examination cannot be overstated. Foremost in the initial evaluation is the primary trauma survey with particular attention to airway, breathing, and circulation. Injuries to dentoalveolar structures can result in fragmented pieces that are potential aspiration risk, mandating the priority toward securing the airway. Once airway and breathing are safeguarded, any uncontrolled bleeding must be staunched to provide better visualization and assessment of the oral cavity. Because the prognosis of dentoalveolar injuries depends on the timeliness of evaluation and management, it is imperative for diagnosis to commence immediately. However, definitive repair of dentoalveolar injuries may be delayed until the primary trauma survey is completed, and life-threatening injuries are controlled. Results of the history and physical examination will inform the diagnosis and guide the dental practitioner toward further diagnostic testing and appropriate management strategies.

18.3.1 History

Obtaining a thorough and pertinent history can provide invaluable information for the diagnosis and management of dentoalveolar injuries. However, children and individuals with impaired consciousness often do not offer a reliable history, especially after a traumatic event. In this situation, one must depend on the accompanying adult or other eyewitnesses. The history obtained should include the time interval between the dentoalveolar injury and presentation to the clinic or emergency room. This information is important since studies have shown that the success of treatment of many dentoalveolar injuries including dislocated teeth, crown fractures with and without pulp exposure, and alveolar bone fractures may be impaired by delayed treatment (MacLeod and Rudd 2012). In addition, the location surrounding the accident provides insight into the severity of bacterial infection and possible need for tetanus prophylaxis. Likewise, the nature of the accident can offer clues to the type of injury to be suspected. For example, a fall can cause injury to the anterior dentition, whereas a blow to the chin will often cause crown-root fractures of the premolar region with concomitant mandibular symphysis or condyle fractures (Murray 2013). The nature of the injury may also provide information regarding other associated occult injuries. For example, if the patient is thrown against the vehicle dashboard as an unrestrained passenger or against the guardrail from a bicycle accident, an injury to the neck should be suspected and ruled out during the initial trauma survey evaluation.

Additional pertinent history should include whether there have been teeth or teeth fragments noted at the site of the accident. If there is high suspicion for avulsed or fractured dentition, radiographic examination of the neck, chest, and abdominal region is warranted. Radiographic images provide visual guidance to unaccounted foreign bodies or fragments of teeth in body tissues and cavities. Dentoalveolar injuries can also disrupt normal occlusion. Such changes may indicate tooth displacement or dentoalveolar or jaw fractures. A pertinent medical and dental history as well as any previous oral and maxillofacial trauma and surgical procedures must be documented to establish any medical conditions or dental factors that can influence the treatment plans.

Moreover, information of the events surrounding the accident should include whether the patient had loss of consciousness, sustained potential head injury, or experienced confusion, nausea, vomiting, or visual disturbances after the accident. If any of these symptoms occurred, intracranial injury with or without cervical spine instability should be suspected and the patient referred for neurological evaluation (Straus 2015). If these symptoms persist or worsen, the patient should be taken to the emergency department immediately for urgent cranial imaging to assess for hematoma and cervical spine subluxation or fracture. In the event of potential life-threatening head and neck trauma, the treatment of the dentoalveolar injury should be delayed until more pressing assessment is completed. Finally, in children, women, and the elderly, any discrepancy between the history and severity of the injury should raise suspicion for abuse. In such circumstances, it behooves the practitioner to carefully document the finding with the patient and report to the appropriate authorities.

18.3.2 Physical Exam and Radiographic Correlates

The physical exam must prioritize the stability of the patient's overall physical status as guided by the principles of ABCDE taught by advanced trauma life support. The history can inform the examination and direct the examiner to anticipate injury patterns, thereby promoting a more comprehensive examination. For instance, abnormalities in vital signs, difficulty breathing, and visible contusions and ecchymoses may indicate intracranial injury, cervical spine injury, chest or abdominal injury, or even aspiration of an avulsed tooth (Dale 2000). The mental status of the patient should also be assessed by asking specific questions and by observing the patient's reaction and behavior during the history and examinations. Once a general examination is completed and a concomitant injury is ruled out, a thorough oral and maxillofacial examination is performed that focuses on injuries to extraoral and intraoral soft tissues, teeth, and alveolus.

Because dentoalveolar trauma does not always result in visible manifestations and can cause occult trauma, radiographic studies are warranted to provide additional information regarding injuries affecting the root portion of the tooth such as root fracture, periodontal ligaments, and status of the bone. Radiographic images can also detect the presence of pre-existing periapical disease, maxillary and mandibular

fracture, tooth fragment, or foreign bodies lodged in surrounding soft tissue. In children and young adults, radiographic examination is an indispensable method to evaluate the extent of root development, size of the root canal, and proximity of succedaneous teeth to the injured primary tooth. Radiographic imaging of dentoalveolar trauma consists of multiple radiographs at different projects such as periapical, occlusal, and panoramic (Woodward 2009). Correctly positioned periapical radiographs provide the most detailed information to adequately evaluate root fracture and dislocation of the teeth. Occlusal radiographs are also useful to diagnose a root fracture and examine the floor of the mouth, tongue, cheek, or lip and are also often made for patient comfort because they place minimal pressure on the traumatized area. Panoramic radiographs are perhaps the most useful of dentoalveolar films as they provide a broader overview of the teeth, alveolus, maxilla, and mandible. Taken together, these three radiographs are indispensable tools to a comprehensive assessment of dentoalveolar trauma in patients that can tolerate such procedures.

Radiographic interpretation requires a methodical approach to the evaluation of soft tissue and teeth, alveolus, and bone (Holan and Yodko 2017; Beeching 1981). Extruded teeth may appear as periapical radiolucency and subluxation of the teeth as a widening of the periodontal ligaments. Intruded teeth often will show minimal radiographic findings or only as blurred periodontal space. If alveolar ridge or mandibular fractures are suspected, extraoral radiographs such as panoramic view of the mandible should be taken. Although panoramic radiographs can demonstrate fractures of the jaw, alveolar ridges, and teeth, they are best suited as a screening tool. For fractures involving the condyle, subcondylar region, angle or body of the mandible, or other facial trauma, computed tomography scans produce sharper detailed images in 3D that enhance diagnosis and surgical management strategies.

18.4 Classification of Dentoalveolar Fractures

Following the diagnosis of dentoalveolar trauma, the practitioner subsequently uses a classification system to provide a universal depiction of the injury for more readily communication and surgical planning purposes. Over the years many classifications of dentoalveolar trauma and surrounding structures have been developed (Diangelis and Kland 1998; Kirthiga et al. 2015). These systems are based on a variety of factors such as etiology of injury, pathology, and therapy. The Andreasen's classification encompasses the system originally adopted by the World Health Organization (WHO) and is the most widely used classification in the literature. This classification system includes detailed portrayal of injuries to the teeth, alveolar bone, supporting structures, gingiva, and oral mucosa as well as incorporates anatomic, therapeutic, and prognostic considerations (Da Feliciano and de Caldas 2006; Andreasen 1981). The classification can be applied to both the permanent and primary dentition for evaluation of injury to both succedaneous and deciduous teeth. In this classification, dentoalveolar injuries are divided into four major categories:

Table 18.1 Classification of dentoalveolar injuries

Dental hard tissue injury	Alveolar bone injuries	Periodontal injuries	Gingival injuries
Enamel infraction	Intrusion of teeth into alveolar socket wall	Concussion	Contusion
Enamel fracture	Alveolar socket wall fracture	Subluxation	Abrasion
Enamel dentin fracture	Alveolar wall fracture	Extrusive luxation	Laceration
Complicated crown fracture		Lateral luxation	Degloving
Crown root fracture		Intrusive luxation	
Root fracture		Avulsion	

dental hard tissue injury, alveolar bone injury, periodontal injury, and gingival injury (Table 18.1).

18.5 Treatment of Dentoalveolar Injuries

Once the appropriate diagnostic information and classification have been established, a treatment plan tailored to each patient's specific surgical needs can be formulated. Factors that influence the treatment plan include the age and cooperation of the patient, whether the injury tooth is a primary, mixed, or secondary dentition, the location and extent of the injury, and any concomitant injuries or medical comorbidities. The overall goal of treatment of dentoalveolar injuries is to preserve the function of the teeth, bone, and gingiva. Although every attempt should be made to maintain all of these structures, it is sometimes necessary to only temporarily maintain the teeth for the overall benefit of the patient. Therefore, the final restorative plan should guide the decision to remove or preserve teeth and bony segments at the initial phase of evaluation and treatment. Accordingly, the teeth not useful in the final restorative plan should be jettisoned. On the other hand, the teeth designated for extraction in alveolar fractures may be retained provisionally to maintain vulnerable alveolar bone. Preserving proper alveolar contour, volume, and bulk will allow for a more efficacious dental rehabilitation. Likewise, avulsed teeth that have an extremely poor prognosis when associated with alveolar fractures may be replanted for a period of time in order to mitigate additional fracture development and maintain alveolar stability.

18.5.1 Soft Tissue Injuries

Dentoalveolar injuries can cause collateral damage to surrounding soft tissues. For instance, depending on the force of the impacted trauma, direct injury mechanism can affect the upper or lower lip, causing laceration of the lip as well as alveolar fractures (Dale 2000; Diangelis and Kland 1998). Dentoalveolar injury from indirect trauma results from direct impact against the chin forcing the mandibular teeth to

collide with the maxillary teeth. The impact of this force can cause fractures in condylar and/or symphysis regions of the mandible as well as intraoral soft tissue and submental laceration. Palpation of both of the temporomandibular joints and assessment of jaw range of motion are necessary to rule out mandibular condylar fracture. Examination of these injuries in addition to abrasions and contusions of the face, chin, forehead, and scalp is needed. A thorough analysis of these injuries is important because the site of soft tissue trauma is a key predictor of associated hard tissue injuries. Inspection of intraoral injuries must also include evaluation for deeply penetrating soft tissue wounds with embedded teeth or teeth fragments, which can be associated with occult hematoma (Leathers and Gowans 2013).

Following extraoral assessment, intraoral soft tissue examination should include assessment of any injury to the buccal and alveolar mucosa, gingiva, lips, tongue, soft palate, and floor of the mouth. If present, such injuries should be carefully evaluated for the presence of foreign bodies, debris, and teeth fragments implanted within such tissues. As described by Leathers et al., intraoral injuries are often associated with neurovascular complications, such as Stenson duct and/or facial nerve damage following buccal mucosal injury (Leathers and Gowans 2013). When visual access to the oral cavity is occluded, it is necessary to perform adequate debridement and staunch any active bleeding before evaluation. Bleeding from lacerated gingiva often indicates tooth displacement, whereas bleeding from non-lacerated gingiva suggests periodontal ligament damage or mandibular fracture. It is imperative that the practitioner accounts for all teeth at this time. Any missing teeth or teeth fragments should be considered to have been aspirated, swallowed, or displaced into the surrounding soft tissues, the nasal cavity, or the maxillary sinus. Therefore, a systematic radiographic examination of the head and neck with panoramic radiographs and chest and abdominal radiographs are warranted to rule out presence of teeth or teeth fragments that have dislodged and embedded in these tissues and organs.

The overall goal of soft tissue injury treatment is to reestablish sufficient soft tissue bony coverage in a timely manner so as to not jeopardize underlying bony tissue devitalization. Injuries to the gingival and alveolar mucosa mainly comprise of laceration, contusion, and abrasion. Laceration of the mucosa involves damage to the superficial epithelial layer including epidermis, dermis, and part of hypodermis. Treatment requires comprehensive cleansing of healthy tissues, debridement of devitalized tissues, and re-approximation of tissue edges with sutures. Because the gingival and alveolar mucosa linings are well vascularized, isolated soft tissue lacerations do not require antibiotic or tetanus prophylaxis administration. Contusion injury results when trauma impacts a region of tissue or skin that injures underlying capillaries with a resulting subcutaneous hematoma. Treatment for contusion injuries often is conservative and involves thorough cleansing and observation. An abrasion injury is less severe than either laceration or contusion injuries and is a superficial wound involving only the upper layers of the epidermis that can result from wearing, grinding, or rubbing by friction. As with contusion injuries, abrasion injuries are best managed with adequate irrigation and local cleansing, consisting of disinfectant soap for the external skin and 0.12% chlorhexidine mouth rinse for the

gingiva. Soft tissue injuries in children are managed with similar principles of close examination, thorough cleaning and debridement, and meticulous alignment of wound edges. Frequently, young children might not tolerate the repair process even when given local anesthesia and sedation and might require general anesthesia for repair in the operating room.

18.5.2 Injuries to the Teeth

Dental trauma is a commonly encountered event both in the clinic and in the emergency department. Appropriate management of dental injuries including fractures, avulsions, and displacement is a necessary skill attained in the career of every dental practitioner. Prompt and comprehensive care in the acute setting is instrumental to not only avoid adverse complications such as bleeding, aspiration, and infection, but more importantly allow for the salvage of viable tooth structure and achieve better patient outcomes. Following timely and astute diagnosis of the acute dental injury, many patients frequently require follow-up with a dentist or an oral surgeon within 24 h. Nonetheless, proper medical and surgical intervention should not be delayed. The original Ellis and Davey classification of dental trauma (1970) provides a succinct and systematic numerical categorization of dental injuries according to a variety of factors including etiology, anatomy, and management recommendations (Ellis and Davey 1970).

This dental trauma classification scheme was initially created for pediatric populations and has since been modified and adopted for adult populations as well (Table 18.2). Class I injury involves fractures to the tooth enamel only without dentin or pulp exposure. Injured teeth are non-tender to palpation and are characterized by their uneven and jagged edges which reflected the fragmented pieces. These teeth can be left alone or smoothed to mitigate rough edges. Class I dental trauma usually does not require urgent treatment and can be followed up

Table 18.2 Ellis Classification of dental fractures

Fracture class	Clinical presentation	Management
I. Enamel	No visible color change, rough edges	Elective referral
II. Enamel and dentin	Tender to touch, exposed yellow-white dentin	Dental consult
III. Enamel, dentin, and pulp	Tender to touch, exposed pink-red pulp	Dental consult
IV. Devitalized tooth with or without crown loss	Tender to touch, may show sign of necrosis	Dental consult
V. Luxation and or tooth loss	Tooth dislocation or loss	Dental consult
VI. Root	Separation of tooth from alveolus, root fractured fragments	Dental consult
VII. Displacement	Displaced tooth without fracture of crown or root	Dental consult
VIII. Crown	En-bloc fracture of crown	Dental consult
IX. Deciduous teeth	Fracture of deciduous teeth	Dental consult

within 24–48 h by a dentist or oral surgeon. On the other hand, class II through class II injuries warrants immediate dental consultation to optimize tissue viability and healing. Class II injury includes fractures that involve both enamel and dentin. These teeth can be tender and are detected as a layer of yellow dentin on examination. Class III injury frequently involves fractures through enamel, dentin, and pulp, resulting in tender teeth and exposed pinkish-red pulp at the center of the tooth. As the hub of vital structures including neurovascular bundle, connective tissue, and odontoblasts, the pulp of the tooth is susceptible to infection from intraoral flora (Zero et al. 2011). Active inflammation and infection of the pulp, termed pulpitis, can lead to chronic infection, abscess formation, and potential tooth loss (Zero et al. 2011). In Ellis and Davey III fractures, in which pulp is exposed, it behooves the dental practitioner to create a calcium hydroxide sealant layer followed by an appropriate pulpal therapy either pulpotomy or pulpectomy to protect the pulp from further insults. The indications for type and duration of antibiotic regimen for class III dental injuries remain controversial.

Class IV injury involves traumatized tooth that has resulted in devitalized tissues. Thorough extirpation of nonviable tooth and surrounding structures followed by debridement is necessary to ensure proper healing and to prevent the necrotic tissue from serving as a nidus for infection. Class V injury includes root luxation and subluxation. Class VI injury includes root fractures with or without concomitant crown fractures and tooth avulsion. For classes V and VI injuries, the management goal is to restore the tooth to its correct anatomical position as securely and expeditiously as possible, without incurring further damage to the tooth, alveolus, or gingiva (Kirthiga et al. 2015). Multiple radiographic images including panoramic views are essential to enhance visualization of the root fragments and their anatomical position within the alveolus (Holan and Yodko 2017). It is recommended that root fragments firmly entrenched in the alveolus be left alone unless they are impinging upon neurovascular bundle and are destabilizing the alveolus (Henley 2006; Jackson et al. 2005). On the other hand, clearly mobile root fragments should be carefully removed by their coronal and apical portions (Jackson et al. 2005; Henley 2006). Class VII injury involves displaced tooth. It is critical to employ a meticulous search for the mobile tooth and/or tooth fragments in nearby soft tissue as unaccounted pieces are suspected to be aspirated. Class VIII injury includes en bloc crown fractures that require prompt intervention to achieve a quick and appropriate seal to protect underlying dentin and pulp. Finally, class IX injury involves deciduous teeth fractures in children and is managed with similar principles as in adults with special care paid to not damage succedaneous teeth.

Injuries to teeth as a result of dentoalveolar trauma can be readily identified by intraoral examination. Assessment of occlusion provides additional insight into the detection tooth displacement. Although shift of teeth as a result of dentoalveolar trauma can occur in any direction, the most common movement is in a buccolingual direction (MacLeod and Rudd 2012). Displaced tooth can impinge on surrounding teeth and encroach upon soft tissues such as buccal and alveolar gingiva. In any dentoalveolar trauma event, all teeth should be tested for both horizontal and axial stability by manual palpation. If a tooth is very mobile but does not appear to be

displaced, a root fracture or periodontal ligament injury should be suspected. In the absence of tooth displacement, increased sensitivity to palpation is suggestive of injury to the periodontal ligament. This test is performed by gentle percussion of the tooth in adults or by ginger fingertip pressure when examining smaller children (MacLeod and Rudd 2012; Dale 2000).

Injuries to the tooth and pulp include crown infractions, which are microcracks seen within the dental enamel and are visualized by transillumination (Leathers and Gowans 2013). No treatment is necessary as they heal well on their own. More severe trauma can cause crown fracture, which involves cracks crossing the enamel-dentin border (Leathers and Gowans 2013). Any fractures of the crowns should be meticulously explored. Crown fractures should be evaluated for extension into the dentin and the pulp. Increased translucency in a traumatized tooth may indicate a pulp exposure (MacLeod and Rudd 2012). It is also important to note that trauma leading to crown-root fractures on one side of the jaw is frequently associated with similar fracture patterns on the ipsilateral side. When no root is involved in crown fractures, treatment entails smoothing the crown edges or repairing the entire crown with composite restoration. However, if crown fracture compromises pulp, then it is necessary to perform conventional root canal treatment (RCT) with future repair. Children ages 12 and under may not need root canal treatment since their teeth are still developing. It has been suggested that stem cells present in the pulps of children can be stimulated to complete root growth and heal the pulp following injuries or infection (Potdar and Jethmalani 2015). Multiple follow-up appointments are needed to monitor the healing process with intervention if any unfavorable changes appear.

For uncomplicated root fractures that encompass the enamel, dentin, and cementum but do not expose the pulp, buildup with full-coverage crown placement is recommended. For root fractures with pulp exposure, RCT with crown lengthening and full-coverage crown replacement is recommended (Leathers and Gowans 2013). If root fractures are severe, the involved teeth should be extirpated without compromising the alveolar segment. This is important because the fractured periapical root is a potential nidus of infection as well as serves to destabilize the neurovascular integrity of the surrounding alveolus. Accordingly, root fracture injuries can result in pulp necrosis and subsequent metaplastic replacement of pulp tissue into nonfunctional cancellous bone (Leathers and Gowans 2013). Otherwise, minimally displaced root fractures without major complications can be left in place for removal at a later date after the alveolar segment has fully healed.

Injuries to periodontal ligament tissue from traumatic forces that cause tooth dislodgment can cause a secondary resorptive process that can heal through normal physiologic manner or through pathologic fashion such as ankylosis and inflammation. Inflammatory resorption can be best treated by RCT. Pulpal revascularization and periodontal ligament healing can also be achieved through splinting. The goal of splinting is to immobilize traumatized teeth or bony segments into proper occlusion that is consistent with preinjury alignment. Indeed, as delineated by Berthold et al., current guidelines recommend that flexible or semirigid splints are best used to stabilize teeth with dislocation injuries or root fractures,

whereas rigid splints such as titanium ring splint are more effective in the treatment of alveolar fractures (Berthold et al. 2009).

In the pediatric population, the practitioner must keep in the mind the large pulp chamber to tooth ratio and the possibility that the succedaneous teeth might be compromised. Much of the principles of teeth repair in adults can be applied to children. For crown fractures that involve the enamel, smoothing rough edges is the essential treatment. For fractures involving enamel and dentin, calcium hydroxide or composite resin restoration is recommended. For teeth fractures that involve pulp exposure, coronal coverage is required. In the event of root fractures in deciduous teeth that does not involve cervical third, no treatment is needed as the apical site sprouts new tooth bud. However, when root fractures compromise formation of permanent tooth buds, the root fragments should be removed. Moreover, for luxations, subluxations, and lateral luxations, conservative management is recommended with close monitoring and follow-up. For extrusion or intrusion injuries, the treatment involves realignment and removal if the tooth impinges upon the permanent successor or becomes infected.

18.5.3 Injuries to Alveolus

Thorough visual examination can readily detect fractures of the alveolar bone protruding through the overlying alveolar mucosa. In the event that the overlying mucosa is not lacerated, manual palpation for mobility and crepitation of the alveolar fracture can confirm the underlying alveolar bone injury. Not uncommonly, severe impact causing alveolar bone fractures can also result in jaw fractures. Visual inspection for the floor of the mouth, ecchymoses and manual percussion for gross malocclusion, step-off deformities, and pain can detect maxillary and/or mandibular fractures. First and foremost, when dealing with alveolar and/or concomitant jaw fractures, systematic debridement of the bone is necessary to prevent necrosis and bacterial contamination as well as enhance visualization.

Fractures of the alveolar process most commonly occur in the incisor and premolar regions. The hallmarks of alveolar fracture treatment involve early reduction and stabilization. Reduction can be achieved through either open or closed technique. The closed method minimizes additional incisions and trauma and involves physical manipulation and rigid splint immobilization for 4 weeks (Leathers and Gowans 2013). On the other hand, the open method is indicated in cases of severe tooth displacement and/or comminuted fractures, which precludes closed reduction. Treatment requires creating an incision below the fracture line to achieve adequate exposure of fractured segments. The alveolar fractures are subsequently repositioned, reduced, and secured with a miniplate. Any mobile teeth can be stabilized by a secondary acid-etch/resin splint, and proper occlusion, teeth alignment, and primary splint placement are attained. The ideal splint must be able to stabilize the injured tooth in the normal pre-injured position, provide adequate fixation throughout the immobilization period, and not interfere with occlusion, articulation, or endodontic physical therapy. Following splint placement, copious irrigation is needed

to cleanse the open wound prior to closure by sutures.For severe blunt facial trauma resulting in significant alveolar fracture with bony exposure, adequate soft tissue coverage with mucosal advancement and interpolation flaps is recommended (Herford 2004). Alveolar fractures in the pediatric population are quite rare and involve the same treatment paradigms as for adults.

18.6 Conclusion

Dentoalveolar injuries are among the most serious emergencies that require the expertise of an experienced dental practitioner for judicious diagnosis and management. Examples of such injuries include lacerations, contusions, and abrasions to the surrounding soft tissues, infractions and fractures to the teeth, and fractures of the alveolar process. These injuries commonly arise from motor vehicle accidents, assaults, falls, contact sports, and interpersonal violence. Dentoalveolar injuries also accompany life-threatening complications such as aspiration and bleeding. Time from dentoalveolar trauma to treatment is a major factor in the outcome of many of these injuries. Focused history and physical examination should be further corroborated with pertinent radiographic findings to arrive at the correct diagnosis. Classification of the dentoalveolar trauma provides a common platform for implementing appropriate care plans according to the class of injury. Treatment is tailored specifically to the nature and severity of dentoalveolar injury and involves debridement, removal of nonviable teeth fragments, stabilization, realignment, and splint fixation. Finally, adequate follow-up is important for dental practitioners to improve functional and aesthetic outcomes and provide the best longitudinal care to patients.

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Part IV

Advanced Oral Surgery

Disturbances of the Temporomandibular Joint Apparatus

19

M. Franklin Dolwick and Danielle Freburg-Hoffmeister

"Let us get a firm grip of the very little which we know, so that when fresh facts arise we may be ready to fit them into their places."

Sherlock Holmes in—The Adventure of the Devil's Foot

Abstract

This chapter focuses on diagnosis and treatment of temporomandibular joint disorders (TMD) including myofascial pain disorder (MPD) and disorders of the joint itself. Noninvasive treatments include physical therapy, pharmacotherapy, massage, thermotherapy, and occlusal appliance therapy. Lastly minimally invasive procedures such as arthrocentesis and arthroscopy as well as surgical procedures such as arthroplasty and total joint replacement will be discussed.

19.1 Introduction

Temporomandibular joint disorder (TMD) is a broad term that encompasses a wide array of pain which is localized to the head and neck region. It can present as tension, pressure, or aching in the head and neck region. TMD is more common in females versus males with age range from 20 to 40 (premenopausal women) (Liu and Steinkeler 2013). It has been shown that approximately 5% of the total population seek medical treatment for TMD, but over 30% of the

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general population experience at least one finding of TMD and never seek treatment (Dolwick and Dimitroulis 1996). Therefore it is clear to see that the general dentist will encounter and need to understand how to screen and treat patients with TMD. To simplify temporomandibular joint disorders, it will be discussed in two general categories: disorders of the muscles of mastication and disorders of the joint itself. Disorders of the masticatory muscles include myofascial pain associated with parafunctional activities, myositis, and neoplasia. Temporomandibular joint disorders include disk derangement disorders, osteoarthritis (noninflammatory disorders), inflammatory disorders hypermobility, hypomobility, traumatic disorders, congenital or developmental disorders, and neoplasia of the TMJ. This chapter will focus on the history and physical examination of the patient who suffers from TMD and will discuss ways to help differentiate muscular versus joint disorders. Often times TMD is caused by both muscular and joint disorders. Once the classifications have been clarified, the treatments will be discussed.

19.2 Clinical Evaluation

19.2.1 History from Patient

Prior to ordering tests and radiographic studies, it is important to perform a history and physical. Much of the patient's symptoms will help differentiate disorders within the actual joint versus muscles surrounding the joint (this may also be termed intra-articular and extra-articular). It is important to have the patient fill out a preexamination questionnaire as shown (Fig. 19.1). As shown in the figure, a patient circling the area of pain will help determine the cause of pain. Generally a patient who circles a wide section of the head will suffer from muscular dysfunction, whereas a patient who circles directly over the joint will tend to have a dysfunction limited to the TMJ. Other clues in the preexamination questionnaire which will differentiate joint dysfunction from muscular include joint noises.

After review of the questionnaire, it is important to interview the patient and find out the patient's chief complaint. The history of present illness should include onset of pain and the exact location of pain. The patient should point with one finger to the area of most perceived pain. The history also should include review of any changes in patient's living situation, recent trauma, and recent stressors. All prior medications should be reviewed as well as current medications. This is important as several medications may cause bruxism. Ask the patient about prior use of corticosteroids systemically as well as steroid injections to the TMJ in other joints. It is important to discuss all surgeries the patient has undergone in addition to surgeries involving the head and neck and/or TMJ.

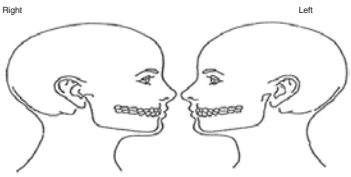
WHAT DOES YOUR PAIN FEEL LIKE?

Some of the words below describe your present pain. Circle ONLY those words that best describe it. Leave out any category that is not suitable. Use only a single word in each appropriate category– the one that applies best.

1	2	3	4
Flickering Quivering Pulsing Throbbing Beating Pounding	Jumping Flashing Shooting	Pricking Boring Drilling Stabbing Lancinating	Sharp Cutting Lacerating
5	6	7	8
Pinching Pressing Gnawing Cramping Crushing	Tugging Pulling Wrenching	Hot Burning Scalding Searing	Tingling Itchy Smarting Stinging
9	10	11	12
Dull Sore Hurting Aching Heavy	Tender Taut Rasping Splitting	Tiring Exhausting	Sickening Suffocating
13	14	15	16
Fearful Frightful Terrifying	Punishing Grueling Cruel Vicious Killing	Wretched Blinding	Annoying Troublesome Intense Unbearable
17	18	19	20
Spreading Radiating Penetrating Piercing	Tight Numb Drawing Squeezing Tearing	Cool Cold Freezing	Nagging Nauseating Agonizing Dreadful Torturing

a

Please use the figure below to draw a circle around those areas where you have pain.



b

PLEASE CIRCLE THE CORRECT RESPONSE WHERE INDICATED:

c

1. Do you have any pain now? Yes No

   a. If YES, please answer Question #2, otherwise go directly to Question #3

2. On a scale of 1 -10, please rate your pain by placing an "X" on the line indicating, (A) your present pain and (B) your usual pain. Mark each "X" with the corresponding letter:

No Pain — Most Intense Pain Imaginable

3. Are you awakened from sleep with pain? Yes No
4. Are you aware of clenching or grinding of your teeth? Yes No
5. Is your pain worse on functioning (chewing, talking)? Yes No
6. Do you have limited opening? Yes No
7. Do you have any dietary limitation related to your jaw problem? Yes No
8. Does your jaw make noises on functioning? Yes No
9. Have you experienced jaw locking? Yes No
10. Please rate your ability to chew by placing an "X" on the line indicating your present ability to chew:

No Difficulty — Unable to Chew

Fig. 19.1 (**a**–**c**) Example of pre-examination questionnaire packet received by every patient which aid in differentiating muscular from joint pain

19.2.2 Physical Examination

The examination is an important part in differentiating masticatory muscle from joint disorders. You should always perform the exam in the same order to avoid missing findings which could contribute to diagnosis. If starting with the extraoral exam, it should include palpation of all muscles of mastication and palpation of the head and neck verifying that no lymphadenopathy or masses are present. While palpating the muscles, pay attention to trigger points as well as masseter and temporalis enlargement, both of which will favor a diagnosis of myofascial pain disorder (Fig. 19.2). A very important and simple test to help with differentiating muscular pain versus joint disorder is to test pain on occlusal loading. As seen in the photo, if the patient has pain on the same side as the side which is being loaded, the source of pain is likely muscular. Conversely, should pain be present in the opposite joint as demonstrated (Fig. 19.3), this is called Mahan's sign and would be consistent with joint dysfunction (McCain and Stroia 2012). It is important to palpate over the joint capsule and ask patient if they experience tenderness to palpation. While palpating over the joints, ask the patient to open and close. You should listen for

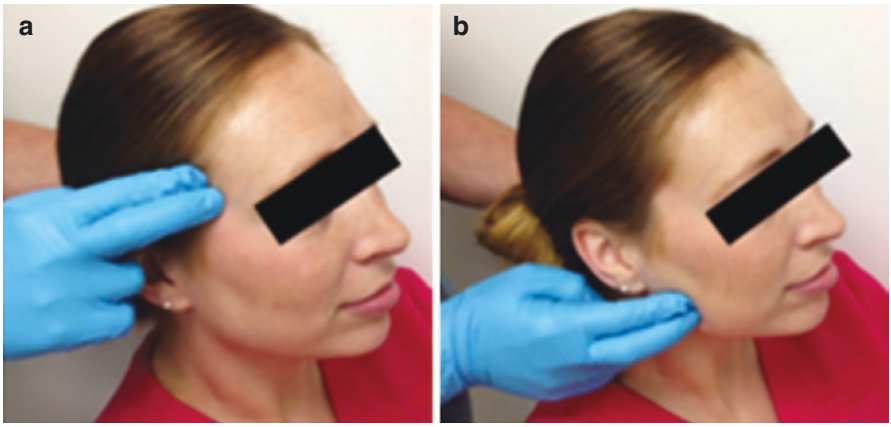


Fig. 19.2 Palpation of the temporalis in picture (**a**) and of the masseter in photo (**b**)

clicking (single sound) and crepitus (multiple sounds which are gravel like) (Tucker and Dolwick 1993).

Next attention should be directed intraorally. Examine the oral cavity assessing the teeth for decay, recession, or other sources which may be contributing to orofacial pain. Wear facets may be present and are consistent with bruxism. One

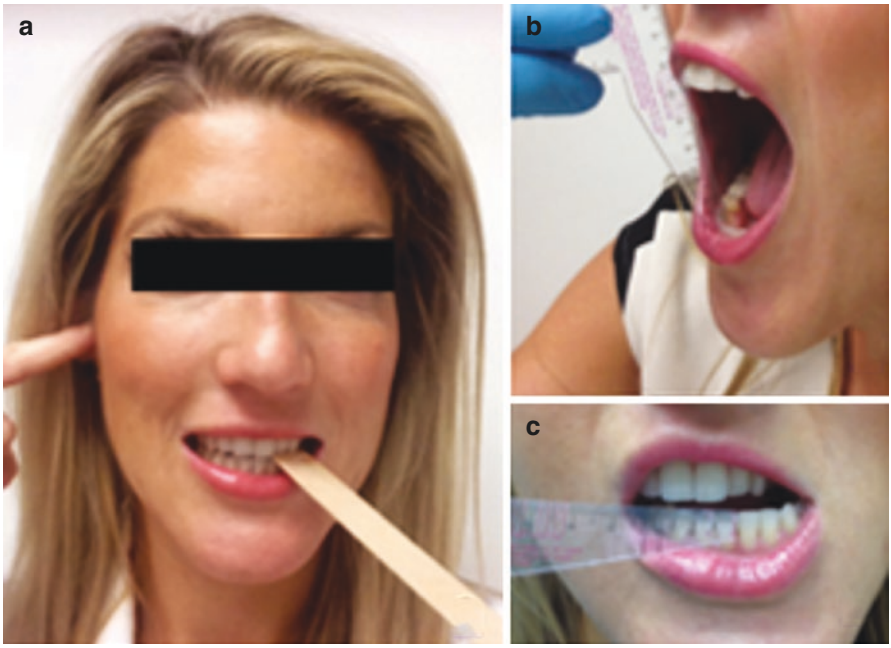


Fig. 19.3 (**a**) Example of Mahan's sign: occlusal load causes pain in the opposite TMJ indicating an intrinsic joint dysfunction. (**b**) Testing MIO: maximum incisal opening. (**c**) Lateral excursion

should note the patient's Angle classification, presence of cross bite or open bite, occlusal interferences, and occlusal stability. If the patient has a class II malocclusion, the examiner should find out if this has always been present or if it has gradually changed with time. A class II malocclusion which has gradually developed should raise suspicion of idiopathic condylar resorption and prompt further imaging (Mercuri 2008). The vertical opening should be assessed. The patient should actively open to the maximum extent without pain and then where they perceive pain. Joint noises should be observed.

19.2.3 Diagnostic Imaging

After the complete history and physical is performed, the next step is to perform any imaging which may aid in diagnosis. The choice of imaging is based on the clinical findings and should always be selected based on the exam findings.

19.2.4 Panorex

Generally, a panoramic radiograph serves well as a screening tool (Fig. 19.4). It will help assess the dentition and rule out any possible lesions which were missed on physical exam. It will also aid in assessing for any bony pathology which may possibly be contributing to the orofacial pain. The panoramic radiograph allows the clinician to assess for a narrowed joint space, flattening of the condyle, and/or osteophytes all of which may be signs of osteoarthritic changes.

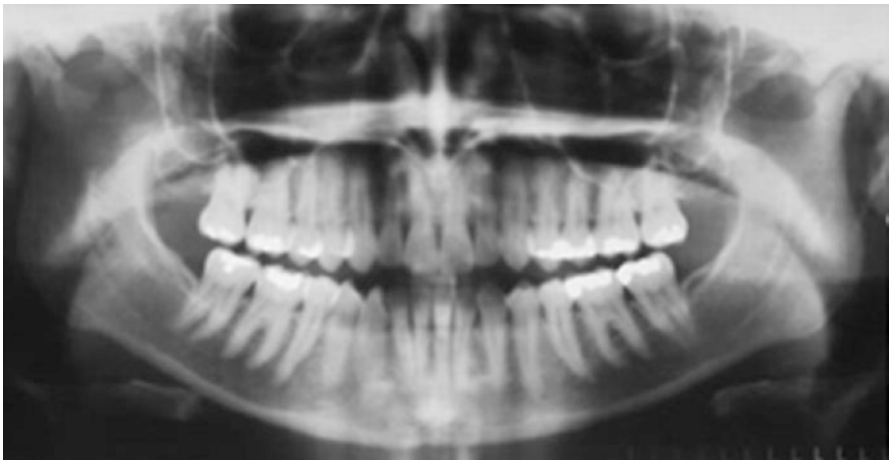


Fig. 19.4 Panorex demonstrating osteoarthritic joint changes

19.2.5 Magnetic Resonance Imaging (MRI)

If soft tissue joint abnormalities (internal derangement of the joint) are suspected, an MRI would be indicated. It is important to inform the radiology technician that the exam is to assess the TMJ disk movement as well as joint effusion. The slices should be perpendicular in the sagittal plane and parallel to the coronal plane (Moore 2006).

A T1-weighted and T2-weighted image should be performed with the patient open and closed. While the disk position and morphology may be better assessed with a T1 image, the T2 is better for displaying joint effusions as seen below (Fig. 19.5).

The included images are T1-weighted images and will display disk position. Figure 19.6a shows the closed joint with the disk in the correct location with regard to the fossa and articulator eminence. Image b shows the condylar after translation forward. The disk remains superior to the condyle and translates down the eminence with the condyle. Conversely Fig. 19.6c and d shows pathology. Figure 19.6c shows the patient in a closed position, but the disk is anterior to the condyle. When the condyle comes forward (Fig. 19.6d), the disk is reduced and superior to the condyle. Figure 19.6e and f shows an example of disk displacement without reduction in which the disk is anterior to the condyle in closed position and remains so as the condyle moves anteriorly along the eminence. Gadolinium-based contrast agents may be used in the T-1 weighted image to differentiate joint effusion versus synovial proliferation which may suggest a more severe inflammatory process. The joint effusion will not light up with contrast, but the synovial proliferation will.

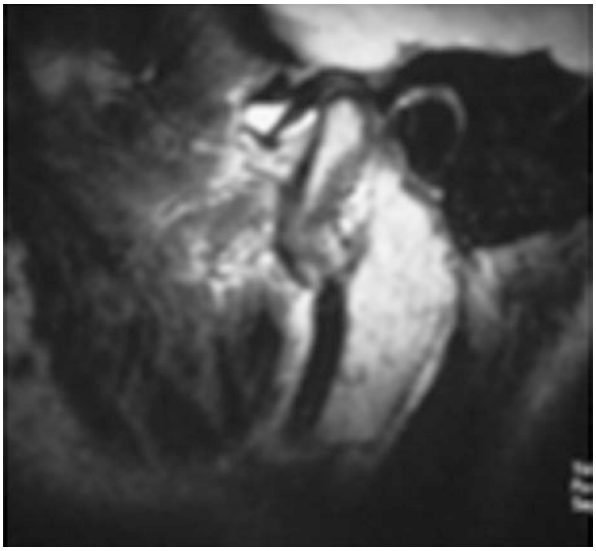


Fig. 19.5 Joint effusion in superior joint space demonstrated on T2 weighted image

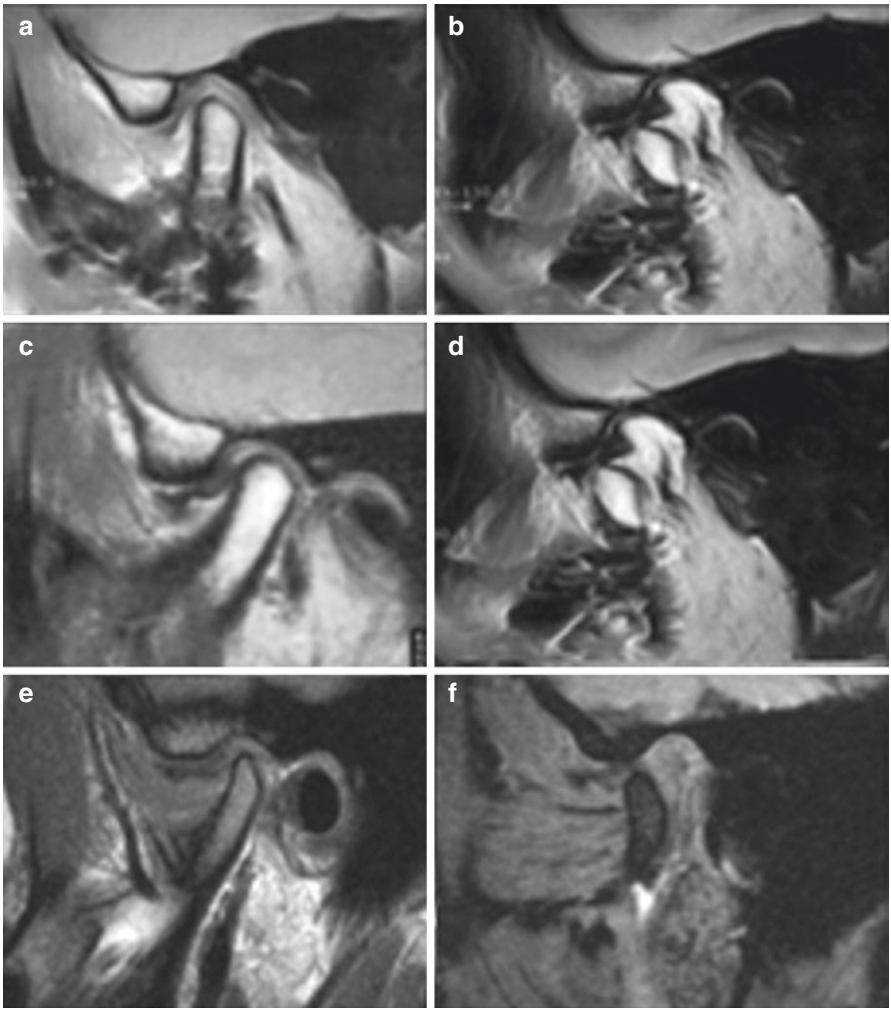


Fig. 19.6 (**a**) Closed normal condyle and disk relationship. (**b**) Open, normal position. (**c**, **d**) Disk displacement with reduction, (**e**, **f**) disk displacement without reduction

Rheumatoid arthritis is an example of a condition with severe inflammation resulting in synovial proliferation (Bag et al. 2014).

19.2.6 Computerized Tomography (CT)

A CT is best to assess bony changes and offers the ability to use 3-D reconstruction (Bag et al. 2014). This would be indicated if the panorex showed concern for possible joint ankyloses or condylar radiolucency. If infectious process is considered,

CT with contrast is indicated. A CT is also necessary if patient requires total joint reconstruction (Moore 2006).

19.2.7 Nuclear Medicine Bone Scan

If there is concern for condylar hyperplasia or another lesion causing rapid bone growth, a bone scan should be ordered. The most common radiolabeled marker is technetium-99M (Tc-99m). This is injected intravenously and will display areas of the bone with rapid turnover consistent with condylar hyperplasia, infectious process, or neoplasia (Moore 2006).

19.3 Developing a Differential Diagnosis

After the history and physical as well as imaging or other diagnostic aids, it is then time to review the information and begin to make a diagnosis for the patient. The most straightforward approach to the TMJ is to assign the pain into either intra-articular or extra-articular causes. Extra-articular causes include muscular pathology (myopathy) or myofascial pain disorder. Intra-articular causes of TMJ disturbance are disk dislocation, disk morphologic changes such as perforation, or inflammatory changes resulting in osteoarthritis. The cause of pain may also be a combination of the aforementioned conditions.

19.3.1 Myofascial Pain and Dysfunction

Myofascial pain and dysfunction (MPD) generally presents as diffuse, poorly localized pain. Patients cannot isolate the pain with one finger but rather point to a region or several regions of their head and neck. Generally patients will draw their pain in a muscle region rather than over the joint itself as with internal derangement of the joint. Patients will generally describe their pain in a cyclic fashion with pain worse in the morning which is related to muscle strain associated with bruxism during sleeping hours. Another symptom patients may report is tiredness and fatigue, again emphasizing the importance of patient history and pre-appointment paperwork. On exam of the patient, you will notice trigger points or areas that the clinician palpates and causes radiation of pain throughout a muscle region as well as tight, hypertrophied muscular bands (Clark 2008). Patients will also demonstrate decreased range of motion, possibly have joint noises, and have wear facets. The patient will have ipsilateral pain on occlusal loading.

The leading cause of MPD is parafunctional activity, namely, tooth clenching and/or grinding. It is important to find out when the patient grinds or clenches in order to attempt to treat. The occlusal guard should be worn at times when patient is known to grind whether during stress of the day or while sleeping. Muscular pain and parafunctional activity can also be caused by a cyclic pattern of pain involving

the internal derangement of the TMJ. As patients continue to grind and clench, they place excessive load on the TMJ. This results in hypoxia of the joint thus leading to free radical production on reperfusion of the joint. The free radicals break down hyaluronic acid which leads to decreased joint lubrication (Leeuw 2008). Ultimately the disk morphology is altered, and disk displacement and degeneration then occur. With the joint breakdown, the patient's parafunctional activities hence affect the masticatory muscle function completing this cycle of pain.

While MPD is similar to fibromyalgia with regard to painful symptoms and trigger points, it is different in that MPD is a regional myalgia and fibromyalgia involves the entire body. Fibromyalgia also is associated with central sensitization of pain which means that elevated neurotransmitter levels and modulation of neuro-receptors exist in the central nervous system in response to chronic noxious stimuli. This neuromodulation makes the patient more susceptible to pain in other sites, thus developing generalized pain (Clark 2008).

Another cause of muscular pain surrounding the TMJ may be due to myositis. This may be from direct trauma to the muscle such as following a motor vehicle collision or may be due to muscular irritation after injection of local anesthesia (Clark 2008). This transient pain generally will resolve with noninvasive intervention such as nonsteroidal anti-inflammatory agents (NSAIDs) and rest.

19.3.2 Internal Derangements and Osteoarthritis

Internal derangement is a very broad category and includes any abnormality within the TMJ. Pain is frequently described as continuous, worsening with function and localized to the joint itself. Joint noise may or may not be present. The condition also is associated with alteration in the joint mechanical function such as deviation on opening, intermittent locking, and a closed lock. As stated in the physical exam portion, there will be tenderness over the temporomandibular joint, there will be pain on the ipsilateral TMJ on occlusal loading, and there will be joint noise or a history of joint noise. The cause of internal derangement is thought to be related to trauma in the form of macro (direct blow) versus micro (clenching or grinding repeatedly). This results in force onto the joint which causes hypoxia which leads to free radical generation. Free radicals regrade hyaluronic acid which leads to decreased joint lubrication. It is thought that this process causes adhesions in the superior joint space as well as disk displacement. The stages of internal derangement were quantified by Wilkes and are summarized in the following table (Table 19.1) (Wilkes 1989).

The disease-free condyle and disk move together with opening and closing. In a closed position, the disk's posterior band lies directly over the condylar as seen in the MRI (Fig. 19.6a, b). Just anterior to that is the intermediate zone of the disk which is a superior and anterior position. The disk then moves forward with the condyle with opening but to a lesser degree thereby remaining over the condyle for the entirety of the opening and closing movement. With disk displacement with reduction, the disk is anteriorly positioned with respect to the condyle in the closed

Table 19.1 Wilkes staging

Stage	Clinical findings	Radiographic findings (MRI/CT)	Surgical/anatomic findings
Early	Reciprocal click, no pain, full range of motion (ROM)	Anterior disk displacement (ADD)	Normal morphology
Early/ intermediate	Increased joint noises, episodic pain, early ROM limits, decreased MIO	Early disk changes and ADD	ADD, thickening posterior band
Intermediate	Increased episodic pain further ROM limitations, closed lock, decreased MIO	ADD with major disk changes, thickening posterior band	ADD, adhesions, disk intact without bony changes
Intermediate/ late	Chronic pain and functional limitations, decreased MIO	Increased changes in disk morphology, ADD with bony changes on CT	Morphologic changes without disk perforation, bony changes, adhesions
Late	Crepitus, variable pain, functional limitations	Disk perforation, bony changes on CT	Disk perforation, bony erosions

Modified from Table 1 of Criteria internal Derangements of the Temporomandibular joint. Arch Otolaryngol Head Neck Surg—Vol 115. April 1989

position. On opening, a click is heard when the posterior band is passed and the condyle is able to sit beneath the disk (Leeuw 2008). When closing, a reciprocal click is heard when the disk resumes to its malposition anterior to the condyle (Tucker and Dolwick 1993). Generally in these patients, an opening over 40 mm is observed, and pain is minimal.

Disk displacement without reduction occurs when the disk is anterior to the joint in closed position. When attempts are made to open, the condyle is never able to pass the posterior bands, and therefore the disk never sits over the top of the condyle as in a disease-free state. The history of patient will include that they used to have a click on opening and that the clicking went away and their maximum interincisal opening (MIO) decreased. The clinical exam for patients with displacement without reduction will include a lack of clicking/popping, MIO <30 mm, and pain to the ipsilateral joint on loading.

Generally no imaging is required for diagnosis of displacement. A plain film (panoramic radiograph) may be taken and will show normal appearance with very mild flattening of the superior condyle (Leeuw 2008). If confirmation of the displacement is required, then an MRI is indicated.

Whether disk position and pain are related is a matter of debate. It has been shown that 30–50% of people may experience clicking without ever experiencing pain. It does not appear that surgeries to reposition the disk reduce pain but rather that simple procedures like joint lavage (arthrocentesis) and arthroscopy with lysis of adhesions have more success with pain reduction. Mandibular dysfunction (limited opening) has also been associated with disk displacement, but it has been shown that lavage and lysis of superior joint space adhesions during arthroscopy or arthrocentesis have effectively treated closed lock. There is an unclear relationship

between osteoarthritis and joint position with theories that the disk helps to protect the condyle and displacement expedites joint degeneration. It is also unclear as to whether disk position may interfere with growth of the joint as there are limited studies comparing symptomatic versus asymptomatic patients with disk displacement (Dolwick and Dimitroulis 1996).

19.3.3 Low Inflammatory Disorders (Degenerative Joint Disease and Osteoarthritis) and High Inflammatory Disorders (Systemic Arthritic Conditions)

The TMJ is affected by conditions which are low inflammatory processes which develop slowly and are isolated to the TMJ. These conditions include osteoarthritis and degenerative joint disease of the TMJ. These conditions are generally detectable on clinical exam with decreased range of motion, joint popping, and crepitus. Patients will have a history of joint pain which worsens through the day and with function as well as joint noises. In severe osteoarthritic changes, the resorption of the condyle can decrease the vertical height of the ramus and therefore cause apertognathia (anterior open bite). Osteoarthritic changes of the TMJ noted radiographically on panoramic imaging may be flattening or irregularity of the condyle, decreased joint space, or osteophytes. A CT may show areas of radiolucency indicating degeneration (Mercuri 2008). Degenerative joint disease, namely, joint perforation, can be visualized with diagnostic arthroscopy or open joint surgery. MRI T2-weighted images will show joint effusion which is suggestive of disk perforation (Fig. 19.5). Low inflammatory disorders are associated with low leukocytes values on lab examination (Mercuri 2008). Move sentence up to the previous paragraph.

Conversely in high inflammatory states such as idiopathic juvenile arthritis, rheumatoid arthritis, or gouty arthritis, there will be elevated inflammatory factors which will aid in diagnosis. The patient will have bilateral TMJ involvement as well as bilateral joint involvement elsewhere in the body (knees, wrists) with erosive changes present on panoramic imaging. If patients present with multiple affected joints, it is important to send them to their primary care provider for additional investigation into their disease process to aid in systemic treatment.

19.3.4 Hyper- and Hypomobility Disorders

Hypermobility of the TMJ can be divided into acute dislocation, chronic recurrent dislocation, and chronic dislocation. Acute dislocation can occur following wide opening such as eating or even during dental procedures. This is very painful and should be treated as soon as possible. The treatment consists of the dentist's thumbs being applied to the posterior mandible, either over the teeth or on the ramus, and fingers to be along the anterior aspect of the inferior border of the mandible. Then a clockwise rotational pressure is applied to overcome the articular eminence

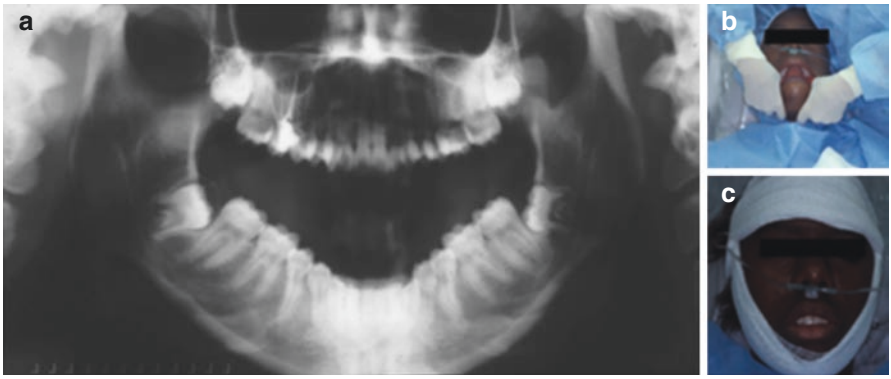


Fig. 19.7 (**a**) Anterior dislocation of the condyle from fossa, (**b**) reduction of the condyles moving in a clockwise direction with thumbs over posterior teeth and fingers supporting inferior surface of mandible, (**c**) jaw support for post-reduction care

(Fig. 19.7). Post-op imaging can be performed to verify reduction, but the clinical exam should be sufficient as the patient is able to occlude again (panoramic radiograph from slide #9). Post-op care includes limited opening for 3–4 weeks with aid of a jaw bra, NSAIDs, and muscle relaxants. Patients with chronic recurrent dislocations will experience dislocation as described above multiple times a week or even day. A chronic dislocation is when a patient dislocates and remains so for several weeks without reduction. These cases should be referred to an oral surgeon.

TMJ ankylosis may be caused intra- vs extra-articular sources. True ankylosis (intra-articular) is caused by fibrous or osseous tissue which eliminates the joint space thus fusing the condyle to the fossa space. This prevents any movement of the mandible. False (extra-articular) ankylosis occurs generally with coronoid hyperplasia in which treatment is coronoidectomy (Fig. 19.8). It may also occur following facial trauma in the case of a zygomaticomaxillary complex impingement.

19.4 Noninvasive Treatment

The majority of patients will not require surgical intervention and will recover with conservative treatment. Muscular disorders do not benefit from surgical intervention. They require a combination of pharmaceuticals, physical therapy, cognitive behavioral therapy, occlusal therapy, massage and thermal therapy, stress reduction, and occasionally psychological counseling (Clark 2008). The majority of patients with disk derangement will recover without surgical intervention. After diagnosis of disk displacement which is made clinically and/or radiographically (MRI), patients are instructed to avoid parafunctional activities (grinding/clenching) and to maintain space between their teeth unless swallowing. They are encouraged to have a soft diet to avoid loading the joint and exacerbating pain.

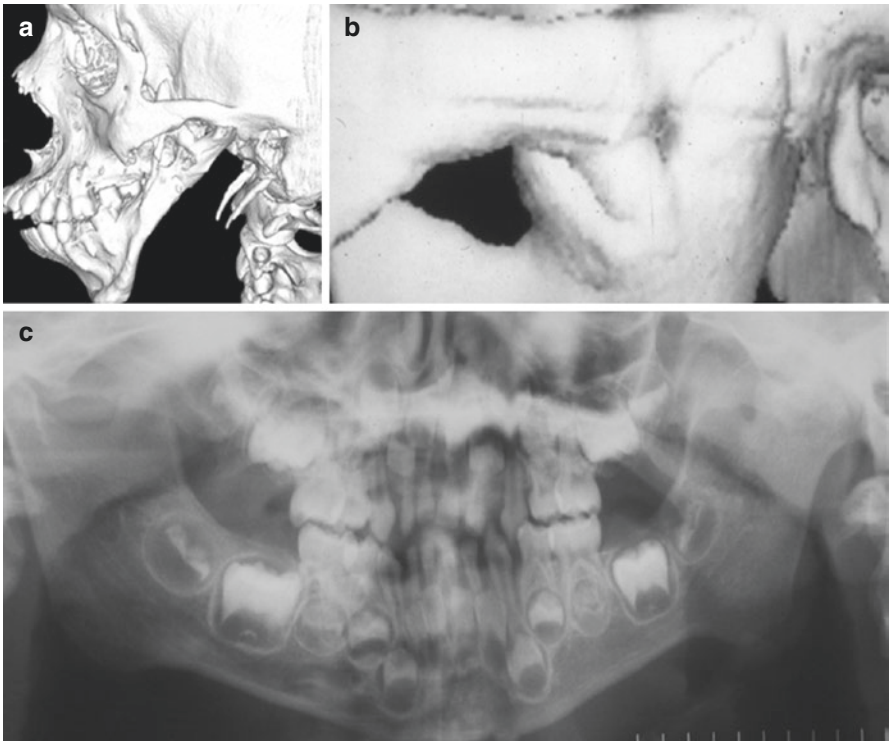


Fig. 19.8 (**a**) Coronoid hypertrophy, not true TMJ ankylosis, (**b**) CT with 3D reconstruction showing true (osseous) ankylosis, (**c**) panorex showing left TMJ osseous ankylosis

19.4.1 Physical Therapy (Professional and Home Directed)

Physical therapy (PT) is very important for both MPD and internal derangement as well as for post-op rehabilitation as in total joint replacement. PT is important to improve range of motion and alleviate symptoms. Patients will then be placed on home exercise routines which may be assigned by the physician, dentist, or physical therapist. The physical therapist will review the patient's history, posture, and habits which may be altered in order to decrease pain and increase range of motion (ROM) (Wright and North 2009). PT also involves manipulation and stretching of muscles and tension bands. A therapist or dentist may suggest a daily regimen. One recommended exercise to aid with masticatory muscle strain involves the patient placing their tongue to the roof of their mouth and attempting to open without disengaging the tongue. The neck should also be addressed with chin to neck exercises. It is important to stress to the patient that the stretching must be repeated once every few hours rather than once per day for a longer session (Clark 2008).

19.4.2 Thermal and Massage Therapy

It has been shown that ice packs, moist heat, and heating pads are effective in the management of pain for MPD by increasing vascularity into the muscles of mastication. Patients are instructed to perform local treatments with hot or cold packs onto the affected muscles for 20 min twice daily (Clark 2008). Patients may seek professional massage therapy or perform their own massage of muscular trigger points with moist warm towels.

19.4.3 Occlusal Splints

Another form of therapy is fabrication of a custom-made occlusal splint. Patient may have their general dentist fabricate the appliance or may be referred to a dentist who consistently treats patients with TMJ discomfort. The patient must be counseled on consistent use of occlusal guards and wearing it at times of known bruxism. Patients with painful anterior disk displacement with reduction may benefit from an anterior repositioning appliance which protrudes the condyle in a closed mouth position. This reduces pressure on the retrodiscal tissues thereby allowing remodeling and decreased pain. This is not meant to eliminate clicking (Leeuw 2008). The full coverage stabilization splint (Fig. 19.9) is effective for patients with osteoarthritis, internal derangement, and MPD. Relief occurs in taking some of the load off of the joint as well as achieving a more balanced occlusion, thereby decreasing muscle hyperfunction (Al-Ani et al. 2005).

A systematic review was performed comparing splint therapy to other noninvasive treatments in MPD. It did not show statistical significance of splint therapy being more effective when compared to other noninvasive treatments but did conclude that splint therapy was more effective than no treatment at all (Al-Ani et al. 2005). Another systematic review found inconclusive data to support one type of splint versus another and found no difference between hard and soft splints but agreed with the first review that splint therapy was more effective at pain reduction than no treatment (Turp et al. 2004).

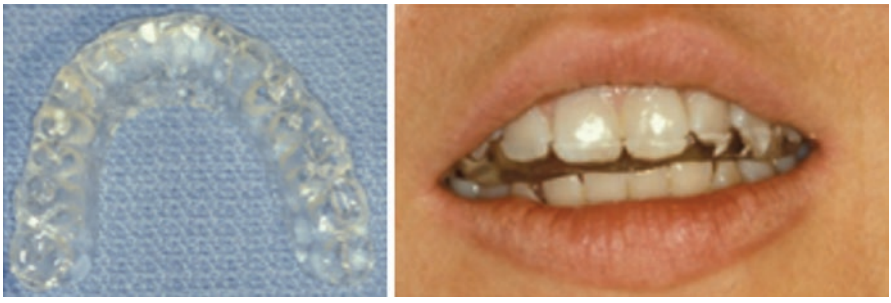


Fig. 19.9 Full coverage occlusal appliance

19.4.4 Life Modifications

It is important to talk to the patient about their diagnosis and discuss the need for conservative treatment prior to considering surgery. Patients who clench when stressed or chew on gum continuously need to recognize these activities as painful stimuli, so they may be avoided. In addition to avoiding certain behaviors, it is important to encourage patient to channel their stress in a more productive way such as aerobic exercise. It is important to counsel patient on exercise that will not exacerbate their symptoms however (Clark 2008). Another simple modification is to have the patient plan timed reminders in their day to have lips together and teeth apart.

19.4.5 Pharmacotherapy

The first-line treatment for both musculoskeletal pain as well as internal derangement is nonsteroidal anti-inflammatory agents (NSAIDs). These drugs do not have risk of dependency and are very effective at analgesia and anti-inflammatory properties if they are taken scheduled rather than as needed. NSAIDs should be avoided in patients with history of gastrointestinal ulcers or patients taking anticoagulation agents as this may lead to a life-threatening bleed. Short-term corticosteroids and intra-articular injections are effective in reducing inflammatory agents and thereby reduce pain. Steroid injections should be used with caution as frequent repeated injections, as well as injections in developing joint, may result in osteoarthritic damage (Mercuri 2008). Opioids should be reserved for postoperative use only and in absence of surgery should be avoided to prevent dependency.

Tramadol which is an opioid agonist is effective in pain management, especially in cases of fibromyalgia, and would do well with musculoskeletal pain, but this drug causes dependence and therefore should also be reserved for postoperative pain only (Clark 2008). Patients with myofascial pain disorder (MPD) may benefit from a benzodiazepine or other sedative hypnotics. This is related to muscle relaxing activity as well as increased sleep architecture. These medications run the risk of being dependence however and should not be used for long durations. Muscle relaxants such as flexeril (cyclobenzaprine) are useful as they act centrally to reduce muscle spasm. They do cause fatigue which is why several patients do not tolerate the medication despite pain reduction (Hersh et al. 2008). Botox has an off-label use in MPD when injected into trigger points. The research to date has inconsistent study models as well as results and therefore offers no conclusion as to Botox's effectiveness in MPD (Chen et al. 2015).

Topical medications are not well studied, but available agents include capsaicin and transdermal lidocaine patches. Antidepressants are also effective at pain reduction, but the mechanism of action with regard to analgesia is not known. The most effective of these is tricyclic antidepressants, but due to side effects, these agents generally are not tolerated well by patients. While selective serotonin receptor inhibitors (SSRIs) have a better side effect profile, their utility in pain management

is disputed (Clark 2008). Anticonvulsants are useful as neuropathic pain modulators; they also reduce muscle spasm and pain perception at trigger points. Again, side effects including fatigue limit their use (Hersh et al. 2008).

19.5 Surgical Procedures

If conservative treatments do not decrease pain or aid with function, then further procedures are indicated. Treatment for internal derangement may be arthrocentesis, arthroscopy, or arthroplasty. Treatment for noninflammatory and inflammatory conditions may be the above in addition to gap arthroplasty and total joint replacement. Hypermobility of the TMJ may be treated with hemarthrosis conservatively or eminectomy.

19.6 Invasive Procedures

19.6.1 Arthrocentesis

After a patient has an occlusal guard for at least 2 months as well as taking scheduled NSAIDs, and if they are still experiencing pain and limited MIO, then arthrocentesis may be effective. Arthrocentesis has a very low risk profile and has success rate of 83.2% according to literature review by Al-belasy and Dolwick (Al-Belasy 2007). The procedure may give benefits of lysis of adhesions, lavage of inflammatory agents, and injection of steroids which may reduce pain (Al-Belasy 2007). The act of washing out an inflamed joint will decrease pressure thus decrease pain (Nitzan 2006). It can be performed in a clinic setting with local anesthesia, potentially augmented with conscious sedation. The procedure consists of two 18 gauge needles placed into the superior joint space (Fig. 19.10). The first needle is placed following an imaginary line connecting the tragus to the lateral canthus. 10 mm anterior to the tragus and 2 mm inferior are the approximate location of the first needle. The second needle is then inserted just anterior to the first as shown.

It is advised to use an actual needle rather than catheter to prevent breakage of the catheter tip into the joint space or tissues. Prior to needle insertion, an auriculotemporal nerve block and local anesthetic infiltration are performed for patient comfort. In one needle lactated ringer (LR) solution is pushed, and in the second needle, the irrigation is expelled. The pressure of the lavage aids to break down superior joint adhesions. This is augmented by intermittently blocking the outflow tract which temporarily increases intra-articular pressure. After irrigation with up to 300 ml of LR, steroids are injected into the joint space. Then the needles are removed and pressure applied over the puncture sites for 5 min. Range of motion is examined and recorded. The patient should be manipulated to MIO, protruded, and test lateral excursive movements (Dimitroulis et al. 1995). Postoperative analgesia may consist of NSAIDs with narcotics for breakthrough pain. The patient

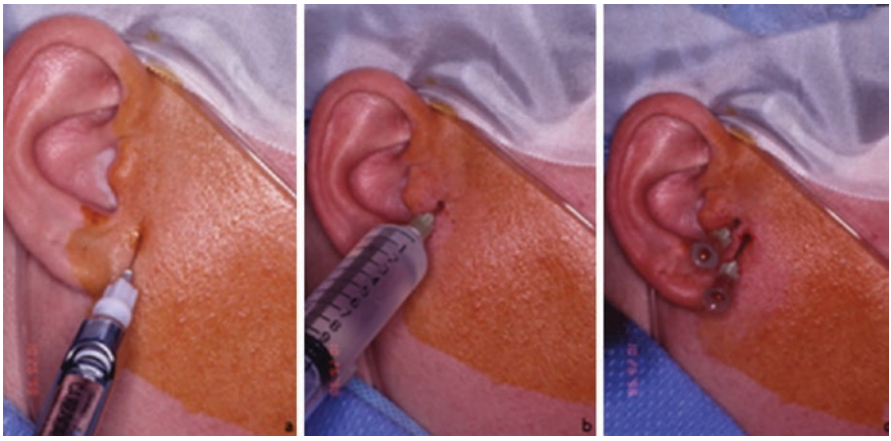


Fig. 19.10 (**a**) Shows an auriculotemporal block, (**b**) insertion of first 18 gauge needle into superior joint space, (**c**) insertion of second needle

should have a soft diet for 3 weeks and begin range of motion exercises the day following the procedure (Al-Belasy 2007; Dolwick 2007).

This procedure has been found to be effective in several studies at increasing MIO and decreasing pain in patients who have failed conservative therapy including NSAIDs and consistent occlusal guard use. Dolwick, Dimitroulis, and Martinez showed an increase in MIO following procedure of 24.5 mm ± 5.2 mm to 42.3 mm ± 6.1 mm in a 21-month follow-up and reduction of pain from 8.8 ± 2.0 to 2.2 ± 0.6 (Dimitroulis et al. 1995). This procedure has few risks which include infiltration of LR into surrounding tissues, hematoma, or infection; these risks are very low however. A transient risk is facial paralysis causing weakness of eye closure. This will last a few hours and require an eye patch until the eyelids have regained function.

In addition to showing that arthrocentesis is highly effective, further studies have shown that arthrocentesis plus occlusal therapy produces the most effective pain reduction for cases of internal derangement and osteoarthritis (Lee et al. 2013; Machon et al. 2011). In a study by Machon, 80 patients with unilateral TMJ symptoms were divided into four groups. The first group received rest therapy plus nonsteroidal scheduled anti-inflammatory drugs (NSAIDs), the second group had splint therapy plus NSAIDs, the third group had arthrocentesis with analgesics as needed, and the forth group had arthrocentesis plus splint therapy with NSAIDs. This study showed the best results in group 4 (arthrocentesis, NSAIDs, and occlusal splint therapy) with an 86% pain and function improvement. Another study demonstrates the importance of combined therapies from Lee which compared three groups. The first group had occlusal therapy delivery, the same day as arthrocentesis, the second group wore the occlusal guard 8 weeks prior to arthrocentesis, and the third group wore occlusal guard as sole treatment. All three groups showed improvement, but the fastest improvement was in the simultaneous arthrocentesis

plus occlusal guard group and slowest improvement in the group that received occlusal guard treatment only (Lee et al. 2013).

19.6.2 Arthroscopy

Arthroscopy can be performed for diagnosis as well as treatment and may be performed in an oral surgeon's office with intravenous sedation or in the operating room. In a diagnostic arthroscopy, the superior joint space is entered similarly with arthrocentesis. An arthroscopic telescope (1.8–2.6 mm diameter) is placed into the superior joint space as well as a second access instrument anterior to the arthroscope. The joint is then examined from posterior to anterior looking for inflammation, capillary hyperemia, adhesions, disk perforation, and cartilaginous degeneration (Fig. 19.11) (Dolwick 2007).

A diagnostic arthroscopy can achieve breakdown of adhesions, but if performing discectomy, plication, or other procedure, general anesthesia in an operating room setting should be considered. Postoperative care is similar to arthrocentesis. The benefit of this surgery is the lack of an incision while allowing visualization of the joint with expense being the main drawback.

19.6.3 Arthroplasty (Open Joint Surgery)

If conservative procedures including arthrocentesis are unable to alleviate pain and improve range of motion, arthroplasty may be considered. This procedure requires general anesthesia through a preauricular incision. Disk repositioning may be performed if the disk is intact and may provide better motility with decreased mechanical interferences. If the disk is diseased or perforated, a discectomy is indicated (Fig. 19.12). The bone may be re-contoured to remove mechanical interferences, but care should be taken to manipulate bone as little as possible as it can lead to heterotopic bone formation. An abdominal fat graft may help prevent heterotopic bone and ankylosis. Postoperative care consists of range of motion exercises the day following surgery and soft diet for 6 weeks. Pain may be addressed with NSAIDs primarily and 1–2 weeks of narcotics for breakthrough pain. The benefits of the procedure are direct visualization of the joint and access for treatment.

The main risk of this procedure is damage to the facial nerve which could result in weakness and elevating eyebrows. This procedure is not performed frequently due to invasiveness and great results with conservative procedures like arthrocentesis; however, it is highly effective. It was shown by Abramowicz and Dolwick in a 20-year follow-up of internal derangement treated with disk repositioning that there was a reduction of pain at rest (77% reduction) and reduction of pain in function (56%), less dietary restrictions, and a 94% improved quality of life for patients who participated in postoperative survey (Abramowicz and Dolwick 2010).

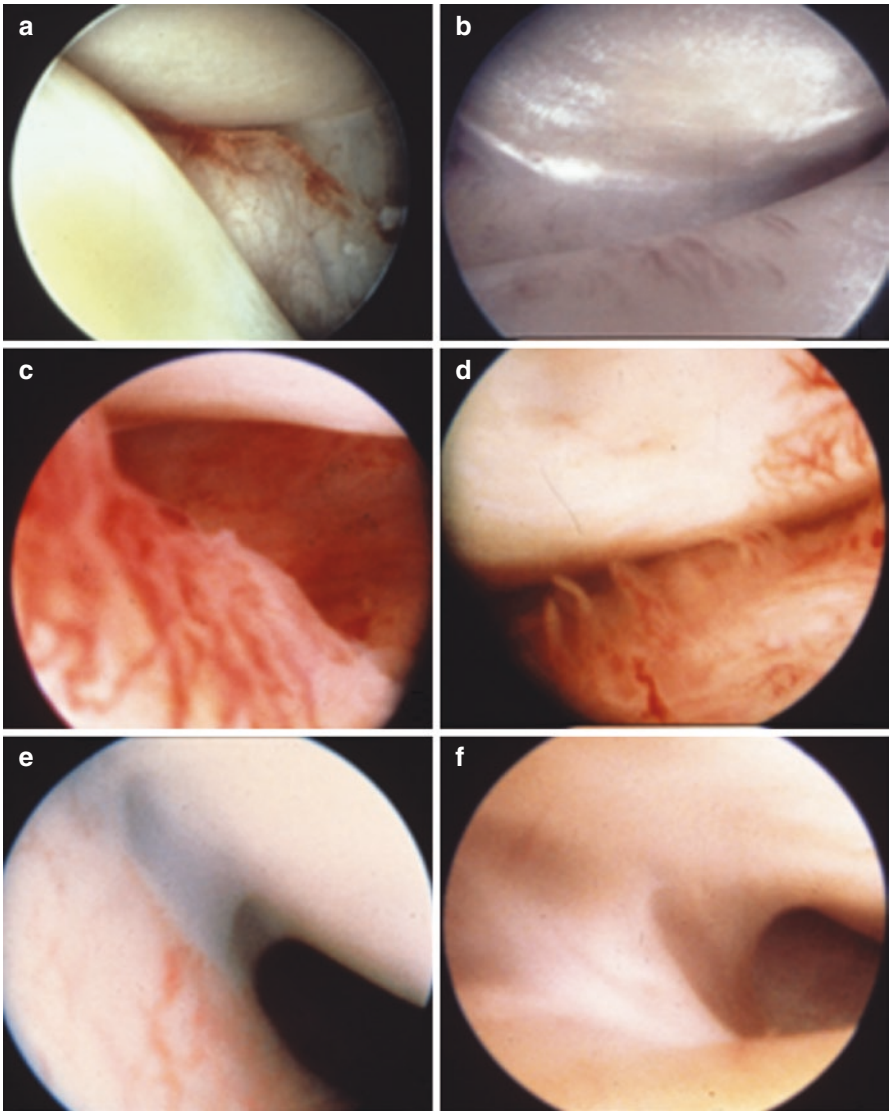


Fig. 19.11 (**a**, **b**) Normal arthroscopic upper joint space, (**c**, **d**) synovitis and inflammatory changes, (**e**, **f**) joint adhesions

19.6.4 Total Joint Replacement

Alloplastic joint replacement has changed much over the years with current FDA-approved products: TMJ Concepts which is a custom-fitted prosthesis and the Biomet stock joint. Previous failed products include the Proplast-Teflon and silastic implants. They had good short-term success but were later taken off the market. The

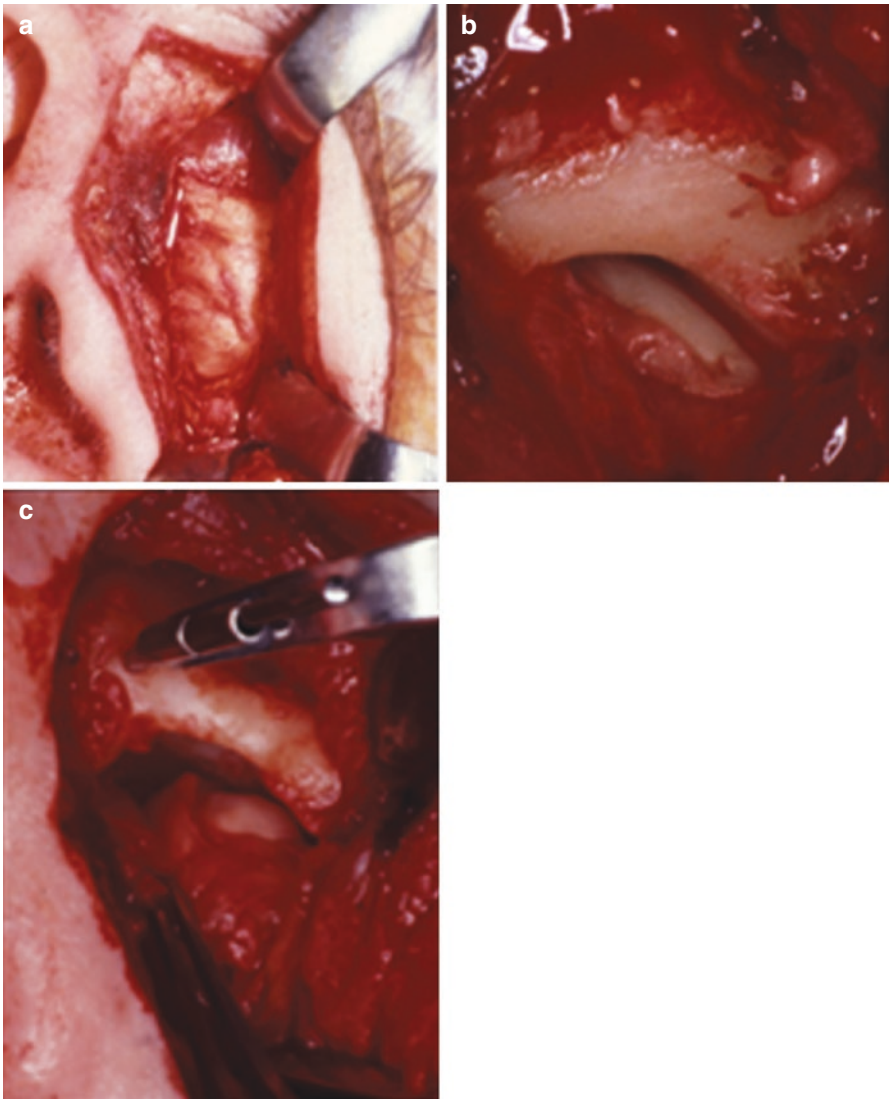


Fig. 19.12 (**a**) Preauricular incision with dissection to joint, (**b**) direct visualization of joint, (**c**) debridement of the joint, discectomy with removal of diseased portion of disk. Through this approach osseous recontouring also performed to remove interferences with movement

functional load placed on the joint was too great which caused breakdown as well as foreign body reactions (Dolwick and Dimitroulis 1994). For the custom prosthesis, a CT of the head is required from which an acrylic model is made and the prosthesis is designed (Fig. 19.13). The stock joint (Biomet) comes in three sizes for the condylar and fossa components. The surgery requires a preauricular and retromandibular incision. The procedure requires two surgical fields: a sterile

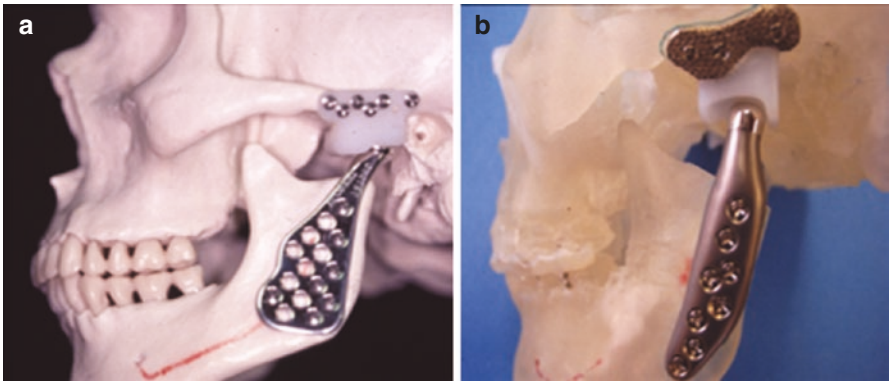


Fig. 19.13 (**a**) Example of Biomet stock joint in which the patients bone is modified to fit the prosthesis, (**b**) example of TMJ concepts custom joint which is fabricated from the patient's CT that is made into a 3D reconstruction model

field for entering the joint and a non-sterile field for accessing the mouth. The mouth is covered with Tegaderm, and the joint is accessed first. A gap arthroplasty is performed to remove the condyle and smooth irregularities of the bone in the fossa. Additional bone may require removal to allow the prosthesis to fit in function. The benefit of the Concepts custom joint is the need for less modification of the native mandible and fossa. The bone that does require removal is marked on the acrylic model which further reduces surgical time. Next the sterile field is isolated, and the mouth is accessed, and patient is placed in maxillomandibular fixation. Finally the joints are placed and secured. In some cases such as ankylosis, previous prosthesis, or other pathologies, a two-stage procedure will be required with the custom joint prosthesis. While the benefits of the custom joint are clear, it does delay surgery as the fabrication process may take 3–4 months (Dolwick 2007).

19.7 Conclusion

In conclusion, disorders of the TMJ may be categorized as either musculoskeletal or intra-articular (involving the joint itself). Treatment of musculoskeletal disorders and myofascial pain is through noninvasive therapy and will not benefit from surgical intervention. Management of intrinsic joint disorders may be noninvasive and/or surgical. The examination findings of both categories were discussed as well as the noninvasive treatments. Radiographic exam involves panoramic imaging for screening, MRI for disk morphology and movement evaluation, and a CT for arthritic changes. Physical therapy, thermal therapy, massage therapy, and occlusal splints have all been shown to be effective in the treatment of TMD. Regarding pharmacotherapy, NSAIDs are the first-line medication for treatment of TMJ both musculoskeletal and intra-articular disorders. Opioids should only be given for a short duration to manage postoperative pain. Surgery is indicated for patients with

intra-articular disorders who have failed noninvasive therapy. Arthrocentesis is the first-line minimally invasive procedure for internal derangement, followed by arthroscopy. Arthroplasty is used to improve function and decrease pain by removing movement interferences. Severe osteoarthritis and ankyloses must be treated with total joint replacement with either a stock Biomet or Concepts custom joint prosthesis. If surgery is indicated, it should be stressed that the noninvasive therapies must continue postoperatively to achieve optimal results regarding pain and function.

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Congenital Facial Deformities

20

Jeff Marschall Green, Eric D. Bednar, and Lewis C. Jones

"My eyes have been trained to examine faces and not their trimmings. It is the first quality of a criminal investigator that he should see through a disguise."

Sherlock Holmes in—The Hound of the Baskervilles

Abstract

Craniofacial deformities encompass a wide array of congenital and acquired syndromes of the head, neck, face, and jaws. The care of these complex patients requires a team-based approach with multiple providers, including but not limited to surgeons, pediatricians, and dentists. Understanding normal growth and development of the maxillofacial complex and the deciduous and succedaneous dentition is essential as it has a profound influence on the timing of surgical and nonsurgical interventions. This chapter is designed to introduce the general dentist who practices on the craniofacial team of the basic principles in the care of these patients.

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20.1 Introduction

Congenital facial deformities (CFDs) consist of a wide array of phenotypes that consist of deviations in varying degrees from "normal" facial proportions and dental relationships. CFDs range from almost imperceptible defects to extremely disfiguring anomalies. Underlying skeletal, soft tissue, and dental abnormalities can result in malocclusion, esthetic deformities, speech impediments, and psychosocial difficulties—each of which may result in decreased quality of life (Proffit et al. 2003).

Optimal care for patients with CFDs requires a team approach to achieve appropriate timing for intervention and ensure that no aspect of care is neglected. A typical craniofacial team includes a craniofacial surgeon (often a maxillofacial, ENT, or plastic surgeon—each of which may be required separately depending upon the craniofacial surgeons background), dentist, speech-language pathologist, audiologist, prosthodontist, psychologist, geneticist, and social worker. The roles of the various practitioners in the team approach are outlined in Table 20.1.

Table 20.1 The personnel of the craniofacial team

Craniofacial surgeon	Usually an oral and maxillofacial surgeon, plastic surgeon, or otolaryngologist with additional fellowship training in cleft and/or craniofacial surgery
Otolaryngologist	Perform tympanostomy and ear tube placement, which is often required in CFD patients
Oral and maxillofacial surgeon	Perform dental extractions, bone grafts, dental implant placement, and corrective jaw surgery (orthognathic surgery) which is often required in CFD patients
Speech pathologist	Help the team decide if speech therapy, prosthetic devices, or surgery is needed to help improve the patient's spoken communication
Orthodontist	Instrumental in the nonsurgical management of maligned jaws and help monitor growth and development via cephalometrics
Audiologist	Often works in conjunction with the speech pathologist, this individual is responsible for completing the hearing test for the patient
Pediatrician	Often the coordinator of care, this individual has a hand in all aspects of care including diagnosis, medical management, and communication between other healthcare providers
Pediatric dentist	This individual coordinates the children's dental care with emphasis on prevention and maintenance of oral health
Prosthodontist	Dental specialist who fabricate prosthesis to replace missing teeth or obturators to close soft-tissue or bony defects that surgery cannot correct
Psychologist	Instrumental on monitoring the mental health of the patient and how to teach the patient to cope with the social aspects of a facial deformity
Clinical geneticist	Helps delineate the genetic etiology of disease and advise on heredity if a specific syndrome is suspected
Social worker	Patient and family counselor and often helps with communication between healthcare teams
Nurse	During hospital stays, the nurse is responsible for the daily healthcare of the patient and carries out physician orders

20.2 Normal Growth/Development

This chapter is designed for the dental provider on the craniofacial team. The dental provider must be well versed in normal craniofacial and dental development to ensure that the interventions are timed appropriately. In brief, bone development can be separated into three general processes: bone growth, remodeling, and displacement. Bone growth and remodeling occur simultaneously—striking a balance between bony resorption and deposition. Displacement occurs as the facial bones grow away from each other from their articular junctions. These processes occur in concert and produce dynamic three-dimensional changes. The maxillomandibular complex enlarges in a downward and forward direction that has been described as an "expanding pyramid" (Enlow and Hans 1996). Disruptions in these processes during growth can result in anomalies. These disruptions can occur as inherited abnormalities (i.e., TCOF1 gene with Treacher Collins syndrome, which is autosomal dominant), spontaneous mutations (i.e., GNAS1 gene mutations resulting in fibrous dysplasia), intrauterine events (i.e., mandibular growth restrictions resulting in Pierre Robin sequence), or environmental factors (i.e., facial clefting resulting from anti-seizure medications such as valproic acid).

The maxillofacial complex encompassing the maxilla, mandible, alveolus, and dentition is an ever-changing region beginning in utero (dental lamina in the maxilla and mandible are evident as early as 8 weeks in utero) and extending into late adolescence/early adulthood when the mandible reaches growth completion (DeAngelis 1975). In the interval between birth and adulthood, primary teeth develop, erupt, and exfoliate as their succedaneous counterparts erupt into occlusion. Teeth start entering the oral cavity at approximately the sixth postnatal month. The primary dentition is completed by 2.5 years of age. The first teeth to exfoliate are the primary incisors at ages 6–7. The permanent dentition begins to emerge as the incisors and first molars first pierce the oral mucosa at about this same age. The permanent dentition is completed by ages 12–14; however, third molars will continue to develop until approximately 17 years of age (Fig. 20.1). During this process, the supporting alveolus grows and is remodeled to support the dentition. The maxilla and mandible should grow in concert to allow for the final result of class I occlusion with appropriate projection and expansion of the maxilla and mandible. Deviation from these normal developing processes can result in malocclusions (Angle's class II or III; Fig. 20.2), crossbite, and/or anterior open bite to name of few. Data extrapolated from the National Health and Nutrition Examination Survey (NHANES III) demonstrated about 2% of the population of the United States suffered from a DFD resulting in a debilitating malocclusion requiring surgical correction (Proffit et al. 1998). The appropriate timing of interventions including maxillary expansion, headgear, orthodontics, and implant therapy is imperative to optimize the care delivered.

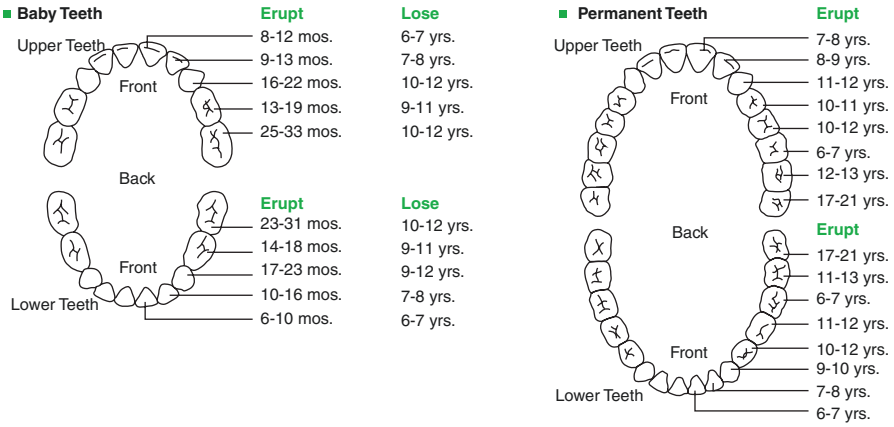

Fig. 20.1 Primary and permanent dental eruption pattern

20.3 Timing of Interventions

Interventions directed by the dentist on the craniofacial team are mainly comprised of dental treatments (including exams, cleanings, imaging, restorations, and extractions), growth modification (headgear, palatal expansion, appliances), and surgical interventions (orthognathic, dental implant, and distraction osteogenesis surgeries). In general, each patient should have appropriate exams with a dental provider on a semi-annual basis at a minimum. Increased frequency of visits will be required in scenarios where an increased risk of dental caries exists. This could be due to a variety of reasons. Patients with cleft lip and/or palate have demonstrated an increased incidence of dental caries over control groups in both primary and

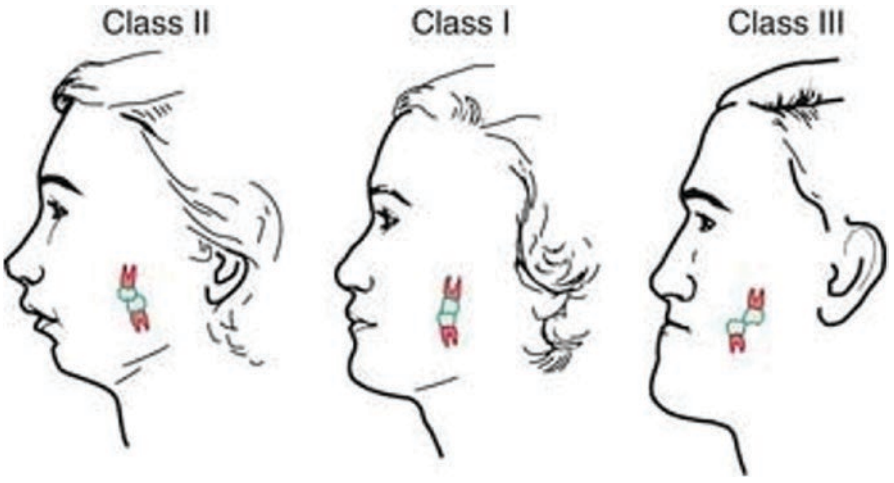

Fig. 20.2 Angle classification of malocclusion

permanent dentition (Bokhout et al. 1996; Kirchberg et al. 2004; O'Neill 2007). Hygiene may be difficult to optimize for some craniofacial patients with extremity and/or digital anomalies (such as Apert syndrome). Judicious fluoride treatments can aid in caries prevention in addition to repeated encouragement and reinforcement of good habits with the patient.

Outside of exams, cleanings, and restorations, one of the first interventions with regard to growth modification in many cleft and craniofacial patients is maxillary expansion. Placement of a stable and effective maxillary (tooth-borne) expander requires adequate eruption of the first molars, which occurs at or around age 6. The midpalatal suture ossifies at ages 12–13; therefore, intervention should occur prior to this, or the expansion will require a surgical midpalatal osteotomy (and associated osteotomies) in order to facilitate expansion of the maxilla. The routine exam administered at each team clinic visit should include analysis of the existence (and degree when it exists) of posterior crossbite and eruption of the first molars to facilitate possible orthodontic intervention. When required, the appropriate referral for extractions due to decay or impaction should be made as soon as detected and prior to development of symptoms. This allows for flexibility in the timing of a procedure. Many cleft and craniofacial patients require multiple procedures throughout their growth and development. All efforts should be made to combine procedures when possible to consolidate the number of general anesthetics a patient must undergo. Extractions can often be performed in conjunction with other procedures. One example of this is the extraction of third molars in conjunction with orthognathic surgery.

Palatal expansion is one type of growth modification—growth modification techniques require that the patient is still growing. Preadolescent referral of patients who exhibit a class II or class III malocclusion will allow the orthodontist flexibility in regard to the timing and method of growth modification. Growth modification techniques strive to apply orthopedic forces to growing skeletal structures to improve jaw position and relationships. Ideal timing of growth modification depends on skeletal maturity and growth potential. Attempts at growth modification that take place after skeletal maturity can alter dental relationships if forces are placed on the dentition but are less effective at altering skeletal relationships. For patients without clefts or syndromes, typical class II growth modification is completed during the adolescent growth spurt. Orthodontic headgear places a distal force on the maxilla and maxillary dentition to restrain maxillary growth while the mandible is growing downward and forward, thus correcting class II dental relationships and improving jaw relationships while the mandible is growing at peak velocity. Other inter-arch tooth-borne appliances (Herbst, MARA, Twin-Block) can be used which transmit distal force through the maxillary dentition to the maxilla and transmit mesial force through mandibular dentition to the mandible. These appliances have a restraining effect on maxillary growth. For patients without clefts or syndromes, ideal class III growth modification takes place in the early mixed dentition, typically before age 9 when the circum-maxillary sutures are still pliable. Treatment is typically done with a reverse pull face mask, in which elastics are attached from the face mask to a tooth-borne appliance on the maxillary dentition, transmitting force to cause suture

separation and maxillary protraction. When considering growth modification for patients with clefts and other dentofacial deformities, adaptation of these general principles may be required to fit the unique conditions and circumstances of each patient.

Surgical interventions for dentofacial deformities include distraction osteogenesis, orthognathic surgery, bone grafting, bone contouring, and dental implant surgery. Timing of the surgery will take into account the risks, benefits, alternative treatments including the limitations of surgery, timing of the surgery with respect to growth maturation, and the psychosocial well-being of the patient.

Distraction osteogenesis is performed for various reasons. A patient with severe mandibular retrognathia at birth (such as a severe Pierre Robin sequence patient) may require early distraction osteogenesis of the mandible to translate the mandible and associated muscular attachments forward, thus opening the airway and (hopefully) obviating the need for tracheostomy (Images 20.1, 20.2, 20.3). Early mandibular distraction is performed with an attempt to place osteotomies proximal to the developing dentition/tooth buds. This is not always accomplished and so monitoring of the developing teeth for appropriate interventions (orthodontics/extractions/etc.) is paramount. A patient requiring distraction osteogenesis to achieve symmetry (such as a hemifacial microsomial patient) may elect to wait until growth completion with the hope that the surgery will be a "one-and-done." With a single intervention after growth is completed to achieve the symmetry. However, the asymmetry may impact the psychosocial well-being of the child, and earlier intervention with distraction osteogenesis may be "outgrown" as the patient continues to develop, but the phenotypical presentation of the patient will be less severe and this can certainly have a positive impact on the psychosocial well-being

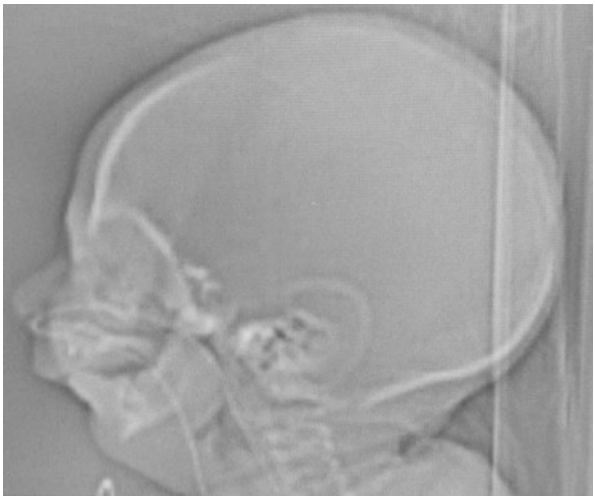

Image 20.1 Lateral scout film of patient with Pierre Robin sequence: total closure of posterior airway and maxillomandibular discrepancy with mandibular retrognathia is observed. This patient was unable to maintain his airway in prone position with supplemental oxygen

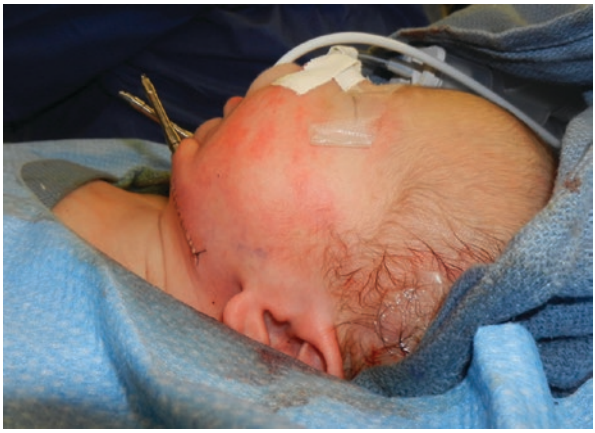

Image 20.2 Internal distractors (KLS Martin Micro Zurich 2) in place immediately post-op. Patient remains intubated during initial distraction

of the patient. Thus it is difficult to assign a timeline to many of these interventions, and it requires each patient be reviewed by the team and include all the appropriate providers to determine the optimal timing of intervention.

Bone grafting to the alveolus is timed differently depending upon the intent for use of the graft. Grafted bone can (and will) resorb if not utilized. Thus, the timing for the graft will depend upon when it will be utilized. An alveolar bone graft in a cleft patient with an oronasal fistula present will need the surgery for alveolar cleft repair prior for several reasons. Indications for alveolar bone grafting include the following: consolidation of the maxillary dental arch, closure of the fistula, provide bone to support erupting dentition and existing dentition on either side of cleft, and

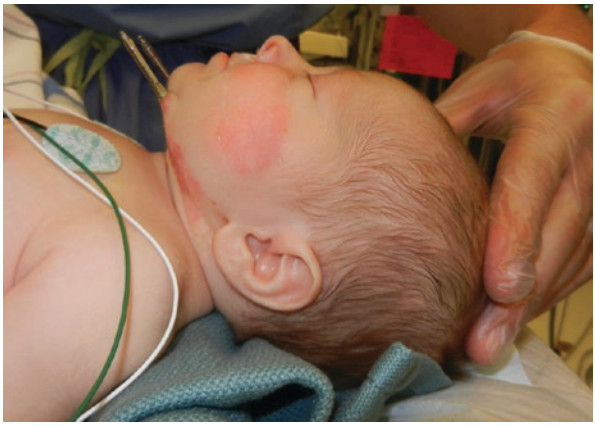

Image 20.3 Patient is now 5 days post placement of distraction with a 1 cm mandibular advancement (2 mm/day—1 mm twice daily). He underwent successful intubation and distraction continued at 1 mm/day for additional 8 days

nasal base support (Coots 2012). Bone grafting in this population is done at different stages depending on the theories to which the operating surgeon subscribes. The majority of surgeons will ensure that the grafting has been performed prior to development and eruption of the canine on the affected side (most often when the root of the canine is 2/3 formed). This is usually around ages 9–10 and the procedure is tolerated very well. Bone used is often harvested from the iliac crest, but other bone utilized may include symphysis, cranial, allogeneic, or rh-BMP2 (Images 20.4 and 20.5). Once the canine is erupting into the cleft, the level of difficulty of surgery increases and quality of bone remaining after grafting is decreased due to exposed cementum, which may exhibit external resorption after exposure to an autogenous graft. Annual visits to the craniofacial team and examination by those with dental backgrounds will help avoid late, compromised grafting in the cleft/craniofacial patient population.

Other bone grafts may be placed to facilitate implant placement. Implants (in most cases) will not be placed until the patient has reached skeletal maturity. (17–18 years of age is usually a "safe" age, but longitudinal observation and exams will help aid in determining cessation of growth prior to placement.) Grafts placed several years prior to utilization often resorb and require additional augmentation prior to (or at the time of) implant placement. For this reason, it is recommended that grafting for implants takes place approximately 6 months prior to placement of the implants. This will help ensure that the grafted bone is stimulated under the stresses of mastication and does not atrophy.

Orthognathic surgery is best timed after growth completion—with the mandible being the final bone to reach growth completion in the craniofacial skeleton. This is especially significant in the class III patient, as early intervention with a LeFort I advancement can correct the occlusion and dentofacial esthetics initially only to "relapse" as the patient's mandible continues to grow and results in a class III

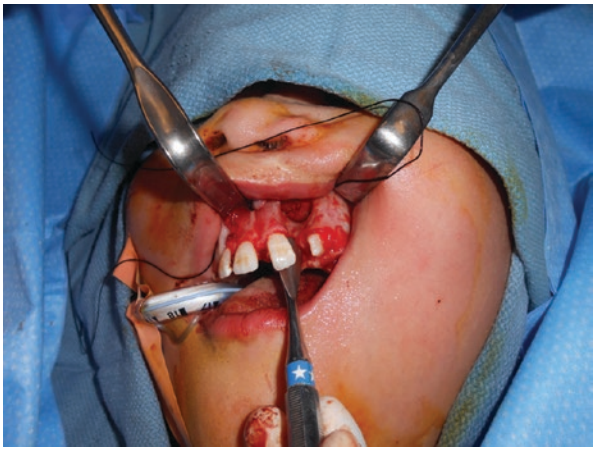

Image 20.4 Alveolar cleft intraoperative view: a 9-year-old female with near-complete alveolar cleft present

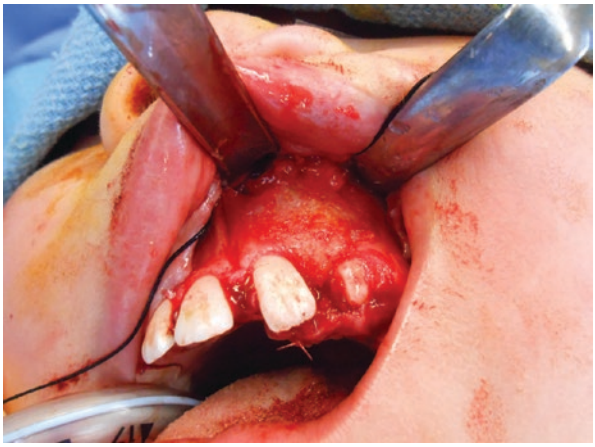

Image 20.5 Alveolar bone graft present and ready for mucosal closure

malocclusion. A thorough understanding of the normal facial growth timeline is essential for treatment planning. Maxillary growth in the transverse plane is complete by 12 years of age (Bjork and Skieller 1977). Anterior-posterior growth of the maxilla is completed by 14 years of age (Savara and Singh 1968). On average, mandibular ramus height increases 1–2 mm per year, and mandibular body length increases 2–3 mm per year. Mandibular growth is completed by 14–15 years of age in females (Foley and Mamandras 1992) and 18 in males (Love et al. 1990) (Table 20.2). Decisions with regard to timing of growth completion may include evaluation of hand/wrist films or serial cephalometric images. These can be used to aid in the decision-making process with regard to surgical timing.

20.4 Conclusion

Thus the dental provider on the craniofacial team can aid in the coordination and care of each patient. The end goal of the team is unified in its desire to rehabilitate the patient's form and function. Much of the function that is desired centers around the ability to masticate and speak—both of which are facilitated by dentition. The dental practitioner is paramount in ensuring that milestones and opportunities to

Table 20.2 Approximate completion of craniofacial bone development

Bone	Age
Cranial vault	8
Anterior cranial base	10
Posterior cranial base	20
Nasomaxillary complex	16–18
Orbits	11 in females; 15 in males
Maxilla	12–14
Mandible	14–15 in females; 18 in males

maximize the patient's outcome are not overlooked. Frequent exams, both in team clinic and in the dental chair at follow-up visits, are important interactions to ensure that high-quality, well-timed care is delivered in a method that is tailored to each patient's circumstance and presentation.

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Dental Implants

21

Martin A. Freilich, David M. Shafer, and Steven Halepas

"There is nothing new under the sun. It has all been done before."

Sherlock Holmes in—A Study in Scarlet

Abstract

Implants are rapidly becoming the gold standard for replacing missing teeth. With new technology related to the planning of implant placement, alveolar bone anatomy can be evaluated in 3D facilitating the reliable differentiation between simple and complex sites. This allows for better case selection to perform surgical procedures by general dentists, thereby relying less on specialists. It is critical for the dentist to properly treatment plan the procedure. Case selection and patient expectations are crucial. Implants are only useful if they can be properly restored and should not just be placed "where the bone is." This chapter provides information on prosthetic planning, implant placement strategies, bone augmentation techniques, and prosthetic principles and addresses frequently asked questions related to dental implant placement and restoration.

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21.1 Introduction

Humankind's battle against edentulism spans back centuries. Although implants have been around for ages, they continue to become a larger part of modern dental practice (Block 2018). Branemark et al. can be credited with bringing the modern-day implants to North America in 1982 (Branemark et al. 1985). Since that time, evidence shows that implants have had high levels of success for long-term tooth replacement (Adell et al. 1981). As technology has advanced, treatment planning and surgical implant placement have become easier. With the utilization of cone-beam computed tomography (CBCT) and radiographic and surgical guides, implant placement has become more predictable and reliable. An increasing number of general practitioners have become comfortable placing implants for many of their cases. It is widely understood that proper treatment planning of implant placement and restoration is critical for surgical and prosthetic success. It cannot be overemphasized that the characteristics (e.g., screw- vs. cement-retained), functional requirements, and esthetics of the implant restoration drive implant selection and the manner of placement where clinical success is attained.

21.2 Discussion

21.2.1 Planning Treatment

Implant success requires integration with the adjacent alveolar bone, which provides for long-term stability and a functional restoration. Implant biocompatibility is a major determinant of osseointegration success. Most implants today are composed of commercially pure titanium or a titanium alloy, where the titanium oxide-bone interface defines the extent of bone integration. Other factors that facilitate consistent integration are the use of graduated sharp size drills, cooling irrigation, and relatively low speed drilling (generally less than 1000 RPM) minimizing heat application to the adjacent bone (temperature below 47 °C) (Friberg et al. 1999). Bone density of the site may aid in obtaining initial implant stability, which is an important factor in achieving successful bone to implant integration (Elias et al. 2012; Lages et al. 2018). Cortical bone is denser than cancellous bone. Implants placed in the anterior mandible with its thick cortical bone layer are managed differently than implants placed in the less dense posterior mandible or maxilla (Heo et al. 2017). Maxillary bone has a thin cortical layer and a high percentage of cancellous bone resulting in less overall bone density (Jensen et al. 1994; Gupta et al. 2017). Nevertheless, achieving primary implant stability in the maxilla is a routine given the current surgical techniques and modern implant design. As with any diagnosis and treatment plan, the initial aspect of the treatment planning process includes determining the patient's chief complaint, expectations, and budget. Patient selection and addressing patient expectations are important considerations. The practitioner should always review the medical history and ensure that there are no major contraindications to implant placement or bone augmentation surgery. Major

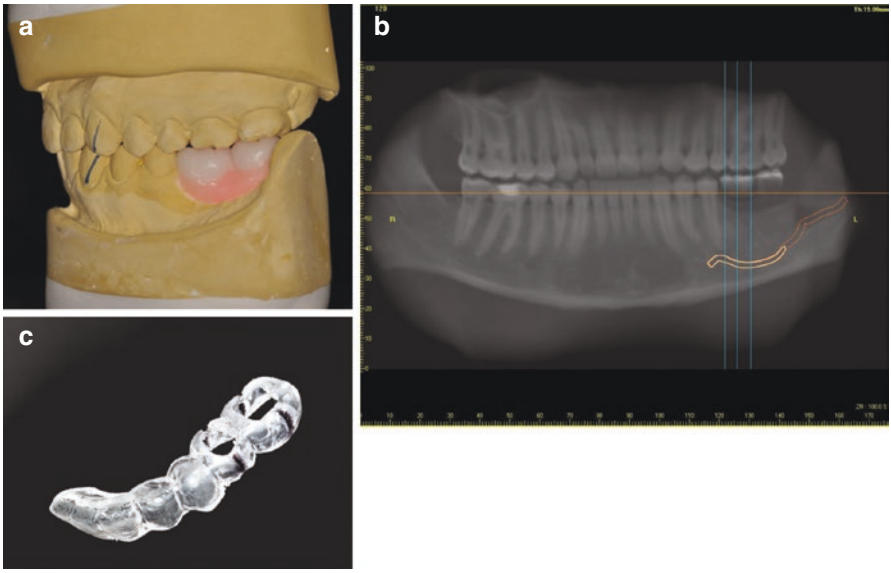

Fig. 21.1 The basic components needed for proper treatment planning of implant cases. (**a**) Mounted diagnostic casts with denture teeth waxed into correct position of the final implant crowns. (**b**) A panoramic view of a CBCT showing the radiographic guide with radiopaque material within the image. (**c**) Surgical guide made through modification of radiographic guide by removing radiopaque material and placing holes at implant placement sites

contraindications generally include uncontrolled systemic diseases that need to be managed prior to implant placement. Minor contraindications to implant surgery include particular medical conditions, the use of some medications, and behavioral habits such as smoking which will be discussed in detail toward the end of this chapter. Planning for less complex cases can be generally accomplished with 2D panoramic and/or periapical radiographs. The evaluation of these radiographs and careful clinical examination may illustrate anatomic challenges where proximity to large undercuts and important anatomic structures, such as the inferior alveolar nerve canal or maxillary sinus, may indicate the use of a CBCT 3D scan (Christman et al. 2014). Figure 21.1 demonstrates the basic components needed for proper treatment planning.

21.2.2 Prosthetic Implant Placement Considerations

21.2.2.1 Implant Restorations

Implant restorations such as crowns and fixed prostheses are attached to the implant via a screw-retained abutment. This abutment may be separate or continuous with a single implant crown. As seen in Fig. 21.2, the abutment and crown can be joined together, and the entire unit is screw-retained. Abutments that are separate from crowns may be premade by the manufacturer or custom-made in the

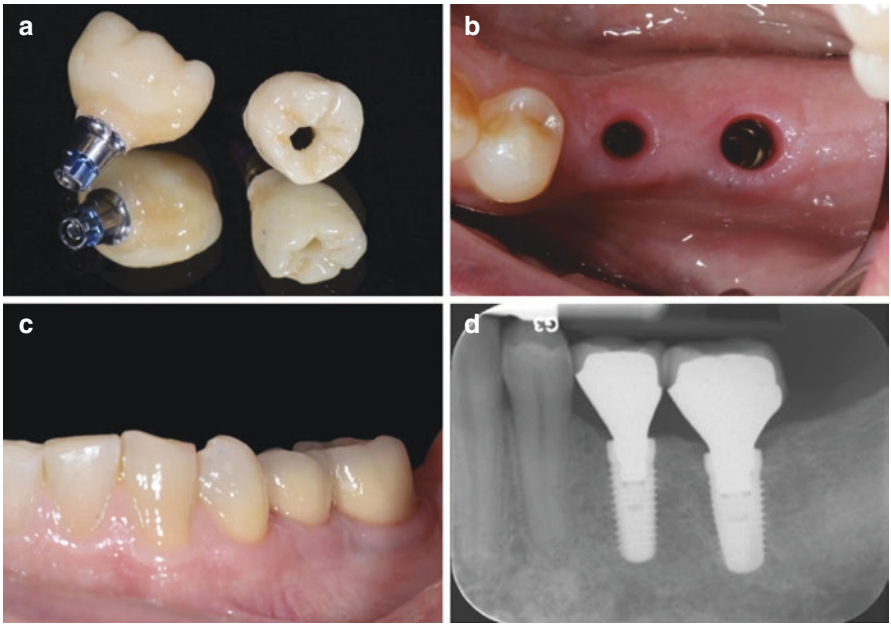

Fig. 21.2 Screw-retained implant crowns are retrievable and having no cement line or potential for excess cement often demonstrate outstanding soft tissue health. (**a**) Single-piece screw-retained abutment/metal ceramic crowns. (**b**) Implant sites demonstrate excellent peri-implant gingival health. (**c**) Final placement of screw-retained implant restorations. (**d**) Periapical radiograph of metal ceramic screw-retained crowns restoring tapered bone level implants at sites #19 and #20 (Photos courtesy of Dr. Florian Kernan)

dental laboratory building upon a manufacturers' foundation (Vigolo et al. 2012). Custom abutments may be made from a metal alloy, ceramic material, or a combination of alloy and ceramic. Various cement-retained abutments can be seen in Fig. 21.3. Cement-retained implant crowns are placed over abutments that have the "resistance form" and "retention form" requirements similar to taper and axial wall length of crown preparations of natural teeth. Examples can be seen in Fig. 21.4.

21.2.2.2 Implant Selection and Placement

A variety of different designs and sizes of implants are seen in Fig. 21.5. Implant selection is dependent upon many factors, including esthetics, biomechanical strength, available vertical prosthetic space, buccolingual ridge width, and mesiodistal edentulous space dimension. Figure 21.6 shows apico-coronal, buccolingual, and mesiodistal landmarks for optimal implant placement (Buser et al. 2004). Implant design and shape also has substantial impact on the emergence profile of implant restoration and gingival embrasure size. Figure 21.7 shows the implant path of placement (MD should be general parallel to adjacent tooth roots and compatible with adjacent proximal surfaces). On occasion, modifications may be required to these

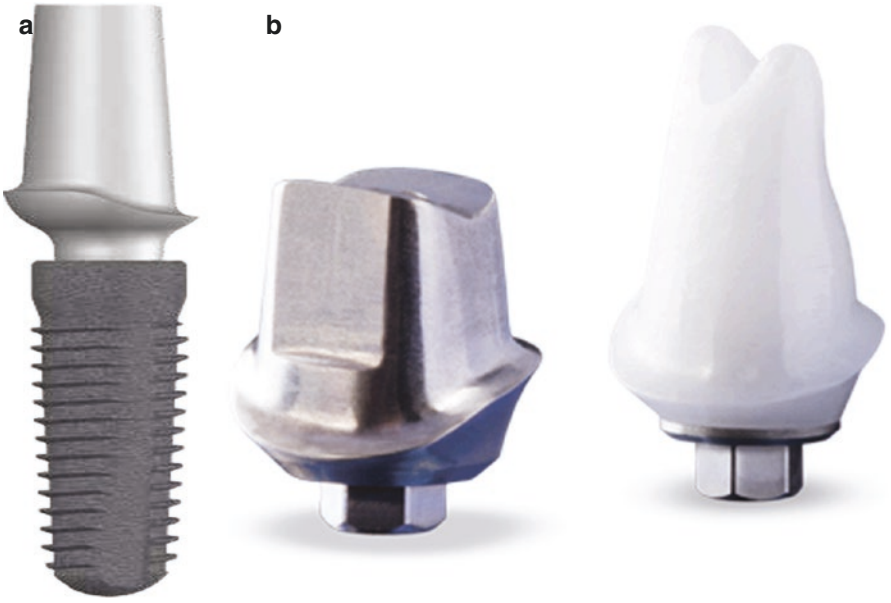

Fig. 21.3 (**a**) Prefabricated abutment placed into a rough surface-tapered implant. (**b**) Two custom cement-retained abutments, one made from metal alloy and the other from a combination of ceramic and metal alloy

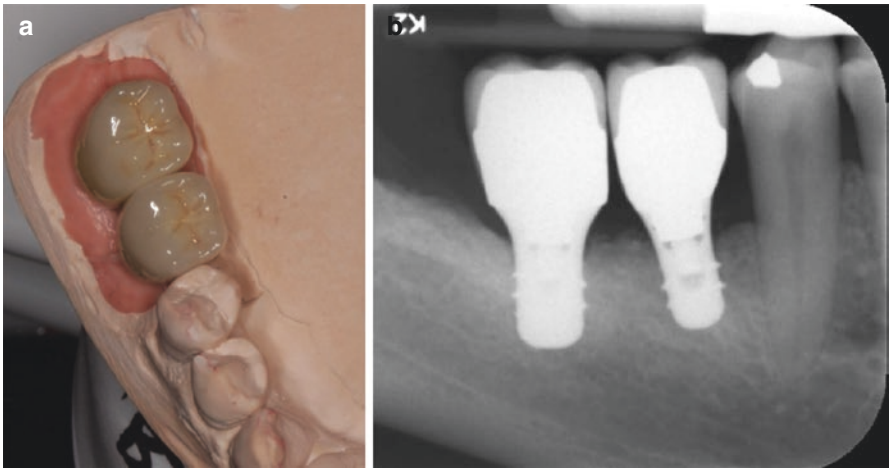

Fig. 21.4 Cement-retained implant crowns have potential for optimal esthetics. Given no screw access hole also exhibits excellent durability and good control over the occlusal surface. (**a**) Cement-retained metal ceramic implant crowns on final cast made to restore tissue level implants at sites #30 and #31. (**b**) Follow-up periapical radiographs (Photos courtesy of Dr. Konstantinos Vazouras)

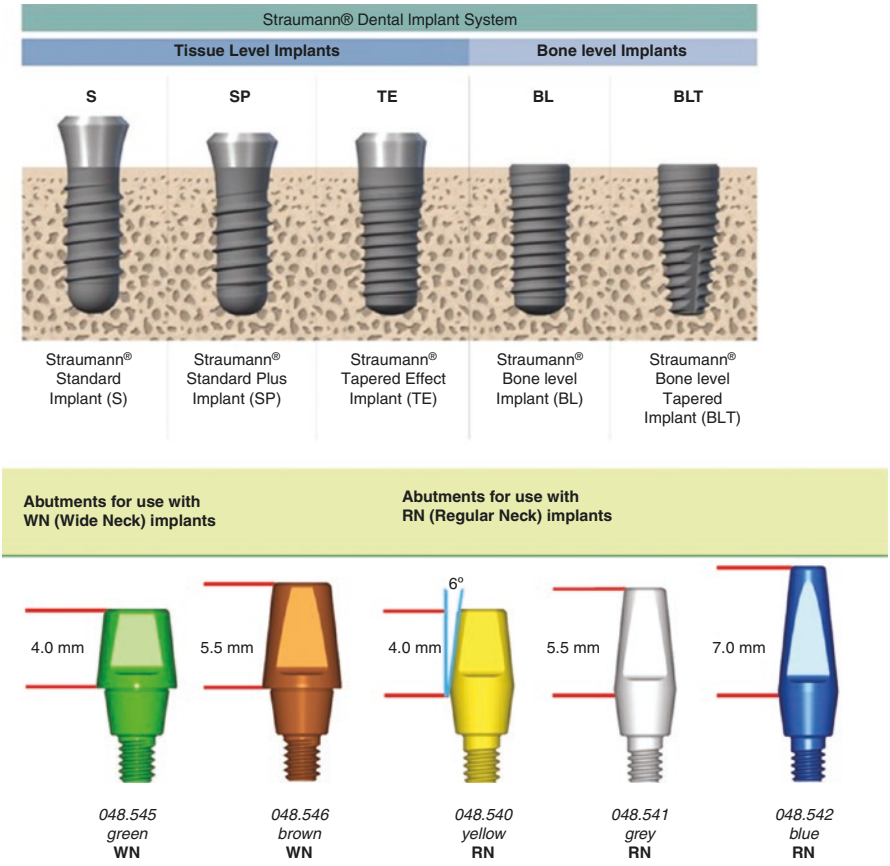

Fig. 21.5 Various implant designs and diameters with various prefabricated abutment heights available for a popular implant system. Available vertical and MD space may influence selection of: Soft tissue level vs. bone level implant, selection of implant with taller vs. shorter smooth collar, selection of optimal implant diameter for edentulous space, selection of pre-fabricated or custom abutment, selection of screw- or cement-retained implant crown

adjacent surfaces in order to allow the path of implant placement with adequately long proximal contacts with the adjacent teeth. Figure 21.8 shows that buccolingual angulation may be somewhat dependent upon angulation of alveolar bone, whether the surgical provider is able to repair any apical buccal plate fenestrations that are made trying to minimize buccal flare. This may be a particularly important consideration when trying to optimize abutment shape or planning for a screw-retained restoration.

21.2.2.3 Prosthetic Space

For restoration of an implant crown or fixed implant prosthesis, there should be a minimum prosthetic vertical height of 8–10 mm space depending on the type of abutment and size of the adjacent teeth. Justification for prosthetic height needed for

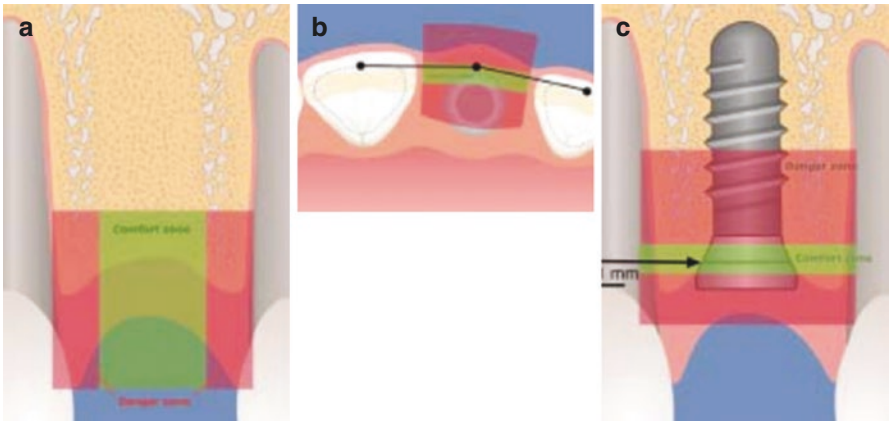

Fig. 21.6 This schematic shows the optimal zone of implant placement in three planes: (**a**) mesiodistal, (**b**) buccolingual, and (**c**) apico-coronal (Buser et al. 2004)

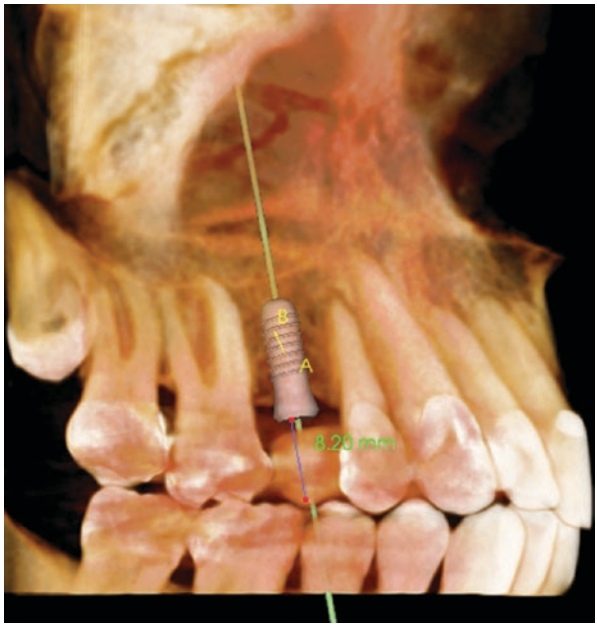

Fig. 21.7 A 3D view of a CBCT scan simulation showing the icon of a Straumann regular neck, tissue level implant with its path of placement parallel to the adjacent tooth roots of the missing maxillary second premolar

a single cement-retained implant crown can be seen in Fig. 21.9. In some cases, the alveolar crest at the implant site may need reduction prior to implant placement, or the opposing tooth should be modified in order to achieve this space requirement. Occlusal plane problems and the lack of adequate prosthetic height can result in ceramic failure and loss of cementation to abutments that exhibit inadequate resistance and retention form. These negative outcomes can be seen in Fig. 21.10, where a four-unit implant prosthesis has failed. As noted above, available mesiodistal

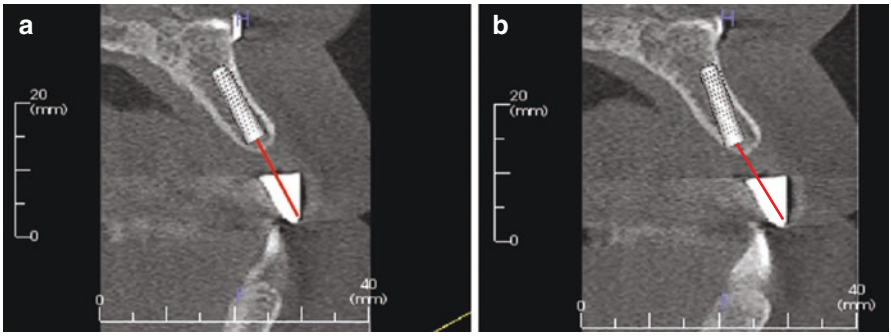

Fig. 21.8 Simulation using CBCT imaging to plan implant placement for a maxillary lateral incisor site showing an edentulous ridge with a pronounced facial undercut. The red line shows the path of the abutment screw channel. (**a**) Acceptable buccolingual implant angulation following the cross-sectional shape of the ridge for a cement-retained implant crown. (**b**) Although more complex for the surgeon, proper buccolingual implant angulation for a screw-retained implant crown. This path of placement likely results in the need to repair an apical fenestration with guided bone regeneration (GBR) methods

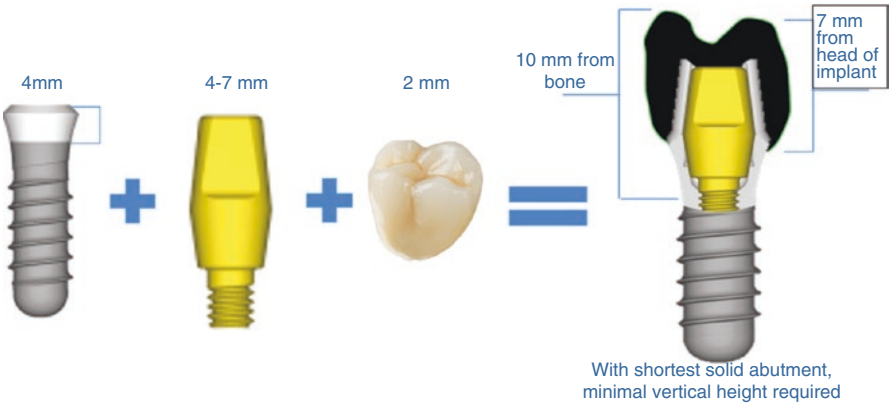

Fig. 21.9 Demonstration of soft tissue level implant components and needed prosthetic vertical height to make a single cement-retained implant crown

(MD) space may determine design and diameter of implant. On occasion, the amount of MD space or angulation of the adjacent teeth may require orthodontic treatment or modification of adjacent tooth surfaces. Examples of various outcomes from efforts at managing the available MD space and teeth adjacent to implant placement are seen in Fig. 21.11.

Figure 21.12 summarizes the approach to prosthetically driven implant planning and placement. These photos show an example of diagnostic and treatment procedures carried out to replace a single mandibular first molar with a metal ceramic implant crown. As seen in this and previous figures, diagnostic casts and diagnostic wax patterns or denture teeth can be used to fabricate a radiographic and/or surgical guide. A

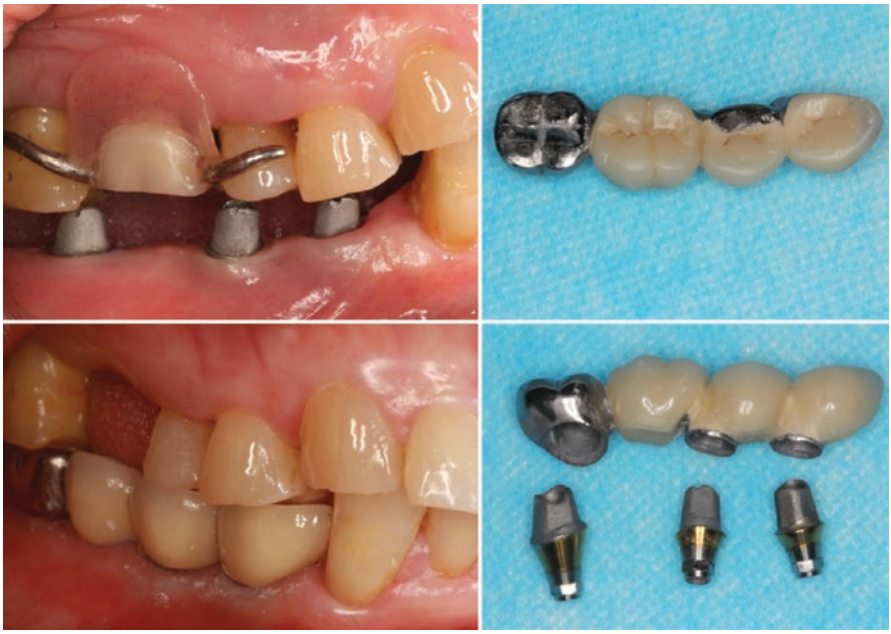

Fig. 21.10 Mandibular posterior metal ceramic-cemented implant bridge failure. The prosthesis failed due to limited vertical prosthetic height with the abutments lacking adequate resistance/retention form. Note the shape of the occlusal plane and limited height due to extrusion of the opposing teeth. Negative outcomes include partial occlusal ceramic failure and loss of cementation (Photos courtesy Dr. Hujuan Xiao)

radiographic guide can be used during 2D or 3D imaging to help best place the implant to support a properly shaped and well-positioned implant restoration. The surgical guide also helps with proper implant location and axial positioning/angulation.

21.2.3 The Implant/Bone Interface Post-Implant Placement

Modern dental implants are most often solid screws that have a rough surface. Manufacturers create this surface with a variety of methods. Upon placement of the implant, its surface should be in close proximity to the adjacent bone with extent of initial or "primary" stability affected by operator skill and bone density, as noted above. Over days and weeks, the bone adjacent to the implant resorbs and is replaced by newly regenerated bone resulting in increasing bone to implant contact area and final or secondary stability. This process can take from 4 to 8 weeks, depending on the nature of the implant surface, patient-related factors, length of implant, initial bone density, and extent of adaptation of the implant to the bone surrounding the osteotomy. Consequently, loading time to place an abutment or provisional restoration after implant placement generally occurs within 8 weeks but may be longer when bone volume and initial stability are compromised (Chidagam et al. 2017; Esposito et al. 2013a).

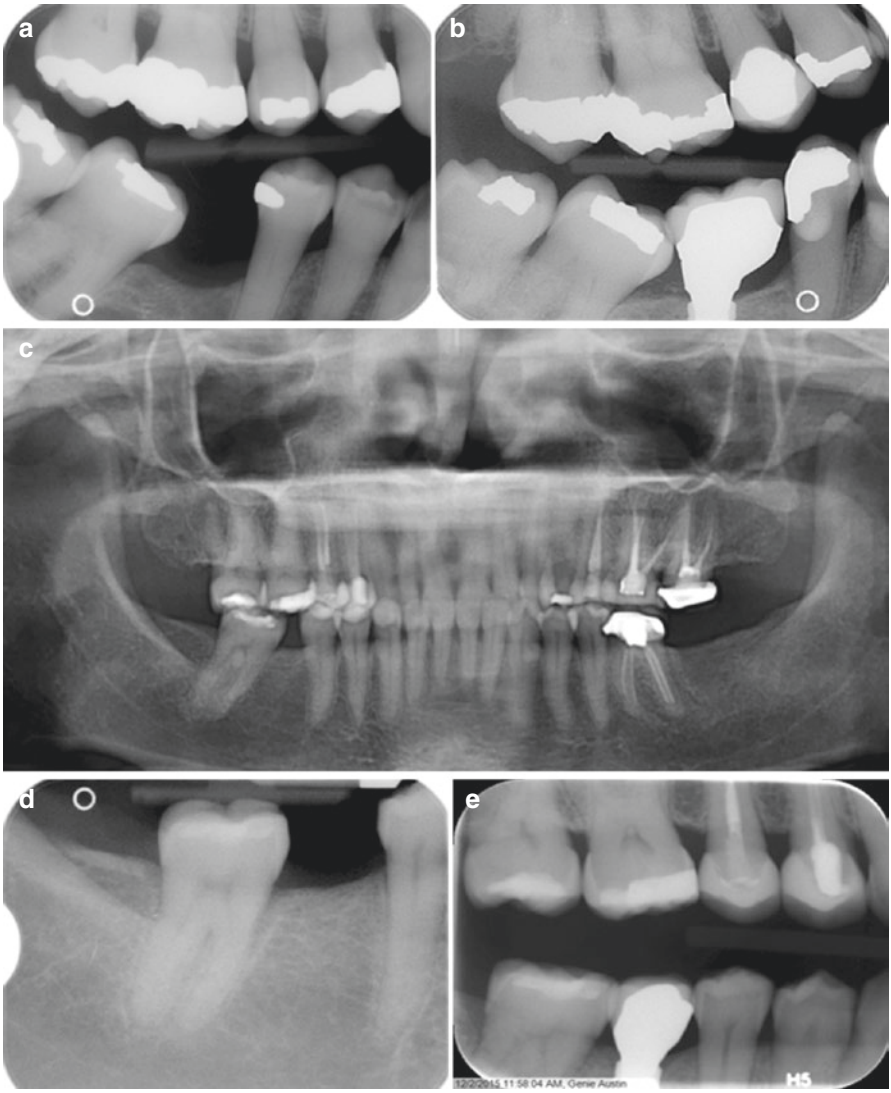

Fig. 21.11 (**a**) Tipped adjacent tooth can lead to difficulty in implant placement and restoration. (**b**) Implant crown with less than optimal emergence profile, gingival embrasure size, and interproximal contacts. (**c**) Panoramic radiograph of a case with mesial drifted first molar limiting the size of the edentulous space. (**d**) Periapical radiograph after orthodontic correction. (**e**) Periapical radiograph showing symmetrical implant crown shape exhibiting good emergence profile and smaller gingival embrasures

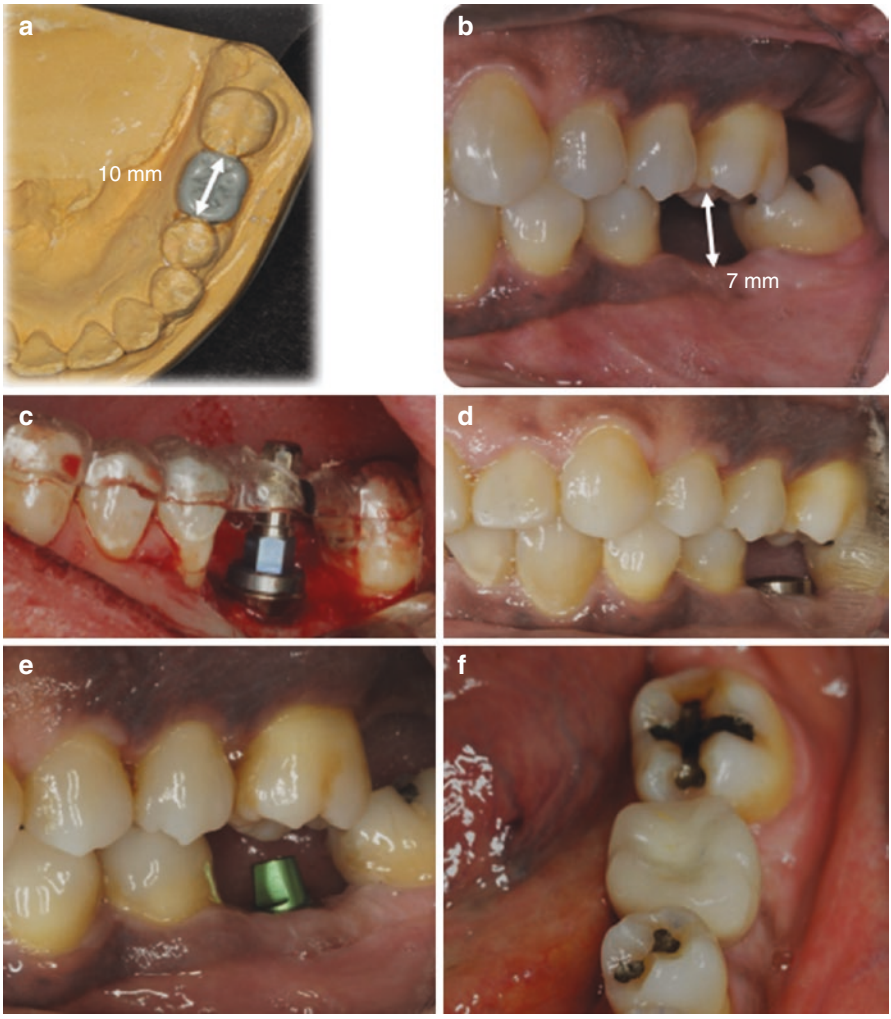

Fig. 21.12 These images show planning, surgical, and prosthetic treatment to replace a missing mandibular molar. (**a**) Diagnostic wax-up showing mesiodistal width for a molar tooth. (**b**) Adequate pretreatment vertical prosthetic height is determined. (**c**) Implant placement and angulation verified with surgical guide during surgery. (**d**) Non-submerged wide neck tissue level implant with healing abutment. (**e**) Placement of prefabricated abutment for cement-retained crown. (**f**) Final metal ceramic restoration (Photos courtesy of Dr. Tyler Thomas)

21.2.4 Surgical Considerations

Skillful soft tissue management enhances implant and bone graft placement outcomes, increases safety, and minimizes pain. This is accomplished by making well-located incisions, full-thickness flap elevation allowing for good visualization of the implant site, maintenance of flap vascularization and tissue volume at interproximal areas, and obtaining primary flap closure with well-placed sutures. Figure 21.13 shows the location and extension of incisions made for placement of an implant in the mandibular first molar site with simultaneous bone grafting on the buccal aspect. Prior to beginning the procedure, the operator should determine whether implants will be submerged, requiring a second minor surgical procedure prior to prosthetic treatment. Alternatively, transgingival healing abutments may be placed prior to flap closure for "non-submerged" implant placement. With regard to proximity to anatomic structures, implants should if possible be placed inferior to the sinus cavity. If this is not feasible, the need for a sinus elevation would be considered. Implants

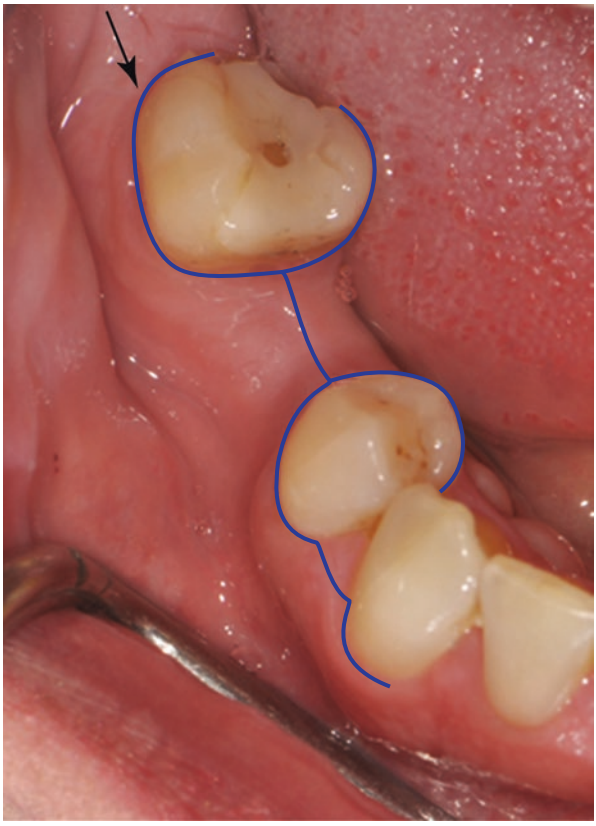

Fig. 21.13 The incision design shows a midcrestal incision extending to intrasulcular incisions of adjacent teeth, terminating with a papilla-sparing incision toward the mesial between premolar and canine (buccal surface only) and a vertical releasing at the distobuccal of the molar. The objective of this flap design is to create a full-thickness flap that contains both the mucosa and periosteum. The flap should offer adequate access for implant and bone graft placement while maintaining a proper blood supply

should be positioned at least 5 mm anterior to the mental foramen and 2 mm above the inferior alveolar nerve canal. At least 3 mm space should be maintained between adjacent implants and 1.5 mm between implants and adjacent roots.

21.2.5 Timing of Dental Implant Placement and Loading

It is possible to place implants directly into the extraction sites of single-rooted teeth in areas of moderate or low esthetic importance and where critical anatomic structures such as the mental foramen or maxillary sinus are not in close proximity. "Immediate" implant placement is technique sensitive with outcomes largely a function of operator skill and careful case selection (Esposito et al. 2007). In areas of high esthetic importance, implant placement at the time of the extraction can prove to be an advantage or additional risk. While the implants may minimize bone and tissue resorption, there is evidence of buccal plate loss in the presence of implants placed into extraction sockets (Araújo et al. 2011). Consequently, the final location of the hard and soft tissues adjacent to the implant cannot be predicted. This can lead to potential for *substantial esthetic problems* in patients with a high smile line (Rodriguez and Rosenstiel 2012). With implants placed into an extraction socket, it is important to minimize the trauma of the extraction. This includes avoidance of elevating a flap, which would remove periosteal vascularization to the buccal plate and the use of any instruments, which can create defects in the adjacent bone. The use of a thin periotome and forceps is often most helpful. Risks of poor esthetic result are increased in the presence of thin, missing, or damaged buccal plate post extraction. It is important to note that the implant osteotomy will *not* likely be an extension of original extraction site, particularly at anterior areas. In these cases, the osteotomy is located to the lingual aspect of the extraction site avoiding implant contact with the buccal plate also avoiding the creation of a fenestration in the bone forming an undercut to the alveolar ridge apical to the buccal plate (Chen et al. 2009).

Care must also be taken to avoid a buccolingual angulation of implant placement with excessive buccal flare. This allows for easy fabrication of cement- or screw-retained crowns and creation of an osteotomy that results in good implant primary stability. There are many references that describe the aforementioned techniques in detail including the use of soft and hard tissue grafting simultaneous with immediate implant placement (Chappuis et al. 2017, 2018; Benic et al. 2017; Benic and Hämmerle 2014). As an alternative to immediate dental implant placement, slowly resorbing "bone graft" substitutes can be placed into extraction sites to minimize tissue resorption, with dental implants placed after a period of soft tissue and bony healing. Please see additional detail below.

Delayed or early implant placement that occurs 4–12 weeks post extraction is generally simpler and more predictable (Kohen et al. 2016). By 4–5 weeks, there is soft tissue closure, and between 8 and 12 weeks (depending upon the size of the

socket), bone regeneration has occurred within the socket with resorption found at the periphery of the site. This more clearly defines the position of the hard and soft tissues at implant placement and allows the operator to elevate flaps to better visualize the remaining alveolar ridge, thereby simplifying the osteotomy, placement of the implant, and any needed graft materials.

Immediate loading of implants has shown to be quite successful (Boedeker et al. 2011; Kacer et al. 2010). This is a particularly well-supported approach when multiple implants with good initial stability are placed in dense bone supporting a splinted prosthesis. In a systematic review assessing the current literature, multiple studies were found to have success rates of 95.7% at 2-year follow-up for immediate loaded implants (Nkenke and Fenner 2006). Immediate loading allows a patient to receive a provisional fixed prosthesis at the time of implant placement, generally eliminating the need for a removable interim prosthesis. Immediate loading of an implant has the potential to decrease bone resorption and maintain proper gingival contouring. However, immediate loading also carries the risk of placing load on the implant at the time period when initial stability is diminishing and prior to establishment of "secondary" stability resulting from integration of the implant with newly regenerated bone at the implant surface interface (Singh et al. 2015). This can lead to early implant failure. A graphic representation of the decrease in primary stability while secondary stability increases is seen in Fig. 21.14.

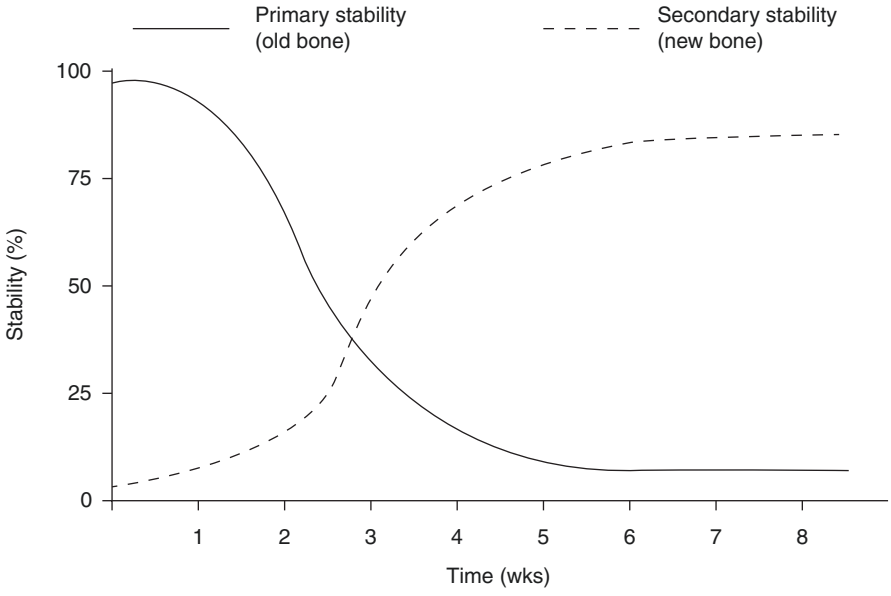

Fig. 21.14 It shows a decrease in primary stability, while secondary stability increases over the first 2 months of implant integration (Raghavendra et al. 2005)

21.2.6 Socket Preservation

"Socket preservation" (actually we do not really want to preserve the socket but rather obliterate it with regenerated bone) is a technique used to theoretically reduce bone resorption after extraction and, hopefully, provide a better foundation for a future implant. Socket preservation is accomplished by placing a slowly resorbing osteoconductive biomaterial serving as a bone graft substitute into the extraction site immediately after the tooth is extracted. The types and derivation of these biomaterials are described in the next section. Ideally, the biomaterial preserves the height and width of the adjacent alveolar bone and resorbs allowing for enhanced formation of newly regenerated bone into the socket. The evidence on the efficacy of socket preservation is very weak. Although several studies exist that support the use of socket preservation, many contain insufficient evidence to draw such a conclusion or have a high degree of bias (Brignardello-Petersen 2018; Moraschini and Barboza 2016). A systematic review was performed to validate the efficacy of socket preservation. Six randomized controlled trials and three controlled clinical trials were reviewed. The authors concluded that evidence shows that although socket preservation may alter the bony dimensional changes after tooth extraction, this procedure does not prevent ridge resorption (Byrne 2012). In a recent study from 2016, a meta-analysis was performed to determine if bone grafting after tooth extraction provides alveolar ridge preservation. This study concluded that socket preservation may prevent bone loss in both the horizontal and vertical dimension after extractions of non-molar teeth (Cheng 2016). The author concluded that the studies analyzed supported that there was a statistically and clinically significant increase in midbuccal height of 2.07 mm. The question then becomes whether socket preservation has a clinical difference beyond just a statistical difference, and this is still yet to be determined. Socket preservation most likely has minimal effect on long-term implant success; however, the esthetics is often a critical factor of clinical success, and it is generally agreed that the placement of bone graft substitutes in the extraction site results in greater overall tissue volume, thereby enhancing the esthetic outcomes. Socket preservation in many clinical situations is likely not to aid in the future stability of the implant but to aid in the overall esthetics of the restored implant. A particularly clinical relevant study compared 40 patients who underwent socket preservation for a single anterior implant with 20 control patients who had single anterior implants placed without socket preservation. Clinical and CBCT analysis demonstrated that ridge preservation was more effective in preserving at least 6 mm alveolar ridge width at the time of implant placement than in the control group in the anterior maxillary zone (Lee and Poon 2017). In instances of high esthetics, many studies have shown great benefit of an immediate implant placement with simultaneous bone grafting at the time of the extraction instead when possible. We do know that placement of slowly resorbing biomaterial graft material into the extraction site will delay implant placement, since the manufacturers generally expect biomaterial resorption and replacement with new bone to occur from 5 to 12 months. At this point with current evidence, one cannot recommend routine socket preservation for all extractions. The determination for placing a biomaterial

into an extraction site is a function of clinical judgment for a particular case. The anatomy and location of the site along with planned timing of implant placement and restoration will have great impact on this decision.

21.2.7 Bone Grafting

Bone regeneration through grafting procedures may be undertaken months prior to implant placement or when there is adequate bone volume to stabilize the implant, but not enough width to provide coverage of all implant surfaces, simultaneous with implant placement (Benic et al. 2017; Benic and Hämmerle 2014). "Guided bone regeneration" (GBR) constitutes grafts that are primarily particulate in nature, while "block grafts" are fastened with stabilization screws (Joshi et al. 2017). Guided bone regeneration can be done months prior to implant placement to develop the site or simultaneous with implant placement as seen in Fig. 21.15. Regardless of the source of the graft material, the primary purpose is to serve as a scaffold and maintain a volume of space (preventing soft tissue collapse) for new bone formation while slowly resorbing and being replaced by newly regenerated bone. At this time, numerous bone graft materials exist. Autologous (or autogenous) bone grafts are bone grafts derived from the patient. Depending on its shape and size, an autogenous bone graft has varying amounts of structural capacity and osteoinductive capacity. Common donor sites include the edentulous ridge during modification prior to dental implant osteotomy, bone removed from the osteotomy, the ramus or symphysis of the mandible, and the nasal spine and lateral wall of the maxillary sinus for the maxilla. The selected donor location generally depends on the type of bone needed (particulate vs. block), the volume needed, and the expected recipient site. Block grafts can often be obtained in the ramus or symphysis regions of the mandible as seen in Fig. 21.16. Particulate grafts can be obtained from all of the potential donor sites. Implants placed after or simultaneous with bone grafting show

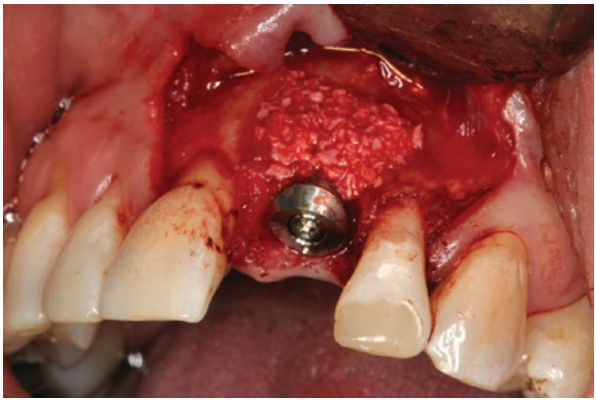

Fig. 21.15 It shows guided bone regeneration simultaneous with implant placement with particulate graft material placed at the facial aspect of an implant replacing a maxillary central incisor (Photo courtesy of Dr. Cho)

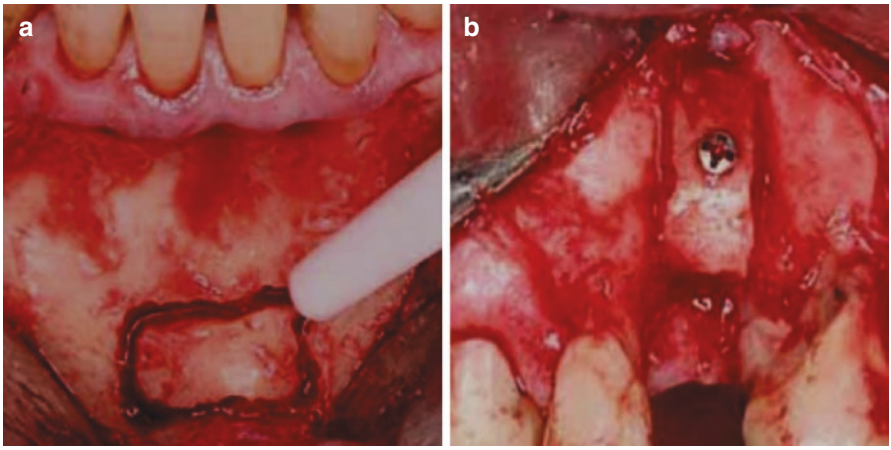

Fig. 21.16 (**a**) Autologous block graft harvested from the mandibular symphysis. (**b**) Block graft secured with titanium screw into defect at recipient site 5–6 months prior to implant placement

excellent outcomes (Benic et al. 2017; Jensen and Sindet-Pedersen 1991). Only clinicians with extensive surgical training should undertake cases requiring more invasive bone grafting procedures.

There are three types of bone graft substitutes: allografts are biomaterials composed of cadaver bone. An important difference from autogenous bone is the loss of endogenous cells and growth factors resulting from processing and sterilizing the allograft, thereby reducing or eliminating osteoinductive capacity. Consequently, the allograft will exhibit varying amounts of bony osteoinduction while also serving as an effective osteoconductive scaffold for new bone regeneration (Sheikh et al. 2017). A xenograft is a graft that is obtained from another species. The most common xenografts used in alveolar bone regeneration are osteoconductive bone graft substitute made of inorganic components but derived from nonhuman sources. Alloplasts are synthetically derived biomaterials that are generally derived from calcium phosphate (CaP) such as beta-tricalcium phosphate (beta-TCP), hydroxyapatite (HA), or combinations of various CaP materials (Choo et al. 2013; Kniha et al. 2018; Singh and Suresh 2012; Gahlert et al. 2016). The different formulations of the alloplasts primarily alter how quickly they are resorbed and replaced. The use of bone graft substitutes allows for the eliminating the harvesting of autogenous bone or harvesting a smaller volume of autogenous bone while providing structure and slow resorption characteristics that stabilize and "protect" the autogenous component of the bone graft. In addition, the use of bone graft substitutes eliminates and donor site morbidity. To take best advantage of these characteristics, clinicians often mix and/or layer autogenous bone and biomaterial bone graft substitute components (Wang et al. 2004). It is expected that implants can be placed into previously placed block or particulate bone grafts

5–6 months post-graft placement; however, there is older data that shows implant stability may be more predictable when placed 6–9 months following bone grafting (Triplett and Schow 1996; Anitua et al. 2015; Levin et al. 2005, 2007). Implants placed into bone-grafted sites tend to have slightly decreased survival rates but still have been demonstrated to be quite stable (Lekholm et al. 1999). When particulate grafting occurs simultaneously with implant placement, the implant will often begin prosthetic treatment approximately 3–4 months after implant placement.

21.2.8 Sinus Elevation

As stated earlier, the maxillary edentulous arch creates its own challenges. The maxillary bone tends to resorb in the apical and palatal direction. In the posterior maxilla, the lack of vertical bone height may prevent implant placement. When minimal vertical bone height exists between the crest of the edentulous ridge and the maxillary sinus, choices need to be made (Kent and Block 1989). One option is to use "short" implants. As currently defined, short implants (4–8 mm) have been demonstrated to have similar success rates to longer implants (Atieh et al. 2012; Guljé et al. 2013). One paper reviewed 18 studies comparing sinus elevation (lifts) vs. using short implants. The study found that sinus lifts had more complications than using a shorter implant (5–8.5 mm) but that the data could not support the use of one or the other (Marchionni et al. 2017). Therefore, the clinician can consider using a shorter implant as a possible alternative to sinus lifts in certain situations. Sinus elevation is the alternative to placement of a short implant. Boyne and Jones described that if space was maintained between an implant and an elevated sinus membrane, the bone will eventually grow in its place (Boyne and James 1980). In contrast, implants placed directly into the sinus membrane tend to form a fibrous tissue interface without any new bone growth to support the apical aspect of the implant (Brånemark et al. 1984). Depending on the bone height and extent of sinus elevation needed, an "internal" sinus elevation may suffice (Pal et al. 2012). Internal sinus lifts can be performed when there is already at least 5 mm of bone between the ridge and the maxillary sinus. There must be adequate bone height below the sinus for the implant to be stable when it is inserted in the alveolar bone. This approach is executed by making the osteotomy just short of the sinus floor. Hand osteotomes can then be used to "up-fracture" the remaining cortical bone at the sinus floor. Typically, 3–5 mm of sinus elevation can be predictably obtained by this technique, with greater vertical bone gain if graft material is placed at the apex of the osteotomy site (Schleier et al. 2008; Summer 1994; Romero-Millán et al. 2012; Chen and Shi 2017). Minimizing the extent of the elevation decreases the risk of creating a hole in the sinus floor and perforating the sinus membrane. The implant can then be placed as soon as sinus floor elevation is completed to the desired extent.

An "external" lateral window sinus elevation is generally considered a more advanced surgical technique, and clinicians with extensive surgical training

should undertake this more invasive type of procedure. This procedure is performed using a window that is created in the lateral sinus wall after reflecting an extensive mucoperiosteal flap with releasing incisions. After flap elevation, the sinus may be visible through the lateral wall showing as a transparent/blue appearance. A rectangular- or oval-shaped window is created with a large round diamond bur or now more commonly with an ultrasonic piezotome using great care to prevent perforating the underlying sinus membrane (Lin et al. 2016). When the osteotomy is completed, the membrane can be visualized and gently elevated with curettes. Bone graft material is spaced into the new space created between the apical aspect of the edentulous ridge and the sinus membrane. A clinical example can be seen in Fig. 21.17. Autogenous bone can be harvested from the iliac crest, chin, ramus, or tuberosity (Block and Kent 1997). Other techniques utilize bone graft substitutes alone or in combination with autogenous bone. The provider should wait 5–6 months after sinus augmentation and then 3 months after implant placement prior to prosthetic treatment. If the sinus elevation is not extensive and enough bone height exists to achieve primary stability, the implant can be placed at the time of the sinus augmentation.

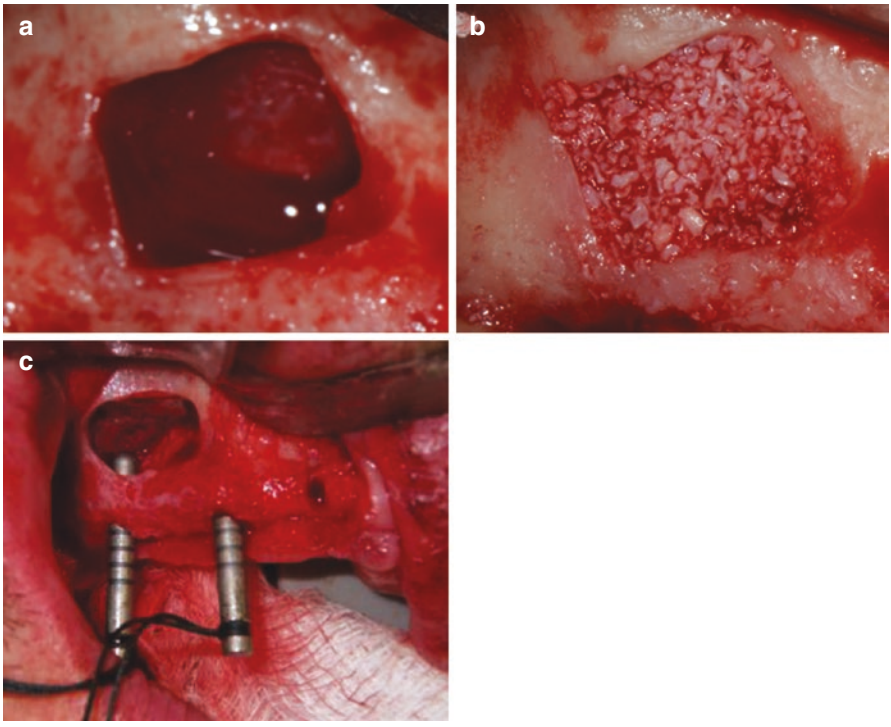

Fig. 21.17 (**a**) Lateral window osteotomy exposing maxillary sinus and elevated sinus membrane. (**b**) Particulate bone grafting placed between sinus membrane and superior aspect of edentulous ridge. (**c**) Sinus augmentation with implant placement showing guide pins used to gauge implant depth and assess potential initial stability

21.2.9 Overdentures

Implants can be used to aid in retention of conventional dentures. In the mandible, two implants, both placed in the lateral incisor region, are generally effective to stabilize and better retain the prosthesis while minimizing anterior/posterior rotation. In the maxilla, four implants optimally placed in the lateral incisor and premolar sites will reliably retain the prosthesis and eliminate the need for palatal coverage (Raghoebar et al. 2014; Sadowsky 2007; Slot et al. 2016; Zitzmann and Marinello 2000). Converting dentures to overdentures is a relatively easy procedure that can be extremely beneficial to your patients (Boerrigter et al. 1995). For the maxilla and placement of four implants, the distance between the anterior and posterior implants is called the anterior-posterior (AP) spread (Jensen and Adams 2009). The greater the AP spread, the greater the potential stability of the prosthesis. For the overdenture prosthesis, is it critical that there is adequate vertical prosthetic space for the implant abutment, housing, and prosthetic material (need photos). This would measure approximately 10 mm from the alveolar crest to the outer (cameo) surface lingual to the anterior denture teeth and from the alveolar crest to the occlusal surface of posterior teeth. From a planning and prosthetic view, *the conventional denture should be made prior to implant placement*. This allows for fabrication of a surgical guide and well-located surgical implant placement. Planning, surgical guide fabrication, and guide pins placed into implant osteotomies during implant surgery can be seen in Fig. 21.18. There are two important surgical notes related to implant placement for the mandibular overdenture: (1) do not minimize the importance of careful full-thickness lingual flap elevation identifying possible intraosseous vessels moving through lingual foramina to the soft tissues, and (2) prevent the osteotomies from making any perforation through the lingual plate near the floor of the mouth.

21.2.10 Anticoagulants

Many dentists are still not questioning how to handle anticoagulants and implant surgery. The literature suggests that 0.6% of patients required more than positive hemostatic pressure such as reducing their anticoagulant dose postoperatively (Wahl et al. 2018). Therefore, the risk of significant/uncontrolled postoperative bleeding is exceedingly low in dental procedures performed on patients who take anticoagulant medications and who are maintained in a normal therapeutic range. The risk of stopping a patient's anticoagulant medication outweighs the benefit of minimizing postoperative bleeding. The vast majority of the literature states that patients on oral anticoagulants in the appropriate therapeutic range can be treated the same as healthy patients (Wahl et al. 2018; Beirne 2005; Jeske and Suchko 2003; Alaali et al. 2012; Mauprivez et al. 2016). If a patient is taking warfarin, it is important to know the patients INR prior to surgery. The 2016 American Academy of Oral Medicine recommends the INR be checked "within a few days" of the procedure (Lockhart 2016). Some providers are worried about the newer medications, such as dabigatran that does

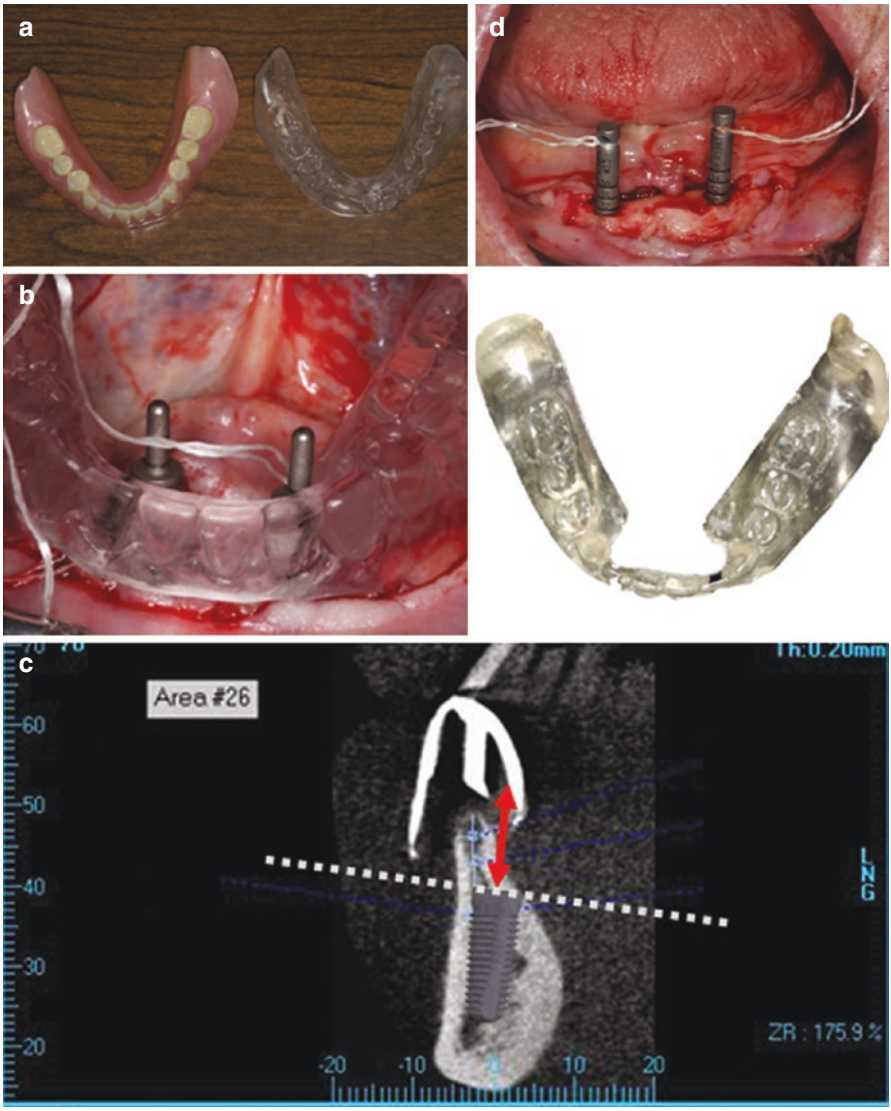

Fig. 21.18 (**a**) Surgical guide fabrication by duplicating complete denture with clear acrylic. (**b**) Surgical guide with window at lingual aspect allowing site visualization, access for drills to make osteotomies, and placement of guide pins. (**c**) The vertical line represents the distance from the head of the implant to the cameo surface on the *lingual aspect* of the denture base, which should be at least 10 mm. If the distance is less than 10 mm, alveolar bone should be reduced in order to create additional prosthetic space and a wider platform (indicated by the horizontal dotted line). The reduction of alveolar bone height just prior to implant placement allows for adequate space for the overdenture abutment on the implant and overdenture housing within the tissue side of the prosthesis. (**d**) Clinical photo showing bone reduction and guide pins placed into implant osteotomies

not have routine monitory tests. If worried about postoperative bleeding in these cases, the provider can plan the surgery between dosing. Plan to have the implant surgery after 12 h from last dose, and resume 8 h after implant surgery for patients taking dabigatran (Gómez-Moreno et al. 2016). Still little evidence suggests stopping or delaying these newer medications for routine dentoalveolar surgery (Napeñas et al. 2013).

21.2.11 Smoking

Although smoking can be considered a relative contraindication, it does not preclude a patient from dental implant placement. Smoking has been demonstrated to increase failure rates (Abt 2009; Hinode et al. 2006). The failure rate appears to be greater in the maxilla than the mandible of smokers. In addition, there is some evidence that the negative effect of smoking may be less critical with dental implants having roughened surfaces such as ones that are sandblasted and/or acid etched. If possible, the provider should counsel the patient on the benefits of smoking cessation, both the dental and the systemic benefit. It is important to explain the increased risk of failure of implants in patients who use tobacco. Patients who smoke need to maintain prestige oral hygiene to minimize the risk of implant failures.

21.2.12 Bisphosphonates

Evidence on the effects of oral bisphosphonates on dental implants still lacks real conviction. Some studies have suggested that oral bisphosphonates initially increase implant stability. Other studies suggest oral bisphosphonates can lead to late implant failure. These late implant failures in patients on bisphosphonate appear to be of a different type than that typically seen in patients not on bisphosphonates. Rather than seeing the typical loss of osseointegration at the bone implant interface in failures associated with bisphosphonate use, implants remain integrated to the bone on their surface. However, this surrounding bone becomes necrotic essentially creating a bony sequestrum with implant attached to it. This type of late implant failure maybe associated with the inability to have adequate bone turnover and bone integration leading to a localized osteonecrosis. Pogrel and Ruggiero suggest that this late implant loss is related to the lack of a periodontal ligament. The masticatory forces placed on the surrounding bone become high enough to cause localized bony necrosis and implant loss. This increased force requires greater bone turnover which can be inhibited by the initiation of bisphosphonate therapy (Pogrel and Ruggiero 2017). Patients on oral bisphosphonates tend to be at a much lower risk of implant loss or osteonecrosis than patients given IV bisphosphonates (Bell and Bell 2008). One study of 468 implants in 115 patients who had history of oral bisphosphonate use found no evidence of bisphosphonate-associated osteonecrosis. In the same study, 466 of the 468 are fully osseointegrated (Grant et al. 2008). Regardless of whether the patient is taking oral or IV bisphosphonate therapy, the practitioner should take special consideration to evaluate the risk of implant failure and osteonecrosis. Current American Association of Oral and Maxillofacial Surgeons (AAOMS)

recommendations are that if dental implants are placed in patients on oral bisphosphonate therapy, informed consent must be obtained related to the possible long-term implant failure and the low risk of developing osteonecrosis of the jaw (Ruggiero et al. 2014). The patients should be placed on regular recall schedule.

21.2.13 Antibiotics and Rinses

As touched in the previous chapter on medical assessment, antibiotic prophylaxis in implant surgery is still a controversial topic, and evidence is limited. Certain studies show antibiotic prophylaxis and also show no apparent difference in postoperative infection for patients who receive dental implants (Keenan and Veitz-Keenan 2015). Other studies have shown that implant failure rates are significantly reduced when antibiotic prophylaxis is given and a single dose of preoperative antibiotics is usually sufficient (Sharaf and Dodson 2011; Deeb et al. 2015; Mazzocchi et al. 2007; Dent et al. 1997). Having patients use 15 ml of 0.12% chlorhexidine gluconate rinse can be prescribed for two times a day for 2 weeks to aid in soft tissue maintenance after implant placement.

21.2.14 Postoperative

It is important to take postoperative radiographs to assess implant placement and angulation. Most providers will prescribe postoperative antibiotics in addition to preoperative prophylactic antibiotics. However, it is questionable that the use of postoperative prophylactic antibiotics is supported by the current literature. In a review in the Cochrane Library from 2013 on the effectiveness of antibiotics to prevent complications in implant surgery (Esposito et al. 2013b), the authors concluded that there was good evidence to support the use of a single dose of antibiotics (specifically 2 g of amoxicillin) was effective in reducing implant failures but that it was unclear whether postoperative antibiotics were beneficial. There does appear that there is a trend to reduced antibiotic use by providers placing dental implants, thus adopting a more evidence-based approach (Khalil et al. 2015). Mild analgesics such as NSAIDs can be prescribed for postoperative pain management. Narcotic pain medications are rarely indicated unless significant adjunctive bony surgery is done such as harvesting and placing cortical bone grafts from the mandible. A 1–2-week follow-up should be scheduled to evaluate soft tissue healing.

21.3 Conclusion

Implants can be a valuable tool for the general dentist and a great option for many patients. It is vital that the general dentists are aware of his/her abilities and limitations. Always act in the patient's best interest, and refer when appropriate. Many cases are straightforward and conventional and will be well suited with the general dentist. It is important to do a proper workup that includes a medical

assessment, a treatment plan that explains the risk and benefits of implants, and alternatives. Implants are not for all patients in all circumstances but can be quite useful for many patients. Being mindful of the relative contraindications can help foresee obstacles and minimize complications.

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Forensic Odontology

22

Kevin Rand Torske

"We balance probabilities and chose the most likely. It is the scientific use of the Imagination."
Sherlock Holmes in—The Hound of the Baskervilles

Abstract

The skills and knowledge of dental professionals may assist the justice system in the investigation of legal issues, especially in the identification of human remains. The detailed analysis of antemortem and postmortem dental evidence is a primary method of identification and, depending upon the condition of the recovered remains, may represent the sole means of scientifically assured assessment. As the requirements to perform this service often arrive with little warning or time to prepare, prior knowledge and understanding of the principles involved greatly assists in successful completion of this important task.

22.1 Introduction

Forensics may be defined as the collection of scientific evidence pertaining to the investigation of criminal activity. A forensic scientist utilizes specific skills in the gathering of evidence and assists law enforcement personnel, lawyers, judges, and juries in understanding the relevance of pertinent information.

The investigation of civil or criminal legal matters involves a wide range of disciplines and expertise. Forensic scientists may have specialty skills in many

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branches, to include psychiatry and behavioral science, pathology/biology, anthropology, criminalistics/crime scene investigation, entomology, accounting, toxicology, digital and multimedia sciences, jurisprudence, questioned documents, or odontology/dentistry.

Forensic Dentistry (*Forensic Odontology*) pertains to the collection and analysis of dental evidence that may apply to a potential criminal event. The primary use of forensic odontology skills is in the identification of human remains. Other possible uses may include investigation of fraud, malpractice, or negligence, assault to include bite mark or pattern injury analysis, determination of dental age, and presenting testimony as an expert witness.

22.2 Forensics in the Dental Office

Whether realized or not, the practice of forensic dentistry is regularly performed in the routine care of patients. The results of dental examinations and treatment as documented in the patient's dental record serve as the basis of forensic dental evidence.

22.2.1 The Dental Record

The dental record is the single most important document in forensic dentistry. Examination forms, dental radiographs, lab requests, and treatment/progress notes all provide significant information as to the restorative dental profile of the patient.

Entries. Accurate and thorough documentation is required within the antemortem dental record. It should ideally contain results of an initial examination, to include charting of the patient's presenting dental restorative profile. All existing and missing teeth are annotated, as are all restored teeth, to include the type of restorations and surfaces involved. This serves as a basis for forensic assessment, with any successive treatment modifying the initial dental restorative pattern.

Subsequent treatment should be detailed, to include tooth number, tooth surfaces, and type of restorations involved. Listing of the exact brand of restoration may also be of forensic use, due to the unique chemical composition of different dental restorative materials.

Legal Issues. The dental record is a legal document owned by the dental professional or practice. As the record is evidentiary material, accuracy and legibility are important. To maintain a provable association to a specific individual, every document, radiograph mount, or CD containing digital images must be labeled with at least two forms of personal identifiable information. This should include the patient's full name, date of birth, and/or identification number (Social Security number, military identification number, etc.). As many individuals have similar names, the use of two forms of identifiable information is required so as to help assure patient identification accuracy. Finally, all entries should be signed or initialed by the provider.

The dental record may be subpoenaed if required for forensic use. In addition, the Health Insurance Portability and Accountability Act (HIPAA) of 1996 allows for submission of dental records to coroners and medical examiners for forensic purposes via 45 Code of Federal Regulations §164.512(g)(1). By means of this statute, submission of the record for forensic purposes may be completed without the need for specific permission from the patient, guardian, or next of kin (GPO 2017).

22.3 Identification of the Deceased Patient

In dentistry, the most common application of forensic science is in the identification of deceased human remains. The establishment of proven identification is vitally important and affects issues such as life insurance, probation of a will, and possible legal matters if the manner of death is in question.

Official identification is determined by the presiding jurisdictional agency—typically the coroner or medical examiner—and documented via the death certificate. Evidence as to identity may be gathered by multiple forensic specialists serving in a consultative role, to include experts in fingerprinting, DNA, and odontology.

The incident may involve only a single unknown individual or encompass mass casualties due to natural disasters, criminal actions, or accidents. Regardless of the size or cause of the event, the identification of deceased individuals follows routine methods and nomenclature.

22.3.1 General Concepts

Types of Identification. The identification of human remains may be performed in many manners with varying degrees of scientific certainty. These methods may be categorized as either circumstantial or scientific. *Circumstantial Identification* is one based upon inference and non-fact-based opinion. *Scientific Identification* is based on facts and data gathered via proven principles and investigative methods.

Categories of Identification. Regardless of method, conclusions are reported based upon the level of certainty of the identification. This may include positive, presumptive, or exclusion from identification.

- *Positive Identification*—Distinct and unique biological commonalities are present between antemortem and postmortem biologic evidence, without presence of any unexplainable discrepancies. Identification is assured beyond reasonable doubt.
- *Presumptive ("Consistent-with") Identification*—Commonalities are present between antemortem and postmortem biologic evidence, without presence of any unexplainable discrepancies; however, an insufficient amount of unique or distinct characteristics are shared for certainty in identification.

- *Exclusion of Identification*—Unexplainable discrepancies exist in the comparison of antemortem and postmortem biologic evidence so as to definitively exclude the establishment of identification beyond reasonable doubt.

If an inadequate amount of antemortem and/or postmortem biologic evidence is available for conclusive review, the term *Insufficient Evidence* may be used.

Discrepancies are often noted in the comparison of antemortem and postmortem evidence and may be either explainable or unexplainable. *Explainable discrepancies* provide for a rational and logical explanation of differences in comparison. In dental analysis, this typically involves progression of dental treatment over time. For example, in an older antemortem dental record, a molar tooth is depicted with a mesial-occlusal amalgam; however, the postmortem remains demonstrate a mesial-occlusal-distal resin restoration in the same tooth. This discrepancy is explainable as simple further treatment for which the corresponding antemortem dental record depicting such continued care is unavailable for review.

Explainable discrepancies may also involve the presence or absence of teeth where mesial drift may be associated. If a permanent mandibular first molar is lost at an early age, the second and third molars may move mesially to fill the gap. The loss of the first molar may be annotated in the antemortem dental records, but in postmortem examination, its absence may not be obvious due to mesial drift. This may lead to a difference in teeth listed as present or missing in comparison of the dental evidence.

Unexplainable discrepancies may also exist, where logical rationale cannot be proffered to clarify differences between antemortem and postmortem evidence. As the human dentition cannot heal from previous antemortem trauma or treatment procedures, unexplainable discrepancies are usually associated with the absence of documented restored tooth surfaces in the recovered remains, or the postmortem presence of teeth that were listed as extracted in the antemortem dental records.

The level of certainty depends upon the amount and uniqueness of shared characteristics between the antemortem and postmortem evidence; however, it may be influenced by whether the postmortem scenario includes an open or closed population. A *closed population* is one that has a defined number of casualties and presumptive identifications, such as from an aircraft accident with a verified manifest of passengers and crew. An *open population* is one for which the potential casualties are undefined, such as the recovery of a single unknown individual without any material evidence so as to provide an initial presumptive identification. If the population is closed, the required amount of unique common characteristics may be lessened, especially if all other possible casualties may be excluded. On the other hand, if the population is open, the importance of uniqueness is amplified so as to confidently arrive at a scientifically reasonable positive identification.

22.3.2 Circumstantial Identification

Circumstantial identification may rely upon multiple approaches, the most common being visual identification or material evidence. Although occasionally used as a solitary means of analysis, the best use of circumstantial methods may be in arriving at an initial presumptive identification. This may serve as a starting point to request antemortem dental records, fingerprints, or DNA reference samples so that a formal scientific identification may follow.

Visual Identification. Visual identification is based upon the recognition of a person via outward physical appearance. Although potentially useful immediately after death, soft tissue decomposition rapidly alters physical appearance, rendering visual identification increasingly unreliable with the passage of time. Unique features such as tattoos or scars may increase the validity of visual identification, especially if such items are documented via antemortem photographs or within a medical record.

Material Evidence. Items found on or associated with a decedent may assist in identification. This may include identification media such as a driver's license, military identification card, passport or "dog tags," or distinctive clothing items or jewelry. Material evidence may be swapped between casualties, whether accidently or intentionally, which may lead to erroneous assumptions upon review.

Forensic Anthropology. Identification based upon forensic anthropology lies on the border between circumstantial and scientific, depending primarily upon the scenario where utilized. The forensic anthropologist's evaluation of the skeletal remains typically provides information regarding the patient's height, age, sex and race. These four items represent the decedent's *biological profile* and are procured via well-established scientific protocols. Unfortunately, exact determinations of height and age cannot typically be established, and a range of possibilities is usually proffered. Should the decedent's biological profile match that found within the antemortem evidence, this may serve as support to identification. However, a biological profile is typically not unique to an individual, so additional forms of identification may be required to arrive at a positive conclusion to identity (Christensen et al. 2014).

22.3.3 Scientific Identification

Three forms of scientific identification are commonly utilized, to include analysis and comparison of fingerprints, nuclear DNA, and dental restorative patterns. Each method has advantages and disadvantages depending upon the situation and quality of the recovered postmortem remains.

Fingerprint Identification. Human fingerprints consist of a pattern of whorls, arches, or loops which may be used as a marker for human identity (Champod 2015; Yager and Amin 2004). Fingerprints are stable throughout life, are difficult to alter, and are relatively unique to a specific individual.

Standardized methods are employed for the collection and analysis of fingerprints, making this technique highly reliable and reproducible. The Federal Bureau of Investigation holds a fingerprint identification database termed the Integrated Automated Fingerprint Identification System (IAFIS) which contains the fingerprint profile of over 70 million subjects. This program may be used to analyze and compare recovered postmortem fingerprints for identification purposes.

Advantages of fingerprint identification include the stability of the fingerprint pattern throughout life, a centralized database of antemortem records, a well-established and standardized protocol for retrieval and comparison, an ability to be performed by an automated system, and the rapidity of comparison and conclusions with high accuracy and relative low cost. Disadvantages mainly involve the postmortem loss of soft tissue due to trauma or decomposition, leading to complications in the recovery of quality postmortem fingerprints.

DNA Identification. The use of deoxyribonucleic acid (DNA) for forensic identification has been performed since the 1980s (Amorim and Budowle 2016; Butler 2015). Two main forms of DNA are commonly analyzed, nuclear and mitochondrial. *Nuclear DNA* is a 50/50 combination contributed by one's biological mother and father, whereas *mitochondrial DNA* is solely inherited via the maternal line.

Two copies of nuclear DNA (nDNA) are found in all nucleated cells of the body, thereby potentially retrieved from all cells excluding red blood cells. Although easily retrieved from healthy soft tissue, changes due to significant decomposition or fire may limit or preclude the recovery of viable nDNA sequences.

Although a significant amount of one's nuclear DNA sequence is shared with other individuals, focal highly variable sequences may be found—termed *minisatellites*—that are unique to an individual. The analysis and comparison of these minisatellites forms the basis of nuclear DNA identification.

An antemortem nDNA reference sample is required for comparison. Hair or blood samples from the presumptive individual are typically utilized, although tissue archived from previous biopsies is occasionally available. The FBI also houses the National DNA Index System (NDIS) and Combined DNA Index System (CODIS) which contain DNA profiles of individuals processed through the justice system.

The nDNA retrieved from the postmortem remains is then compared to antemortem reference samples for potential identification. This process requires specific scientific equipment and time for analysis and comparison.

Advantages of nuclear DNA identification include high accuracy, reliability, and international standardization. Limitations may include difficulty in obtaining antemortem reference samples, longer time required for processing and analysis compared to other forms of identification, and relative high cost. In addition, the retrieval of viable postmortem nDNA may not be possible from skeletonized remains or those suffering from significant soft tissue decomposition or degradation.

Mitochondrial DNA (mtDNA) may be found in all cells, and as opposed to only two copies of nDNA per cell, mtDNA is relatively abundant due to hundreds of mitochondria found within the cytoplasm. In addition to greater abundance, mtDNA

is relatively more resistant to degradation from decomposition and may be harvested from osseous hard tissues such as skeletonized remains.

Mitochondrial DNA is inherited solely from one's biological mother and does not significantly change though generations. An individual, therefore, has the same mtDNA sequence profile as their mother and all relatives born via the same maternal lineage. Antemortem mtDNA reference samples may therefore be obtained from any maternal relative.

Advantages for mtDNA identification are greater ability to retrieve viable postmortem DNA and relative ease in locating antemortem DNA reference samples. The greatest disadvantage for mtDNA is lack of specificity for a single individual, as positive sequence matches only prove relationship to a maternal family line.

22.3.4 Dental Identification

22.3.4.1 General Information

A third form of scientific identification utilizes the comparison of antemortem and postmortem dental evidence to determine potential similarities. An individual's dentition may display extremely distinctive characteristics due to restorations, anatomy, or pathology, and this uniqueness may be utilized to form a scientifically valid opinion as to identity.

Dental remains are the strongest tissue in the human body and the most resistant to decomposition and damage from fire. This presents an advantage over fingerprints and DNA as identification may be performed on skeletonized or severely burned remains. Dental analysis is also relatively quick and inexpensive.

Dental identification drawbacks often revolve around access to antemortem dental records. As opposed to large, centralized databases of antemortem fingerprints or DNA reference samples, antemortem dental records are often held individually by a dental provider or practice. Identity of the provider may be difficult to determine and unknown to friends or relatives. The quality and accuracy of the antemortem record may also influence identification.

Fingerprints and DNA remain stable throughout life; therefore, even older antemortem reference samples may be utilized for comparison. The fluctuating nature of a dental profile, however, may negatively impact analysis. Evolution from deciduous to adult dentition and continuing changes via caries, periodontal disease, and resultant dental care constantly alter the antemortem dentition over time. The accuracy and usefulness of older antemortem dental evidence may consequently be lessened, hampering dental identification.

22.3.4.2 Antemortem Evaluation

Antemortem dental evidence analysis primarily involves the review of obtained dental records, with the goal of creating a snapshot of the most likely dental restorative profile of the patient immediately before death.

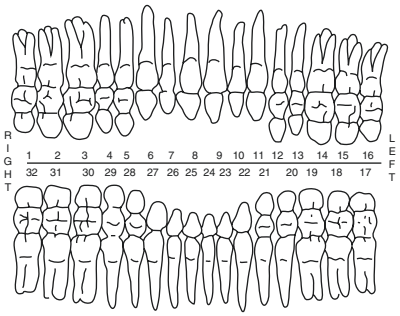
The antemortem charts should be obtained and distributed by the law enforcement group with jurisdiction over the identification event, typically being the local

medical examiner or coroner. Care must be taken to verify receipt of the correct record and all pages reviewed to confirm belonging to the same individual.

The initial dental examination results, progress/treatment notes, and dental radiographs are reviewed. Laboratory forms may also provide useful information. The most up-to-date information should be reviewed first as this ought to provide the most accurate portrayal of the dentition at the time of death.

ANTEMORTEM DENTAL RECORD

Last Name:	First Name:	Middle Initial:
Social Security Number (ID number):	Date of Birth / Age:	
Sex:	Race:	Grade/Rank:
Date of Analysis:	Analyst(s): _____ _____	Signature(s): _____ _____



SYMBOLS

Primary Codes		Secondary Codes	
M	Mesial	S	Silver amalgam
O	Occlusal	E	Resin (composite)
D	Distal	R	Root canal
F	Facial	C	Crown
I	Incisal	H	Porcelain
L	Lingual	P	Pontic
U	Unerupted/Impacted	N	Non-precious
V	Virgin (unrestored)	G	Gold
X	Extracted	T	Denture tooth
J	Missing crown	Z	Temporary
I	No data	B	Primary tooth (deciduous)
/	Not recovered	~~~	Fracture line

Tooth Number		DESCRIPTION
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		

Comments:

Radiographs Used:	Date:
Radiographs Used:	Date:
Radiographs Used:	Date:
Radiographs Used:	Date:
Radiographs Used:	Date:

Fig. 22.1 Antemortem dental record form

All information regarding the patient should be recorded on a single antemortem dental record, to include the patient's full name, date of birth, identification number (Social Security number, military identification number, etc.), sex, and race (Fig. 22.1). Dental information should likewise be documented, to include teeth present, extracted, and restored. Restoration type and surfaces involved should be detailed, both within the narrative description section and within the odontogram. An annotation should be made for every tooth, even ones that are present and unrestored.

Any unusual or unique features may be described in the Comments section. Dental or surgical treatment such as permanent retainers, dental implants, or fracture repair should be annotated. Distinctive anatomic features such as root dilacerations, diastemas, sinus morphology, atypical tooth anatomy, or tooth location should also be charted, as should any evident pathology.

Challenges: Tooth Numbering. The acquired antemortem dental records may utilize different tooth numbering systems, confounding accurate analysis (Table 22.1). Knowledge of these systems is important, especially if mass casualty identifications include decedents from multiple countries.

In the United States, the *Universal system* is most common. The adult Universal system begins with the maxillary right posterior third molar as tooth #1 and proceeds to the maxillary left third molar as tooth #16. The numbering progresses in a clockwise circle to the mandibular left third molar as tooth #17 and onto the mandibular right third molar as tooth #32. The deciduous dentition numbering follows a similar progression but utilizes letters A thru T instead of numbers and begins with the maxillary right second deciduous molar.

Table 22.1 Common tooth numbering systems

Right															Left
Universal—adult															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
Federation Dentaire Internationale—adult															
1-8	1-7	1-6	1-5	1-4	1-3	1-2	1-1	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8
4-8	4-7	4-6	4-5	4-4	4-3	4-2	4-1	3-1	3-2	3-3	3-4	3-5	3-6	3-7	3-8
Zsigmondy/Palmer—adult															
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
Universal—deciduous															
			A	B	C	D	E	F	G	H	I	J			
			T	S	R	Q	P	O	N	M	L	K			
Federation Dentaire Internationale—deciduous															
			5-5	5-4	5-3	5-2	5-1	6-1	6-2	6-3	6-4	6-5			
			8-5	8-4	8-3	8-2	8-1	7-1	7-2	7-3	7-4	7-5			
Zsigmondy/Palmer—deciduous															
			E	D	C	B	A	A	B	C	D	E			
			E	D	C	B	A	A	B	C	D	E			

Maxillary teeth, top row; mandibular teeth, bottom row

The *Federation Dentaire Internationale (FDI) system* is utilized by the World Health Organization and many countries outside the United States. The system is quadrant based, beginning with the central incisor as tooth #1 and progressing to the third molar as tooth #8. The quadrants are labeled 1 thru 4 in a clockwise direction, beginning with the maxillary right. When in use, this gives all teeth a two-digit designation, with the first digit being the quadrant and the second being the specific tooth. For example, the maxillary right central incisor is tooth 1-1 and the mandibular left second premolar is 3-5. The deciduous FDI system is likewise similar, with the teeth numbered 1 thru 5, but the quadrants designated as 5 thru 8.

Although a dash is ideally present between the first and second digits in the FDI system, this is often omitted in practice. This may create confusion as tooth "13" in the FDI system would be the maxillary right canine whereas tooth "13" in the Universal system is the maxillary left second premolar. Care must therefore be taken when analyzing international records so as to correctly identify the tooth in question.

The adult *Zsigmondy/Palmer system* is also quadrant based, with tooth numbering similar to the FDI system. The quadrants, however, are designated by symbols instead of numbers:

- ┘ = maxillary right
- └ = maxillary left
- ┌ = mandibular left
- ┐ = mandibular right

The teeth are then designated with both the symbol and tooth number. For example, the maxillary right second premolar would be 5┘. The deciduous dentition follows a similar pattern, but the five primary teeth are designated as A thru E.

Challenges: Dental Radiograph Assessment. Film orientation in dental radiograph review strongly influences evaluation of right vs. left and therefore tooth numbers. Correct assessment of orientation is critical if accurate review of the teeth is to be accomplished.

Plain films for periapical or bitewing radiographs have a raised dot in one corner, and its location helps determine orientation of the film. In forensic events, these radiographs are oftentimes digitally scanned for submission. The scanned image, however, loses the elevation of the dot, and orientation may come into question.

If the radiograph film is placed in a horizontal position, the raised dot will be in the upper left or lower right corners. This orientation will present the image as if looking at the teeth from the outside of the patient. If the dot is in the opposite corners—upper right or lower left—then the film is reversed, and the image presents the teeth as if looking from inside the patient's mouth. Noting the location of the dot may therefore assist in establishing accurate orientation of the film.

22.3.4.3 Postmortem Evaluation

The postmortem phase of dental identification includes the thorough evaluation of recovered dental remains. Dental radiographs and charting should be performed, with the goal of accurate representation of the decedent's dental restorative profile.

Access into the oral cavity is the first step in postmortem evaluation. This may be complicated by rigor mortis, with resultant contraction of the muscles of mastication. Opening of the oral cavity may be assisted by manual or surgical means.

Manual opening of the mouth may be done by hand or accomplished by multiple methods:

- *Tongue depressors*: Place two tongue depressors into the oral cavity along the right or left molar occlusal plane. Then place a third in between the first two, tapping it in with a bone mallet. Repeat with the addition of more tongue depressors until the mouth is opened and rigor mortis broken.
- *Rib spreader*: The blades of a rib spreader may be inserted along the molar occlusal plane, taking care not to leverage on incisor or canine teeth. The rib spreader may then be compressed to open the oral cavity. Although more expedient, the use of a metallic rib spreader risks fracture of cusp tips, so care must be taken with use.

Surgical opening of the oral cavity involves reflecting the buccal skin and soft tissues, exposure of the mandibular ramus, and sectioning of the ramus with a Stryker saw or a similar battery-powered saw. This serves to fully loosen the mandible for access and provides unobstructed view of the facial surfaces of all teeth. Surgical opening, however, should only be attempted after approval from the coroner or medical examiner, as the facial remains may contain evidence for autopsy or be viewable during funeral ceremonies.

After access is obtained, thorough cleaning of the dentition is accomplished with 2×2 or 4×4 surgical gauze. Use of a tooth brush is not recommended, as this may abrade decomposing gingival soft tissues leading to additional levels of debris on the tooth surfaces.

A full set of periapical and bitewing dental radiographs should be taken, with the goal to recapitulate what may have been taken during normal dental examinations and treatment. Stabilization of the sensor or film may require additional assistance or may be attached to the lingual surfaces of the relevant teeth via rope wax.

A full dental examination is performed, to include charting of teeth present, missing, and restored, with all information listed on a single postmortem dental record form (Fig. 22.2). A detailed listing of the types of restorations and surfaces involved should be annotated in both the narrative description and odontogram. Unique anatomic or pathologic features may be described in the Comments section. The case number, analyst names, and biologic information of sex, race, and estimated age should also be noted.

POSTMORTEM DENTAL RECORD

Case Number:	Analyst(s): _____ _____	Signature(s): _____ _____
Date of Analysis:	Place of Examination:	
Sex:	Racial Traits:	Estimated Dental Age::
Associated Information:		

DESCRIPTION

Tooth Number		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
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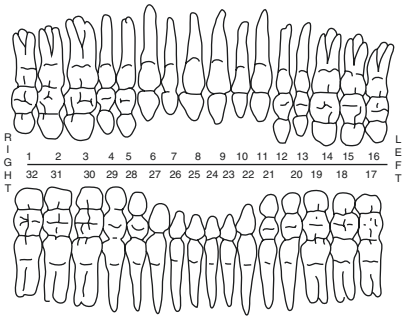
32		



SYMBOLS

Primary Codes		Secondary Codes	
M	Mesial	S	Silver amalgam
O	Occlusal	E	Resin (composite)
D	Distal	R	Root canal
F	Facial	C	Crown
I	Incisal	H	Porcelain
L	Lingual	P	Pontic
U	Unerupted/Impacted	N	Non-precious
V	Virgin (unrestored)	G	Gold
X	Extracted	T	Denture tooth
J	Missing crown	Z	Temporary
I	No data	B	Primary tooth (deciduous)
/	Not recovered	~~~	Fracture line

Radiographs Used:	Date:
Radiographs Used:	Date:
Radiographs Used:	Date:
Radiographs Used:	Date:
Radiographs Used:	Date:

Comments:

Fig. 22.2 Postmortem dental record form

22.3.4.4 Comparison Assessment

The antemortem and postmortem dental record forms are mirror images of one another, providing for simplified side-by-side comparison. Upon review, unique and distinct commonalities should be sought, especially in the size, shape, location, and type of dental restorations. Shared anatomic or pathologic features should also be reviewed, such as missing teeth, root dilacerations, diastemas, and maxillary sinus

DENTAL IDENTIFICATION SUMMARY REPORT

Case Number:			**Number of Deceased:**	
Rank:	**DOB:**	**Sex:**	**Race:**	**Social Security Number:**
Analyst(s):			**Place of Examination:**	
Date analysis started:			Date analysis ended:	

Comparison of Antemortem and Postmortem Dental Records and Radiographs Reveal Compatibility on Teeth Number (Describe Feature)

1/	**9/**	**17/**	**25/**
2/	**10/**	**18/**	**26/**
3/	**11/**	**19/**	**27/**
4/	**12/**	**20/**	**28/**
5/	**13/**	**21/**	**29/**
6/	**14/**	**22/**	**30/**
7/	**15/**	**23/**	**31/**
8/	**16/**	**24/**	**32/**
Key: V = unrestored tooth; X = tooth missing; M = mesial surface; O = occlusal surface; D = distal surface; F = facial surface; L = lingual surface; I = incisal surface; U = unerupted tooth; R= root canal filling; S = silver amalgam; E = resin (composite); C = Crown; G = gold; H = porcelain; P = pontic; B = primary (deciduous) tooth			

Remarks:

Opinion (circle one):	Positive Identification	Probable ("Consistent With") Identification	Insufficient Evidence	Excluded

Signature of Analyst:	**Date:**
Signature of Reviewer:	**Date:**

Fig. 22.3 Dental identification summary report form

morphology. Radiographic comparison typically provides the most substantial and convincing visual evidence and may be used to verify an association.

If a match is obtained between the antemortem and postmortem evidence, this is detailed in a Dental Identification Summary Report form (Fig. 22.3). The postmortem case number and name of the deceased are noted, along with other relevant information. A detailed description of all comparative dental commonalities is provided, along with any remarks pertaining to the assessment. An identification category is finally chosen depending upon level of certainty. This document is then presented to the coroner or medical examiner as the consultant odontologist's opinion of identity.

Challenges: Lack of Evidence. The largest obstacle in forensic dental identification is a lack of evidence from which to form an opinion. This may be due to minimal availability of antemortem dental charts or radiographs, a lack of recovered postmortem dental remains, or insufficient uniqueness via comparison. The category of *Insufficient Evidence* is included on the Dental Identification Summary Report should this situation exist.

Table 22.2 Dental identification go-kit items

Access	Tongue depressors (box) Bone mallet Rib spreader Bite block Surgical scalpel and blades Surgical scissors Autopsy (Stryker) saw and blades Periosteal elevators
Radiographs	Laptop computer with associated software Sensors Sensor holders and rope wax Portable X-ray machine Multi-outlet and extension cord
Cleaning	4 × 4 gauze Surgical basin (bowl) Isopropyl alcohol
Examination	Lighting (head lamp, flashlights, etc.) Dental mirrors Dental explorers Cheek retractors
Personal protective equipment	Gloves Masks Eye protection Surgical gowns Shoe protectors Head covers Lead vest and gloves (radiographic hygiene)
Documentation	Antemortem, postmortem, and comparison documents Clipboard Writing instruments

22.3.5 Role in a Mass Disaster

Mass disasters may be due to multiple reasons, to include criminal actions, natural catastrophes, or accidents, all of which resulting in multiple casualties in a short period of time. Depending upon location and size of the event, the responsibilities associated with victim identification fall to different agencies, to include city, county, state, or federal. The forensic dentist may act as a consultant to any of the agencies and assist in the identification effort.

Preparations for Forensic Dental Identification. The requirement to perform a forensic dental examination often appears suddenly, with little warning or time to prepare. The forensic dentist may need to travel to relatively austere sites without a proper operatory for equipment and lighting. To alleviate stress and assure preparedness, the prior creation of a forensic "Go-Kit" is recommended (Table 22.2). This kit should contain all items required for the identification, to include postmortem examination, antemortem chart assessment, and final comparisons. Having a pre-made kit to "grab and go" greatly assists in the identification effort so that required items are not forgotten.

22.4 Bite Mark (Pattern Injury) Analysis

The evaluation of pattern injuries due to bite trauma is occasionally undertaken by forensic odontologists. A bite on exposed skin may leave an imprint with a specific configuration, which may potentially correlate with the arch shape and tooth location of a suspect. In theory, a positive correlation may connect the suspect with a crime, while unexplainable discrepancies may support innocence. In practice, however, the use of bite mark evidence has proven relatively unreliable and has led to false convictions in court (Reardon 2014).

The human skin is a relatively poor impression material due to elasticity, and a bite mark pattern may change over time due to healing. The human dentition may display unique characteristics via restoration morphology, type, and location, yet arch shape and tooth position may be relatively nonspecific to an individual. These factors lead to ambiguity in assessment and possible erroneous conclusions. Even if all factors are perfect and analysis and conclusions are properly performed, the American Board of Forensic Odontology (ABFO) does not sanction a "without doubt" identification of a perpetrator based upon bite mark assessment (ABFO 2017).

Although utilizing bite mark analysis to ascertain guilt may be scientifically questionable, its use may assist in supporting innocence, especially if the suspects arch shape and tooth location are radically different than the pattern injury. The specific procedures for bite mark analysis are highly detailed and may be performed via physical or computer-aided assessment. The basic steps include:

- Pattern recognition as a true bite mark
- Photographic documentation of the trauma
- Evidence collection and preservation
  - DNA and physical evidence of bite mark
  - Impressions and casts of suspect
- Analysis and comparison of collected evidence
- Communication of conclusions

Detailed instructions for bite mark analysis are beyond the scope of this text yet may be found within the ABFO website or numerous textbooks on the subject (ABFO 2017).

22.5 Conclusion

The skill sets of forensic odontology are performed daily in routine care of patients yet may also be called upon in the event of a mass disaster. The detailed comparison of antemortem and postmortem dental evidence provides for the accurate, reliable, and expedient identification of human remains. As the need to perform this important task often arrives suddenly and unannounced, thorough knowledge of the required

steps and subsequent preparation minimizes stress and increases efficiency of the dental team.

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Part V

Illustrative Case Reports

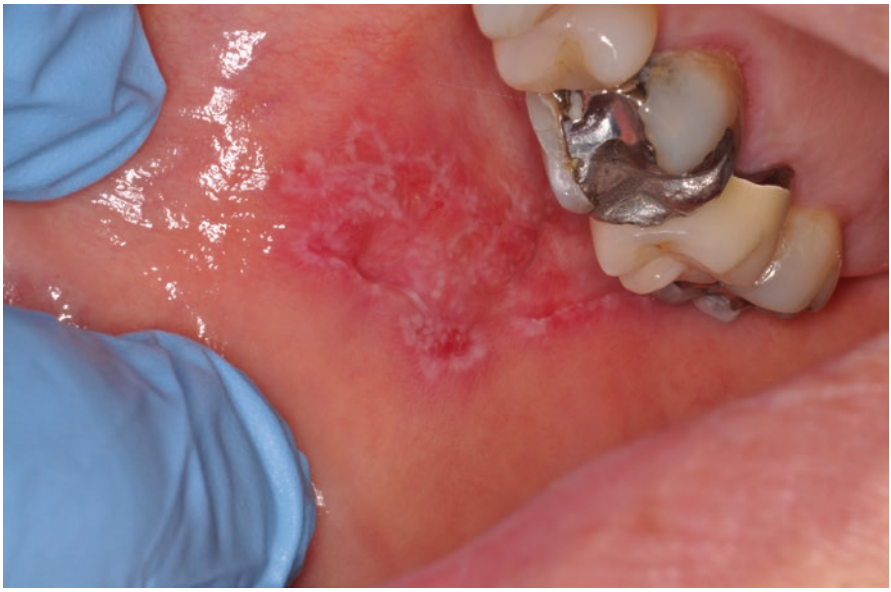
Case 1: Diagnostic Dilemma - White and Red lesion

23

Easwar Natarajan

23.1 Case 1: Parts I and II

Case 1: Part I



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E. M. Ferneini, M. T. Goupil (eds.), *Evidence-Based Oral Surgery*,
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This 55-year-old woman is a patient who recently transferred care to your practice seeking comprehensive dental rehabilitation, including the replacement of several, poorly contoured amalgam restorations. You delivered a full-coverage crown for tooth # 2 3 months ago and are planning other full-coverage restorations in the coming months. Today, she is here for a routine hygiene visit.

During this appointment, the patient brings the area (photograph Case 1) on the right buccal mucosa to the hygienist's attention. She reports being aware of sensitivity and a stinging sensation in this area for the past month. Sometimes, the cheek feels burnt, especially when she eats foods that are salty, abrasive, minty, or acidic (e.g., citrus, vinegar in salad dressing). She tried using a commercial mouthwash to try to address what she assumed was an infection—she was unable to tolerate the rinse as it "burned" this area of her mouth.

The patient reports being otherwise healthy and active. She is regular with annual physical evaluations. Her medical history is significant for a long history of hypertension and type II diabetes, both of which are controlled with diet and exercise. She also has a past history of exercise-induced asthma and rheumatoid arthritis, neither of which require any medication at this time. She takes no medications on a regular basis and takes a daily multivitamin. She has never smoked cigarettes. She drinks a glass of wine with dinner but has found that red wine tends to irritate her right cheek.

Case Work-Up Questions

Question 1.	What additional questions (if any) would you ask this patient?
Question 2.	In order to evaluate this finding, what other information will you seek during the oral exam?
Question 3.	Based on the brief history and findings as seen above, what is your clinical differential diagnosis?
	What is the respective pathological process for each diagnosis? Justify.
Question 4.	In view of the differential diagnosis considered, what is your next step?
Question 5.	If a biopsy of this lesion was obtained and the diagnosis reported was "lichenoid stomatitis, perivascular inflammation," how would you manage this patient?

Case 1: Part II

Approach to clinical diagnostic work-up and management summary	
1. Additional questions—data gathering specific to this patient	**Patient responses**
(a) Temporal relationship. Did the sensitivity start shortly after you received the full-coverage crown on # 2?	(a) Reports that sensitivity may have started a few weeks after full-coverage crown # 2 was delivered
(b) Have the symptoms remained constant, or are they intermittent in nature? Do you have pain?	(b) No history of pain. Symptoms of discomfort/burning are intermittent, not constant
(c) Do you have similar areas on any other oral surfaces? On the left cheek, gingivae, tongue surfaces, labial mucosae, palate?	(c) The only area affected is the right side. Right buccal mucosa and attached gingiva of # 2 and 3. No other oral sites involved
(d) Do you have discomfort when you brush your teeth? Do they peel away?	(d) Mild discomfort in the area of # 2 and 3. No pain. No gingival sloughing reported
(e) Do you have any scaly, itchy, rashes, or spots on your skin? Especially around the wrists, ankles, nails, scalp? Hair loss?	(e) There is no history of cutaneous pruritus, scaly plaques, and papules. No nail, scalp involvement
(f) Have you noticed redness, stinging/ irritation or gritty sensations involving the eyelids?	(f) There is no history of eye irritation, except for occasional eye dryness—Uses artificial tears
(g) Any genital mucosal discomfort?	(g) No history of genital discomfort
(h) Any nasal discomfort/bleeding?	(h) No nasal bleeding/discomfort
(i) Any recent joint-related issues re: rheumatoid arthritis	(i) No recent disease activity reported

2. Oral examination—things to look for in this patient	**Examination findings**
(a) Source of potential chronic irritation? Evaluate # 2 and 3 restorations	(a) No evidence of sharp margins on # 2 crown. No obvious inciting agent detected
(b) Distribution—is this the only such finding in the oral cavity? Is this a generalized finding? Is it bilateral?	(b) Erythematous, erosive, and lichenoid change is localized to the right posterior buccal mucosa in the region of # 2. This is unilateral
(c) Appearance of gingival tissues in the area and beyond	(c) Focal lichenoid erosion # 2 region. Rest of the gingivae are within normal limits
(d) Size (in cm), borders, and extent of lesion	(d) 1.5 × 3 cm erosive lichenoid lesion extending to the buccal vestibule adjacent to # 1,2,3
(e) Areas of sloughing/blistering on pressure (Nikolsky sign)	(e) No evidence of tissue sloughing/blistering
(f) Are the white changes wipeable or non-wipeable?	(f) The white changes are non-wipeable
(g) Ulcerated/non-ulcerated	(g) Non-ulcerated
(h) Palpation—is this finding supple, indurated, nodular, or tender?	(h) Tender on palpation. No induration, nodularity

3. Differential diagnoses (pathological process)	Discussion
I. Lichen planus ***Pathological process*****—** *systemic immune-mediated*	**Pros (findings that support diagnosis)** Red and white, lacy lesion on the buccal mucosa and gingiva. Discomfort and sensitivity to acidic/abrasive food. Middle-aged woman. Chronic duration >3 weeks. Erosion. Intermittent
	Cons (findings that do not support diagnosis) Unilateral and too focal. Not widespread within the mouth. No cutaneous or other mucosal involvement
II. Lichenoid stomatitis ***Pathological process*****—** *Iimmune-mediated condition (local/systemic)*	**Pros (findings that support diagnosis)** Red and white, lacy lesion on the buccal mucosa and gingiva. Discomfort, sensitivity to acidic food. Chronic duration. Potential temporal relationship with crown # 2 suggesting a localized contact-type hypersensitivity reaction manifesting as a lichenoid lesion
	Cons (findings that do not support diagnosis) The focal findings militate against lichenoid stomatitis resulting from systemic sensitization (i.e., medication-related lichenoid stomatitis)
III. Discoid lupus erythematosus ***Pathological process*****—** *systemic immune-mediated condition*	**Pros (findings that support diagnosis)** Red and white, lacy lesion on the buccal mucosa and gingiva. FOCAL oral lichenoid finding is suggestive. Discomfort and sensitivity to acidic food. Chronic duration
	Cons (findings that do not support diagnosis) No cutaneous lesions. Scaly plaques, hypopigmentation not reported. No history of alopecia. Systemic lupus is ruled out as the patient is generally healthy and active
IV. Traumatic irritation/ erosion ***Pathological process*****—** *localized reactive/ inflammatory process*	**Pros (findings that support diagnosis)** Red and white lesion on the buccal mucosa. Foci of erosion, atrophy, and associated discomfort. Sensitivity to abrasive foods. Recently placed crown # 2 (potential ill-fitting margins), rough surfaces. Temporal relationship—symptoms correlate with approximate time the crown was placed
	Cons (findings that do not support diagnosis) Examination revealed no evidence of obvious surface or margin irregularity. The area is above the line of intercuspation and hence not prone to occlusive friction

4. Management—next steps based on differential diagnoses specific to this patient
Based on the clinical history and examination findings, we favor a benign immune-mediated process. This is a chronic, red-white lichenoid lesion on the buccal mucosa with intermittent symptoms
• Topical immunomodulation with a steroidal rinse or ointment is an option. However, any management should be accompanied by follow-up visits
In this patient, a topical steroidal agent was used for a period of 1 month. At the follow-up visit, the lesion appeared larger and unresolved. Patient symptoms persisted. There were no other oral lesions. At this point, a biopsy was indicated
• Incisional biopsy of the lichenoid red-white lesion on the right buccal mucosa is recommended. A punch or scalpel biopsy approach may be employed
Justification: *There is no identifiable inciting agent/frictional source. This red-white finding is a solitary finding and is unilateral. The findings are NOT compatible with lichen planus which tends to be bilateral. The lesion has not responded well to topical immunomodulation. This is a clinically indeterminate lesion and warrants investigation,* i.e., *tissue biopsy. Ensure that you discuss your thought process and approach to differential diagnosis with the patient*

5. Biopsy diagnosis: "Lichenoid stomatitis; perivascular inflammation." Management

- **Interpretation**
  - The presence of a "lichenoid" inflammatory infiltrate implies that there is a T-lymphocyte-mediated epithelial-stromal interface disorder
  - Lichenoid inflammation with interface stomatitis and perivascular inflammatory aggregates can be seen in a range of disorders:
    Contact hypersensitivity—inciting agents include cinnamon/amalgam/restorative metals
    Discoid lupus erythematosus—immune-complex-mediated disorder almost always accompanied by cutaneous manifestations
    Systemic lupus erythematosus—immune-complex-mediated systemic disorder almost always accompanied by a range of multi-organ/systemic involvement
- **Patient education**
  - Emphasize that all findings are benign. Findings are likely secondary to the metal backing in the crown. Potentially could be unrelated
  - Discuss options of another attempt of topical immunomodulation. Alternately replace the metal-backed crown with a full-coverage crown made of a different material
- **Management guidelines (specific to this patient)**
  - Another brief course of topical immunomodulation—rinse/ointment with follow-up to track progress
  - Alternate restorative material in fabrication of new full-coverage crown for # 2 and 3. Evaluate compatibility prior to proceeding with extensive restorative plan
  - Regular monitoring visits to evaluate this red-white lichenoid lesion

Patient progress:

The current patient was diagnosed with "lichenoid stomatitis; perivascular inflammation." The biopsy report contained a comment that stated, "The presence of perivascular inflammation suggests the possibility of a localized contact hypersensitivity response (e.g. amalgam/restorative material)"

The patient was provided with the option of 1 more month of topical immunomodulation to evaluate response. Topical steroidal mouth rinses were prescribed to use t.i.d. × 1 month and q.d. × 1 month. At a 3-month follow-up visit, the lesion appeared at less than 90% of its original dimension. At a subsequent follow-up visit, the lesion was absent

The treatment plan was modified slightly to reflect a potential sensitivity to some component of the original full-coverage crown on # 2; subsequent crown fabrication was planned with this potential reaction in mind

Case 2: Diagnostic Dilemma - Crusty Lips

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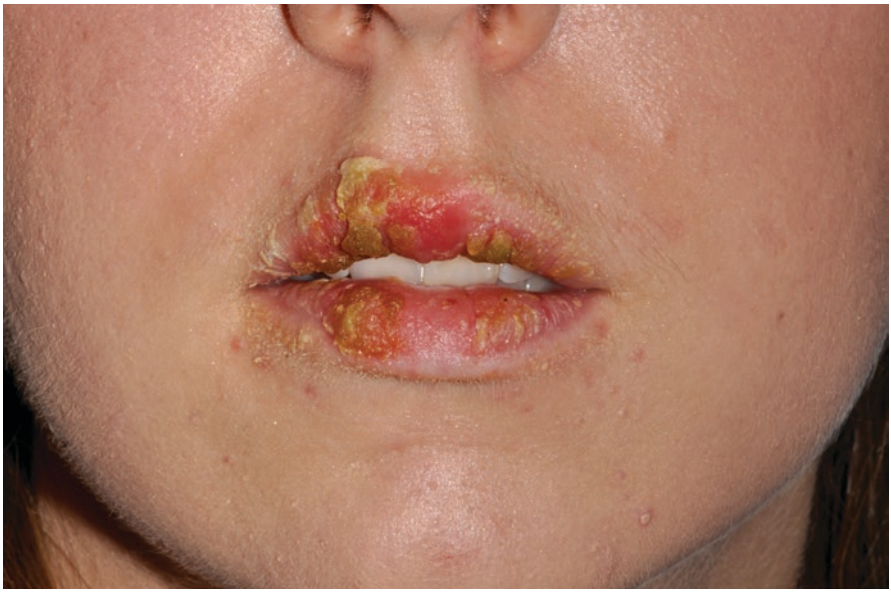
24.1 Case 2: Parts I and II

Case 2: Part I



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This 22-year-old woman is referred to you by her physician for evaluation and management of the findings noted on her lips. The patient reports that around 4 months ago, she developed a "cold sore" on the lower lip likely due to prolonged sun exposure during a sailing trip. Her initial attempts to address this with over-the-counter docosanol cream were unsuccessful. She consulted with her physician who prescribed penciclovir cream. The lesions were unresponsive after two courses of penciclovir and continued to progress in severity and extent (they involved the whole lower lip and upper lip vermilion). She was prescribed valacyclovir PO and has been on this medication for the past 3 months.

The patient is generally healthy with no significant medical history. In addition to 500 mg valacyclovir taken once/day, she takes an oral contraceptive and a daily multivitamin. She is reportedly allergic to penicillins. She works at a local bank and is understandably frustrated and conscious about the appearance of the lips. She does not smoke cigarettes, does not use recreational drugs, and does not drink alcohol. She has a past history of cold sores.

Case Work-Up Questions

Question 1.	What additional questions (if any) would you ask this patient?
Question 2.	In order to properly evaluate this finding, what other elements of information will you seek to establish during the course of your oral examination?
Question 3.	Based on the brief history and findings as seen above, what is your clinical differential diagnosis?
	What is the respective pathological process for each diagnosis? Justify

Case 2: Part II

Approach to clinical diagnostic work-up and management summary	
1. Additional questions—data gathering specific to this patient	**Patient responses**
(a) Specific duration? Onset? Have the lesions been present for all these months, or have they fluctuated? Periods of quiescence	(a) Lesions present continuously for 4 months. No periods of quiescence. Progressed in severity
(b) Any new medications around the time of onset?	(b) No new medications or other exposure reported
(c) Do you, or have you had, sores/similar areas inside your mouth?	(c) There are no lesions reported inside the mouth
(d) If you have oral lesions, are they all over the place? On the gingiva, tongue surfaces, buccal mucosa, hard palate, soft palate?	(d) No intraoral lesions reported. All lesions restricted to the vermilion and skin of the lips
(e) Do the areas on the lips bleed, crust?	(e) Yes. Occasional bleeding followed by yellow crust
(f) Do you have pain? If yes, describe the nature and quality of pain.	(f) No pain. Substantial discomfort and burning
(g) Did you take any new medication shortly before the lip lesions presented? Any change from generic to brand name or vice versa?	(g) No new medications other than docosanol to address initial "cold sore"
(h) Do you have similar areas, rashes, scaly patches on other skin surfaces?	(h) No history of other skin lesion, rashes, or other findings
(i) Do you have a history of irritation, burning, pain involving other "wet surfaces"—nose, eyelids, throat, vulvovaginal areas?	(i) No extraoral mucosal involvement reported. No conjunctival burning, nasal, genital involvement

2. Oral examination—things to look for in this patient	**Examination findings**
(a) Presence of skin rashes—palms, soles, wrists (visible surfaces). Conjunctival and nasal mucosal exam (cursory exam)	(a) No evidence of extraoral lesions. No evidence of nasal or conjunctival redness, erosions etc.
(b) Extent of involvement around the lips	(b) Involvement restricted to vermilion and skin of lips
(c) Is the skin at the base of the amber crusts intact? Do the crusts peel away?	(c) The underlying skin is intact but notably atrophic. Natural vermilion markings are indiscernible
(d) Is there intraoral involvement? Any evidence of vesicles, ulcers?	(d) No intraoral lesions noted. There are no intraoral ulcers/vesicles noted

3. Differential diagnoses (pathological process)	Discussion
I. Herpes labialis *Pathological process—reactivated herpes simplex viral infection*	**Pros (findings that support diagnosis)** Reportedly began as a "cold sore" after sun exposure. Discomfort. Amber-golden crusty lesions on the vermilion and skin of lip. Previous history of herpes labialis
	Cons (findings that do not support diagnosis) Duration >2 weeks is inconsistent. Too widespread (upper, lower, right, and left) on the vermilion. Nonresponsive to antiviral agents for over 3 months
II. Impetigo *Pathological process—bacterial infection of the skin (staphylococcal/streptococcal)*	**Pros (findings that support diagnosis)** Amber-colored crusted, scaly lesions on the vermilion and skin. Exfoliation of vermilion surfaces. Discomfort and sensitivity. No intraoral involvement. No other extraoral sites. Prolonged sun-exposure caused potential lip exfoliation, lip fissures, and potential portals of entry for bacterial infection
	Cons (findings that do not support diagnosis—none
III. Erythema multiforme *Pathological process—systemic immune-mediated mucocutaneous reaction*	**Pros (findings that support diagnosis)** Involvement of the vermilion and skin of the lip. Occasional bleeding. Crusty, scaly lesions
	Cons (findings that do not support diagnosis) Duration >2 weeks. Onset is not acute/explosive. No report of severe pain. All lesions localized to the vermilion and skin of lips. No extraoral cutaneous lesions (rashes, targetoid lesions). No oral ulcers. No history of sensitizing agent (e.g., new medication, drugs, alcohol)

4. Management—next steps based on differential diagnoses specific to this patient

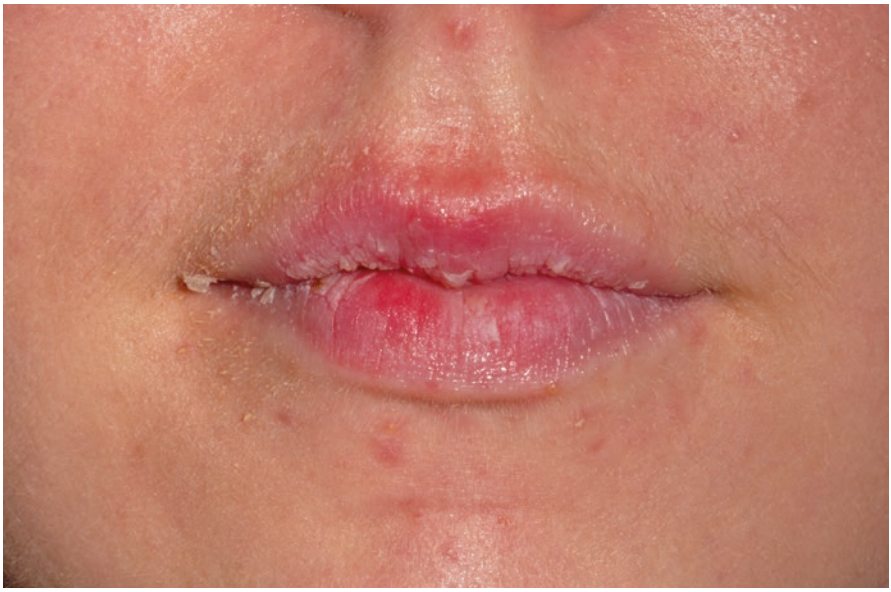
- The diagnosis in this patient's case was made on clinical grounds. The historical information, clinical presentation, and correlation were most consistent with impetigo—a cutaneous bacterial infection (commonly staphylococcal/streptococcal). In the setting of exfoliative cheilitis on the vermilion/lip skin, there could be an element of candidal infection
- **Patient education (specific to this patient)**
  - Explain that she does not have herpes infection. Stop antiviral mediation
  - Explain that impetigo is a bacterial skin infection. In her case, this is has been a prolonged course over 3–4 months. This will likely require antibiotic therapy (systemic and topical)
  - Emphasize keeping the vermilion and skin of the lips clean and well lubricated during therapy. Avoid drying, soap-containing face washes. Frequent gentle face washes (wash cloths) in between topical antibiotic applications
- **Management**
  - Prescribe systemic antibiotics—penicillins, cephalosporins, or clindamycin (in case of penicillin allergies)
  - Topical mupirocin ointment application—used q.i.d. × 1 week
  - Maintain lip and skin surfaces clean and lubricated (recommend petroleum jelly product) in between antibiotic ointment application

Patient progress:

The current patient was diagnosed with impetigo and was managed with clindamycin (P.O.) and topical mupirocin ointment applications. She was diligent in following facial hygiene measures during this time. At her 1-week follow-up visit, there was significant improvement in her presentation (see photograph below)

She continues to be lesion and symptom free since this initial episode but does report occasional sensitivity in areas of vermilion surface atrophy (secondary to chronic infection and exfoliation). The natural surface markings of the lower vermilion are lost and appear atrophic

Patient Progress—1 Week s/p Antibiotic Therapy for Impetigo Presenting with Significant Improvement



Case 3: Diagnostic Dilemma - White Patch

25

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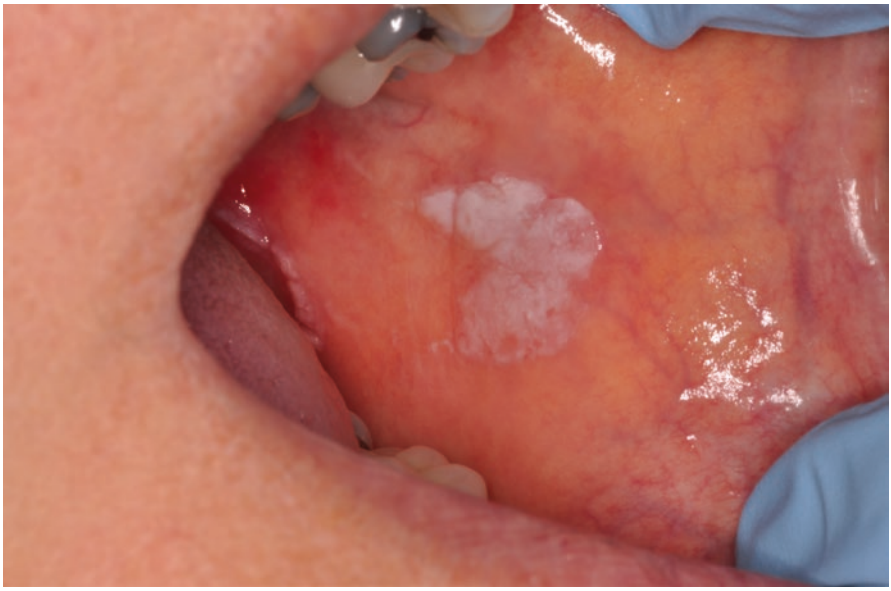
25.1 Case 3: Parts I and II

Case 3: Part I



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This 62-year-old woman who recently moved to your state is a new patient to your practice. Her last dental visit was over 2 years ago. She has no particular complaints but would like to see the hygienist and have a comprehensive dental evaluation.

During the course of the initial oral examination, your hygienist notes the asymptomatic, incidental white plaque shown in the clinical photograph (Case 3). The hygienist brings this plaque to your attention. On questioning, the patient says that she is unaware of this finding.

The patient is otherwise healthy and active. She is regular with her annual physical evaluations and has identified a primary care physician in your area. Her medical history is significant for well-controlled hypertension, hypercholesterolemia, and hypothyroidism. Her medications include lisinopril, pravastatin, and levothyroxine. She also has a long-standing history of cutaneous and vulvar lichen planus, diagnosed when she was in her early 30s, and uses topical steroidal ointments for occasional cutaneous flares. She reports having smoked cigarettes (1 pack/day) for around 4–5 years in her 20s and quit 36 years ago. She drinks an occasional glass of wine.

Case Work-Up Questions

Question 1.	What additional questions (if any) would you ask this patient?
Question 2.	In order to properly evaluate this finding, what other elements of information will you seek to establish during the course of your oral examination?
Question 3.	Based on the brief history and findings as seen above, what is your clinical differential diagnosis?
	What is the respective pathological process for each diagnosis? Justify
Question 4.	In view of the differential diagnosis considered, what is your next step?
Question 5.	If a biopsy of this lesion was obtained and the diagnosis reported was “epithelial dysplasia,” how would you manage this plaque?

Case 3: Part II

Approach to clinical diagnostic work-up and management summary	
1. Additional questions—data gathering specific to this patient	**Patient responses**
(a) Do you recall biting, chewing your cheek? Other parafunctional habits? (b) Do you place cinnamon or other substances in this area? (c) Given your history of cutaneous lichen planus, do you have, or have you ever been told that you have oral lichen planus?	(a) No history of trauma or chewing habits (b) Denies placing cinnamon in this area (c) No history of oral lichen planus

2. Oral examination—things to look for in this patient	**Examination findings**
(a) Source of chronic friction/trauma—sharp teeth, malocclusion along occlusal plane, ill-contoured restorations/prostheses (b) Size (in cm), borders, and extent of lesion. Are the borders demarcated or diffuse? (c) Does this plaque extend beyond this area? (d) Distribution—is this the only finding in the oral cavity? (e) Wipeable or non-wipeable (f) Ulcerated/non-ulcerated (g) Palpation—is this plaque supple, indurated, nodular, or tender?	(a) No evidence of sharp teeth/ traumatic agent on exam (b) 1.5 × 1.0 cm. Irregular shapeWell-defined, demarcated border (c) Plaque is confined to this area (d) Only finding in the oral cavity (e) Non-wipeable (not debris) (f) Non-ulcerated. No erosions (g) Supple, non-tender (non-indurated)

3. Differential diagnoses (pathological process)	**Discussion**
I. Benign frictional hyperkeratosis *Pathological process—reactive hyperplasia*	**Pros (findings that support diagnosis)** Solitary, asymptomatic, non-wipeable white plaque in a trauma prone location on the buccal mucosa Demarcated, non-ulcerated, supple, non-indurated
	Cons (findings that do not support diagnosis) No history of specific trauma/friction. No identifiable traumatic source on examination
II. Epithelial dysplasia *Pathological process—potentially malignant/premalignant*	**Pros (findings that support diagnosis)** Solitary, asymptomatic, non-wipeable white plaque No history of specific trauma/friction. No identifiable traumatic source on examination History of cigarette smoking. DO NOT DISMISS distant history of tobacco use Non-ulcerated, supple, non-indurated
	Cons (findings that do not support diagnosis) Not in a classic cancer prone location, i.e., lateral/ventral tongue, floor of mouth Not a diffuse white plaque with ill-defined borders

4. Management—next steps based on differential diagnoses specific to this patient

- Incisional biopsy of the non-wipeable white plaque is recommended. A punch or scalpel biopsy approach may be employed

Justification: *There is no identifiable inciting agent/frictional source. The patient's distant tobacco history (however brief) is significant. By definition, this is a clinically indeterminate lesion and warrants investigation,* i.e., *tissue biopsy. Ensure that you discuss your thought process and approach to differential diagnosis with the patient*

5. Management following biopsy proven diagnosis of epithelial dysplasia

- **Patient education (specific to this patient)**
  - Explain that epithelial dysplasia is a premalignant epithelial process resulting from genetic deregulation
  - Tobacco use (however distant) may be a contributing risk factor
  - The changes may be irreversible. There is a risk of transformation to squamous cell carcinoma (oral cancer)
  - Emphasize indefinite clinical monitoring/follow-up at regular intervals (3–6 months)
  - Inform and educate patient about "things to look out for"—ulceration, redness, discomfort, pain, and bleeding. If the patient notes any "evolutionary" changes, they should contact you/oral surgeon, warranting further biopsies
- **Management guidelines (specific to this patient)**
  - The white plaque on the left posterior buccal mucosa was diagnosed as "epithelial dysplasia." The grade of epithelial dysplasia (mild, moderate, severe) is not a predictor of malignant transformation potential
  - The left buccal mucosal plaque was 1.5 × 1 cm (<2.0 sq. cm). Surgical excision of the visible plaque is recommended
  - Baseline photographic documentation of the white plaque prior to and post-excision
  - Establish defined monitoring schedule (3–6 months recall)
  - Evaluate for suspicious findings at recall visits—increase in size, change in color, change in surface texture, and symptoms
  - Biopsy suspicious findings (if any) at recall visits

Patient progress:

This patient was diagnosed with epithelial dysplasia following incisional biopsy of the left buccal mucosal plaque. The plaque was surgically excised. During her monitoring visits (3-month schedule), the lesion recurred appearing diffusely white with milky white borders. At her 2.5-year follow-up visit, the plaque measured ~ 1.5 sq. cm and exhibited a small focus of erythema with pebbly surface change (not noted in photographs obtained at her previous 3-month visit). The white plaque and the internal area of pebbly change were surgically excised Histopathological exam revealed "epithelial dysplasia with a focus of superficial microinvasive squamous cell carcinoma" (stage I)

Following surgical excision with wide margins, the patient required no further adjunctive therapy (stage I disease)

She continues to be monitored on a regular basis with routine photographic documentation

Case Studies Evidence-Based Treatment Planning

26

Michael T. Goupil

26.1 Introduction

In Chap. 1, the approach to evidence-based patient care was defined as looking at the three areas—the patient, the dentist, and current knowledge. The major portion of the chapter provided suggestions on how to access the most current literature, as well as a systematic method to critically evaluate that literature using the Paul-Elder Critical Thinking Model™. The following case studies will provide a framework to ensure that the "patient" portion section is reasonably complete.

When collecting patient data, four major domains can be used to categorize the data—dental issues, medical issues, socioeconomic issues, and legal/ethical issues. The most applicable treatment plans for a patient need to be developed by looking at all four of these domains. The first two domains, medical and dental, are fairly straightforward. The ability to accomplish many dental procedures may be directly affected by the patient's medical condition. The relationship between diabetes and periodontal disease is well known. But the other two domains, socioeconomic and legal/ethical, may be equally important. For example, what does the patient truly want and is it realistic, and what can they reasonably afford?

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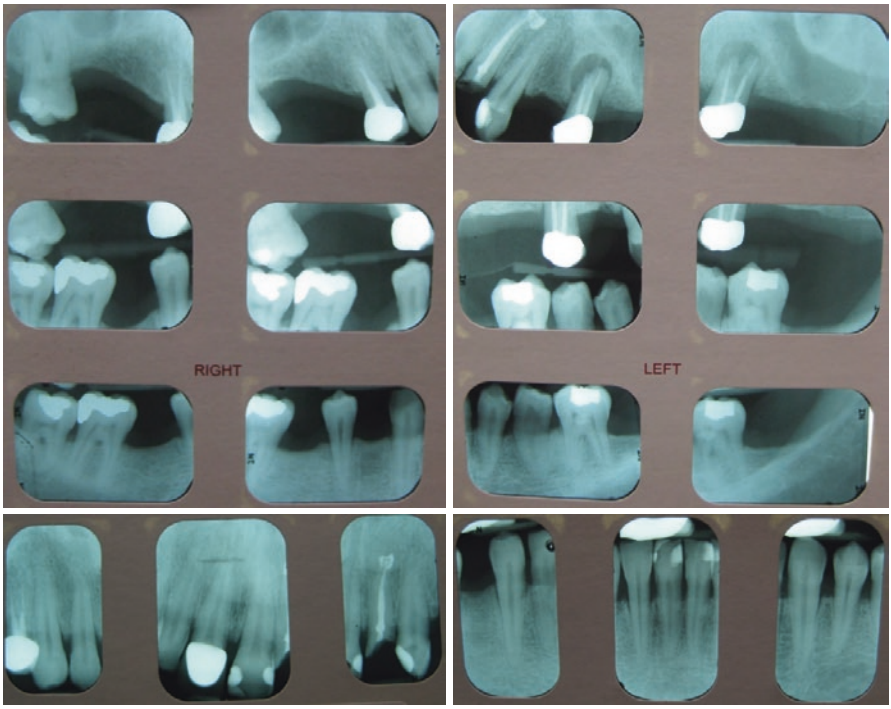
26.2 Case Study #4

A 58-year-old male has just moved into your area and presents as a new patient "seeking a new front tooth and a new plate". He filled out your standardized medical history form which revealed the following:

1. Hypertension controlled with lisinopril and atenolol
2. Prostate cancer which is treated with Lupron® injections every 4 months
3. Past history of heroin abuse and currently on methadone maintenance

The patient has copies of previous radiographs as he is seeking legal compensation for his previous dental care. He tells you that he had root canal treatment on the upper left lateral incisor [#10] which fractured 1 month after placement of his current "upper plate," and it was then "pulled." He also had to have another tooth "pulled" [maxillary left second bicuspid, #13] which became loose after being an "anchor for the plate."



Patient presents with full mouth series of radiographs taken at time of insertion of maxillary removable partial denture.

26.3 Domain Problem List

26.3.1 Medical Issues

Hypertension
- Need to take blood pressure at every patient visit.
- Are you concerned about the use of epinephrine? Some physicians are and if you get a medical consultation you may be told not to use local anesthesia with epinephrine; there is no science to substantiate this.
- Patients on antihypertensive medication may have orthostatic hypotension and become syncopal.
- Some antihypertensive medications may cause gingival hyperplasia.

Prostate Cancer
- Usually will not affect long-term survival.
- May develop metastatic lesions to the jaw.
- Hormone therapy affects bone density.
- Patients are significantly prone to periodontal disease.

Past Heroin Use on Methadone
- What is hepatitis status? Liver function?
- Methadone in syrup form is high in sugar with increased caries risk.
- Methadone also decreases salivary flow.
- What will you prescribe if you need to give analgesics?

26.3.2 Dental Issues

Increased caries risk
Non-serviceable maxillary removable partial denture
Wants a permanent tooth in upper left anterior maxilla [#10]

26.3.3 Socioeconomic Issues

Past drug user
Limited funds
Single with no children—lack of family support system

26.3.4 Legal/Ethical Issues

Current dental situation is a result of unethical dental care.
Patient seeking legal recourse.
Will patient be super critical of future dental care?
Should you consider reduced fees to compensate for poor care provided by another dental provider?

There may be a number of other issues to be addressed, but a critical assessment and integration of the above issues will help develop rational treatment options.

The patient was provided with the following treatment plans:

Option #1

New maxillary removable partial denture to replace all missing teeth even though patient did not want a removable maxillary anterior tooth.

Option #2

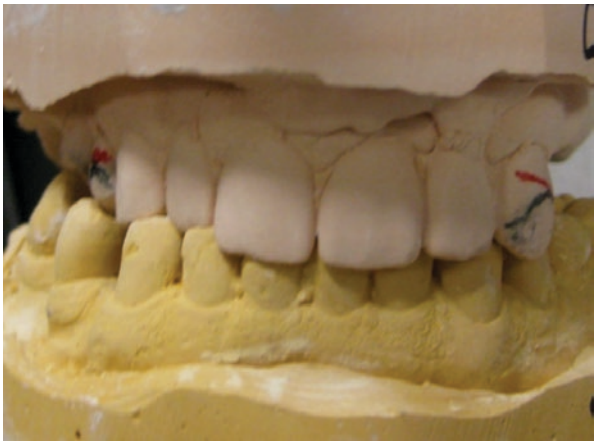
Permanent anterior fixed partial denture to replace the missing lateral incisor. This is reasonable as the abutment teeth are already heavily restored and full crowns may be advantageous.

Option #3

Dental implants to replace missing maxillary teeth.

There are pros and cons to each of the above treatment plans. The dentist needs to consider his/her own abilities. What is the patient or health-care system going to be able to afford? What is the patient's motivation as to ability to maintain the provided care?

This patient opted for treatment plan #2.



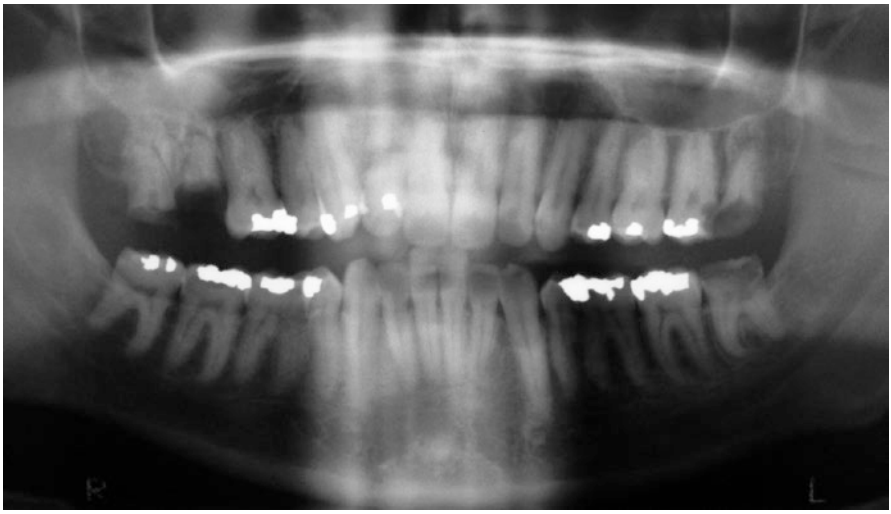
Mounted casts with maxillary fixed partial denture completed and ready for survey design for removable partial denture

26.4 Case Study #5

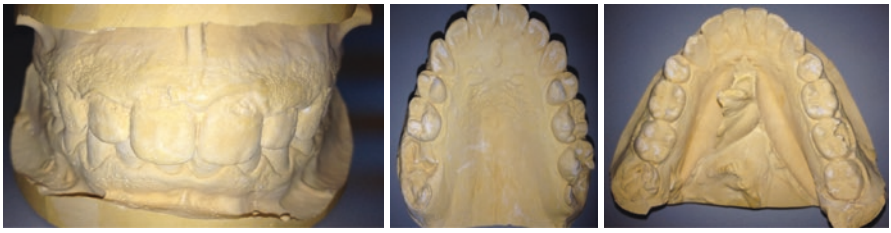
A 34-year-old make patient presents as a new patient to your practice. When the patient called to make the appointment, he told the receptionist that he was in some discomfort due to "broken teeth" and that he had not been to the dentist in at least

10 years. He was told to fill out the medical history form that would be mailed to him and to bring it in for his evaluation appointment.

The medical history form revealed that he had no allergies, but he did have depression and anxiety that were being treated with Effexor® and Wellbutrin®. When the patient introduced himself at the consultation appointment, he stated that he preferred to be called "Cassie" and that he was currently undergoing gender reassignment.



Pretreatment panoramic radiograph



Pretreatment study casts

26.4.1 Medical Issues

Transgender Status

Individuals whose sense of gender identity does not correspond to their genetic/anatomical sex.

Treatment options include psychological, hormonal replacement/blockers, real-life experience, and genital surgery and may affect cosmetic dentistry goals.

Depression
- May affect patient's understanding/acceptance of treatment plans

Anxiety
- May affect patient for certain aspects of care being provided and reliability to keep scheduled appointments.
- Patient may be more prone to syncopal episodes.
- Need to consider anxiety reduction protocols.

Prescription Medications
- Wellbutrin® [bupropion]
  - Adverse effects include tachycardia, headache, and significant xerostomia.
- Effexor® [venlafaxin]
  - Adverse effects include headache, somnolence, and significant xerostomia. May impair platelet aggregation.

26.4.2 Dental Issues

Dental Pain

High Carries Risk—medication induced xerostomia
- Consider topical fluoride [PreviDent®] and chlorhexidine antiseptic rinses

Heavily Restored Dentition

Multiple Fractured Posterior Teeth

26.4.3 Socioeconomic Issues

Limited Funds

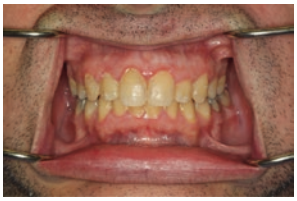
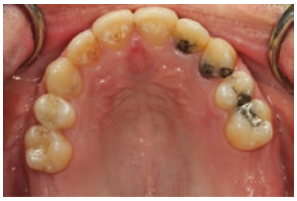
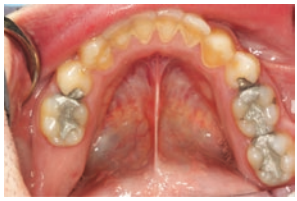
26.4.4 Legal/Ethical Issues

Transgender Status
- The dental record must reflect the legal sex of the patient—this designator may change. Patient may have their name legally changed; this needs to be reflected in the chart.
- The patient may be subjected to illegal discrimination or substandard care on the part of the dentist and/or staff.
- Most graduation dentists do not feel prepared to treat patients with a LGBT background.

There may be a number of other issues to be addressed, but a critical assessment and integration of the above issues will help develop rational treatment options.

The patient was provided the following treatment plan:

Oral Surgery—extraction of all four third molars [#s 1, 16, 17, and 32] and maxillary right and left second molars [#s 2 and 15] and the mandibular right second molar [#31].
Periodontics—gross debridement, prophylaxis, close monitoring of oral hygiene.
Endodontics—carious exposure maxillary left canine [#11].
Restorative—multiple Class II, III, IV, and V restorations.
Anxiety reduction protocol could include show/tell/do, oral antianxiety medication, nitrous oxide sedation, and parenteral sedation.
Although not functionally necessary, the extracted second molars could be replaced with dental implants at a later date.

Posttreatment Results

The patient will require close follow-up for oral hygiene maintenance and encouragement.