J Oral Maxillofac Surg
63:832-837, 2005

Failed Root Canals: The Case for Apicoectomy (Periradicular Surgery)

*Thomas von Arx, PD Dr med dent**

Apicoectomy involves the surgical management of a tooth with a periapical lesion which cannot be resolved by conventional endodontic treatment (root canal therapy or endodontic retreatment). Because the term "apicoectomy" consists of only one aspect (removal of root apex) of a complex series of surgical procedures, the terms "periapical surgery" or "periradicular surgery" are more appropriate. The expressions "periapical endodontic surgery" and "apical microsurgery" are also found in the literature.

The objective of periapical surgery is to obtain tissue regeneration. This is usually achieved by the removal of periapical pathologic tissue and by exclusion of any irritants within the physical confines of the affected root.

Indications/Contraindications

Because the majority of periapical lesions are associated with endodontic pathology, except in cases of rare developmental cysts or tumors, the primary goal of treatment is orthograde occlusal approach for root canal instrumentation and obturation. However, in certain cases, endodontic treatment, or retreatment, is not feasible or is contraindicated, and hence an indication[1] for periradicular surgery arises (Table 1). In addition to these "objective" indications, we have to consider demands by the patient regarding finances, psychological issues, and treatment time. Contraindications for periradicular surgery are listed in Table 2.

*Associate Professor, Department of Oral Surgery and Stomatology, University of Berne, Berne, Switzerland.

Address correspondence and reprint requests to Dr von Arx: Department of Oral Surgery and Stomatology, School of Dental Medicine, University of Berne, Freiburgstrasse 7, CH-3010 Berne, Switzerland; e-mail: thomas.vonarx@zmk.unibe.ch

0278-2391/05/6306-0018$30.00/0
doi:10.1016/j.joms.2005.02.019

Treatment Outcome of Periradicular Surgery

Prior to the introduction of microsurgical techniques, inconsistent success rates were reported for periradicular surgery varying between 44% and 90%.[2] Based on a weighted average calculation of reviewed studies, a success rate of 81% was found for periradicular surgery with simultaneous orthograde treatment compared with only 59% for periradicular surgery without simultaneous orthograde treatment.[2] Interestingly, conventional retreatment of teeth with apical periodontitis showed a weighted average success rate of only 66%, whereas retreatment to correct radiographically or technically deficient root fillings in teeth with periapical disease had a weighted average success rate of 95%.[2] Considering the limitations of different studies, randomized and prospective clinical trials comparing surgical to nonsurgical retreatment are needed. Two such studies have been published.[3,4] One study described a higher success rate for surgery after 1 year (58% versus only 28%), although not statistically significant.[3] The other study reported a statistically significant higher healing rate for surgical retreatment after 1 year, but at the 2-year examination, no such difference was found: 60% versus 55%.[4]

Following the introduction of microsurgical techniques, treatment outcomes have improved considerably and success rates have approached or exceeded 90%[5-17] (Table 3). These increased success rates are credited to a number of factors that have all contributed to the improved outcome of periradicular surgery: microinstruments, magnification and intraoperative inspection, root-end filling materials, and regenerative techniques.

Microinstruments

Root-end cavities have traditionally been prepared by means of small round burs or inverted cone burs in a microhandpiece. In the early 1990s, sonically or ultrasonically driven microsurgical retrotips became commercially available. This new technique of retrograde cavity preparation has been established as an essential adjunct in periradicular surgery.[18] Clinically,

Table 1. INDICATIONS FOR PERIRADICULAR SURGERY (ACCORDING TO ESE 1994)

Obstructed canal with radiologic findings and/or clinical symptoms
Extruded material with radiologic findings and/or clinical symptoms
Failed root canal treatment when retreatment is inappropriate (isthmus tissue, persistent acute symptoms or flare-ups, risk of root fracture)
Perforations with radiologic findings and/or clinical symptoms, and where it is impossible to treat from within the pulp cavity

Abbreviation: ESE, European Society of Endodontology.

Thomas von Arx: Periradicular Surgery. J Oral Maxillofac Surg 2005.

the most relevant advantages are the improved access to root-ends in a limited working space and the smaller osteotomy required for surgical access because of the angulation and small size of the retrotips.[19] However, a number of experimental studies have demonstrated other advantages of using microtips, such as the preparation of deeper cavities, and cavities following more closely the original path of the root canal.[20] The more centered root-end preparation also lessens the risk of lateral perforation. In addition, the geometry of the retrotip design does not require a beveled root-end resection for surgical access, thereby decreasing the number of exposed dentinal tubules and possible leakage through patent tubules. This is consistent with the criteria established for the minimal depth of a retrograde filling with regard to the bevel of the cut root face.[21,22] Any concern about increased formation of cracks or microfractures by (ultra)sonic root-end preparation have been addressed and proved otherwise in several experimental studies and in one clinical study.[23-27]

Magnification and Intraoperative Inspection

Parallel to the advent of microinstruments, well-focused illumination and magnification have been recommended as a standard of care in periradicular surgery.[28] Working with loupes or with a surgical microscope has become a widely accepted practice in conventional and surgical endodontics. It was discovered that only the identification and treatment of microscopic findings, such as isthmuses, accessory canals, or microfractures of the root, would result in periradicular healing or prevent failures, respectively. Rubinstein and Kim[11,15] have reported very high success rates after periradicular surgery: 96.5% for the 1-year and 91.5% for the 5-year examination periods. They thought that with the use of the surgical microscope, the identification of microanatomical structures containing deposits of necrotic tissue and bacterial toxins have significantly contributed to the better healing success following periapical surgery. Careful examination of lingual canals or buccal walls of retropreparation cavities is most often possible only with micromirrors, because loupes or microscopes do not allow the surgeon to look "around the corner." Another magnification device to circumvent such difficulties is the endoscope. Although its application has been limited in dentistry, there has been a growing interest in the use of endoscopy for intraoperative diagnostics, particularly in periradicular surgery.[29,30] The endoscope complements the increasing popularity of applied magnification techniques in dentistry. The advantages of endoscopy in periradicular surgery compared with microscopy include rapid and easy adjustment of the viewing angle, and the direct viewing without the need for the use of dental micromirrors. In addition, the endoscope is a readily transportable, versatile, and expandable system.

Recently, 2 experimental studies have substantiated the power of endoscopes for identification of microstructures.[31,32] One in vitro study compared the effectiveness of visual enhancements as aids in identifying artificially created dentinal cracks in resected root-ends. Statistically, the endoscope was significantly superior compared with unaided/corrected vision, loupes, or the microscope.[31]

The other in vitro study evaluated the diagnostic accuracy of endoscopy following root-end resection and root-end cavity preparation. Endoscopic findings were compared with those obtained with scanning electron microscopy (following root-end duplication) serving as the "gold standard." Specificity and sensitivity of endoscopic identification of isthmuses, accessory canals, obturation gaps, microfractures, and chipping of cavity margins were high, ranging between 73% and 100%.[32] It was concluded that the endoscope is a highly accurate device for intraoperative diagnostics in periradicular surgery.

Table 2. CONTRAINDICATIONS FOR PERIRADICULAR SURGERY (ACCORDING TO ESE 1994)

Local anatomical factors (eg, inaccessible root end)
Tooth with inadequate periodontal support
Nonrestorable tooth, tooth without function (no antagonist, no pillar for removable or fixed prothesis)
Uncooperative patient
Compromised medical history

Abbreviation: ESE, European Society of Endodontology.

Thomas von Arx: Periradicular Surgery. J Oral Maxillofac Surg 2005.

Table 3. CLINICAL STUDIES ON PERIRADICULAR SURGERY PUBLISHED BETWEEN 1996 AND 2003

Author	Year	n	Follow-up	Retroprep	Retrofill	Success Rate
Sumi et al[5]	1996	157	6 mo to 3 yr	Ultrasonic microtip	SuperEBA	92.4%
Rud et al[6]	1997	153 (Root canal empty)	2 to 4 yr	Shallow concavity with ball-shaped diamond bur	Retroplast	81%
		153 (Root filling insufficient)	2 to 4 yr	Shallow concavity with ball-shaped diamond bur	Retroplast	85%
		167 (Root filling to apex)	2 to 4 yr	Shallow concavity with ball-shaped diamond bur	Retroplast	92%
Sumi et al[7]	1997	108	1 to 12 mo	Ultrasonic microtip	Titanium-inlay and Super EBA	100%
Bader and Lejeune[8]	1998	76	12 mo	Ultrasonic microtip	IRM	95%
		72	12 mo	Ultrasonic microtip + CO_2 laser	—	90%
		*54	12 mo	Conventional bur + CO_2 laser	IRM	67.5%
		*52	12 mo	Conventional bur	IRM	65%
von Arx and Kurt[9]	1999	43	12 mo	Sonic diamond microtip	SuperEBA	82%
Testori et al[10]	1999	95	1 to 6 yr (mean 4.6 yr)	Ultrasonic microtip	SuperEBA	85%
		*207	1 to 6 yr (mean 4.6 yr)	Conventional bur	Amalgam	68%
Rubinstein and Kim[11]	1999	94 (Originally 128)	12 mo	Ultrasonic microtip + surgical microscope	SuperEBA	96.8%
Zuolo et al[12]	2000	102	12 mo (doubtful cases followed for 4 yr)	Ultrasonic diamond microtip	IRM	91.2%
von Arx et al[13]	2001	25 (Only molars)	12 mo	Sonic diamond microtip	SuperEBA	88%
Rud et al[14]	2001	834 (Only mandibular molars)	1.6 to 12.5 yr (mean 4.8 yr)	Shallow concavity with ball-shaped diamond bur	Retroplast	92%
Rubinstein and Kim[15]	2002	59 (Originally 91)	5 to 7 yr	Ultrasonic microtip + surgical microscope	SuperEBA	91.5%
Maddalone and Gagliani[16]	2003	120 (Originally 154)	3 yr	Ultrasonic microtip	SuperEBA	92.5%
Chong et al[17]	2003	47	2 yr	Ultrasonic microtip	IRM	87%
		61	2 yr	Ultrasonic microtip	MTA	92%

Abbreviations: EBA, ethoxybenzoic acid; IRM, intermediate restorative material; MTA, mineral trioxide aggregate.
*Entire entry represents conventional retropreparation technique.

Thomas von Arx: Periradicular Surgery. J Oral Maxillofac Surg 2005.

Root-End Filling Materials

With regard to root-end obturation, the majority of studies published in the last decade have used a modified zinc oxide and eugenol–based cement (SuperEBA [ethoxy benzoic acid] or IRM [intermediate restorative material]; SuperEBA, Staident International, Staines, Middlesex, England; or H. J. Bosworth Company, Skokie, IL; IRM, Dentsply/Caulk, York, PA) as a retrofilling material (Table 3). Amalgam, glass-ionomer-cement, or composite retrofilling materials have been less frequently reported in recent years.

SuperEBA and IRM both have good experimental and clinical documentation.[33] These fortified versions of zinc oxide eugenol were found to be more biocompatible and less soluble than other formulations of zinc oxide eugenol. They have good antimicrobial action and minimal dye leakage.[34]

A new root-end filling material that has received much recent attention is Mineral Trioxide Aggregate (MTA; Dentsply/Tulsa, Tulsa, OK). MTA appears to be equal or superior to other root-end filling materials with respect to biocompatibility, dye and bacterial leakage, marginal adaptation, solubility, and compressive strength.[35] Interestingly, this material also appears to induce cementogenesis with new cementum deposition on the surface of the retrofilling material.[36,37] In cases with inadequate hemorrhage control, MTA has been reported to be superior to other root-end filling materials. However, the downsides to this material are the high cost and the difficult intraoperative handling of MTA, which has a setting time of approximately 3 hours. Therefore, care must be exercised not to wash out the material after placement. A recently published randomized clinical study comparing MTA and IRM with a 2-year follow up has reported success rates of 92% and 87%, respectively.[17] The difference was not statistically significant.

A completely different approach for root-end sealing has been reported by a Danish group.[6,14] A specially developed and chemically curing composite resin (Retroplast; Retroplast Trading, Ronne, Denmark) is used in combination with a dentine-bonding agent. The resection surface is prepared slightly concave with a ball-shaped diamond bur. The shallow cavity is etched with EDTA before placing the primer and the composite resin. The composite resin will then seal root canals, accessory canals, and isthmuses, as well as infractions and exposed dentin tubules. A prerequisite for this technique is strict hemorrhage control.

The Retroplast technique is particularly helpful in cases in which a sufficiently deep root-end cavity cannot be prepared, such as teeth with posts or screws at the resection level, or obliterated root canals (post-trauma, developmental disturbance).

Regenerative Techniques

It has been shown that (pathologic) interactions exist between pulpal and periodontal tissues.[38] An endodontic infection evident as a periapical radiolucency appears to influence periodontal parameters such as probing pocket depth and attachment loss.[39-42] It has also been demonstrated that a significant correlation exists between marginal periodontal and apical healing following periapical surgery.[43]

A challenging problem in periapical surgery remains the loss of buccal bone with partial or complete root exposure (apicomarginal lesions). It has been shown that healing outcome in periapical surgery is related to the condition of the buccal bone plate.[44,45] Epithelial downgrowth along the denuded buccal root surface is considered as a major negative factor preventing successful healing in such cases.

Although regenerative techniques have become a standard of care in periodontology and implant dentistry, these techniques have yet to be established in endodontic surgery. A substantial number of case reports have described the successful outcome of regenerative techniques for treatment of apicomarginal lesions in periapical surgery, but there remains a great need for experimental and clinical studies.[46]

In a recent clinical study, we have found a frequency of 12% of apicomarginal lesions in 100 cases subjected to periradicular surgery. In addition to a standard surgical protocol (root-end resection, root-end cavity preparation with microtips, SuperEBA as retrograde filling), teeth with apicomarginal lesions were treated with collagen membranes or an enamel matrix derivative. Healing outcome in teeth with and without apicomarginal lesions did not differ significantly (93.2% versus 83.3%) (unpublished data). Application of regenerative techniques in teeth with apicomarginal lesions, or in teeth with through-and-through periapical lesions, might further expand the field of periradicular surgery.

Treatment Alternatives to Periapical Surgery

Before planning a periradicular surgery, treatment alternatives must be discussed with the patient and/or the referring dentist. Informed and written consent should be obtained from the patient.

Nonsurgical Retreatment

Revision of an existing root canal obturation should always be considered as a first option. However, pros and cons must be carefully evaluated. As discussed in the treatment outcome section, healing following conventional retreatment appears to be highly dependent on the periapical condition (lesion size), as well as on the anatomy of the endodontium.

Root Resection Therapy

In multirooted molars, resection of a complete root (mostly mesiobuccal root in maxillary first molars) or tooth separation (hemisection of mandibular first or second molars) should be considered as treatment options. The procedure is indicated in particular for roots with compromised periodontal support or deep decay.

Tooth Extraction

It is generally accepted that extraction of a tooth with periapical pathology will eventually result in healing. However, subsequent vertical and/or horizontal bone loss may lead to soft and hard tissue deficiencies. This is of particular concern in the growing child or in the anterior maxilla with high esthetic demands. Whenever possible, teeth should be salvaged to preserve the unique scalloped anatomy of hard and soft tissues around natural teeth or to avoid multiunit edentulous spaces in the anterior maxilla, a situation that is extremely difficult to manage from an esthetic perspective.

Limitations of Periradicular Surgery

In contrast to other specialties in dentistry, that is, implant dentistry, long-term studies (duration of at least 5 years, dropout rate below 10%) are scarce. In addition, periradicular surgery only implies the surgical treatment of a short part of the tooth, that is, the root end. Periradicular surgery does not address the treatment of coronal leakage, and therefore, a certain risk remains for periradicular reinfection. Consequently, indications and treatment alternatives must be evaluated carefully and thoroughly.

In conclusion, 1) strict case selection based on clinical and radiographic parameters is of utmost importance in periradicular surgery; 2) the advent of microsurgical principles, ie, the use of microinstruments, illumination, and magnification, have simplified the surgical technique, and have contributed to higher success rates in periradicular surgery; and 3) regenerative techniques should be considered as adjunctive treatment options in periradicular surgery.

Acknowledgments

The author thanks Dr Alvin Yeo, BDS, MS, Department of Oral Surgery and Stomatology, University of Bern, Switzerland, and Department of Restorative Dentistry, National Dental Center, Singapore, for proofreading the manuscript.

References

1. ESE/European Society of Endodontology: Consensus report of the European Society of Endodontology on quality guidelines for endodontic treatment. Int Endod J 27:115, 1994
2. Hepworth MJ, Friedman S: Treatment outcome of surgical and non-surgical management of endodontic failures. J Can Dent Assoc 63:364, 1997
3. Danin J, Strömberg T, Forsgren H, et al: Clinical management of non-healing periradicular pathosis. Surgery versus endodontic retreatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 82:213, 1996
4. Kvist T, Reit C: Results of endodontic re-treatment: A randomized clinical study comparing surgical and nonsurgical procedures. J Endod 25:814, 1999
5. Sumi Y, Hattori H, Hayashi K, et al: Ultrasonic root-end preparation: Clinical and radiographic evaluation of results. J Oral Maxillofac Surg 54:590, 1996
6. Rud J, Rud V, Munksgaard EC: Long-term evaluation of retrograde root filling with dentin-bonded resin composite. J Endod 22:90, 1996
7. Sumi Y, Hattori H, Hayashi K, et al: Titanium inlay—a new root-end filling material. J Endod 23:121, 1997
8. Bader G, Lejeune S: Prospective study of two retrograde endodontic apical preparations with and without the use of CO_2 laser. Endod Dent Traumatol 14:75, 1998
9. von Arx T, Kurt B: Root-end cavity preparation after apicoectomy using a new type of sonic and diamond-surfaced retrotip: A 1-year follow-up study. J Oral Maxillofac Surg 57:656, 1999
10. Testori T, Capelli M, Milani S, et al: Success and failure in periradicular surgery. A longitudinal retrospective analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 87:493, 1999
11. Rubinstein RA, Kim S: Short-term observation of the results of endodontic surgery with the use of a surgical operation microscope and Super-EBA as root-end filling material. J Endod 25:43, 1999
12. Zuolo ML, Ferreira MOF, Gutmann JL: Prognosis in periradicular surgery: A clinical prospective study. Int Endod J 33:91, 2000
13. von Arx T, Gerber C, Hardt N: Periradicular surgery of molars: A prospective clinical study with a one-year follow-up. Int Endod J 34:520, 2001
14. Rud J, Rud V, Munksgaard EC: Periapical healing of mandibular molars after root-end sealing with dentine-bonded composite. Int Endod J 34:285, 2001
15. Rubinstein RA, Kim S: Long-term follow-up of cases considered healed one year after apical microsurgery. J Endod 28:378, 2002
16. Maddalone M, Gagliani M: Periapical endodontic surgery: A 3-year follow-up study. Int Endod J 36:193, 2003
17. Chong BS, Pitt Ford TR, Hudson MB: A prospective clinical study of Mineral Trioxide Aggregate and IRM when used as root-end filling materials in endodontic surgery. Int Endod J 36:520, 2003
18. Carr GB: Ultrasonic root end preparation. Dent Clin N Am 41:541, 1997
19. von Arx T, Kurt B, Ilgenstein B, et al: Preliminary results and analysis of a new set of sonic instruments for root-end cavity preparation. Int Endod J 31:32, 1998
20. von Arx T, Walker WA: Microsurgical instruments for root-end cavity preparation following apicoectomy: A literature review. Endod Dent Traumatol 16:47, 2000
21. Tidmarsh BG, Arrowsmith MG: Dentinal tubules at the root ends of apicected teeth: A scanning electron microscopic study. Int Endod J 22:184, 1989
22. Gilheany PA, Figdor D, Tyas MJ: Apical dentin permeability and microleakage associated with root end resection and retrograde filling. J Endod 20:22, 1994
23. Lloyd A, Jaunberzins A, Dummer PMH, et al: Root-end cavity preparation using MicroMega sonic retro-prep tip. SEM analysis. Int Endod J 29:295, 1996
24. Beling KL, Marshall JG, Morgan LA, et al: Evaluation for cracks associated with ultrasonic root-end preparation of gutta-percha filled canals. J Endod 23:323, 1997
25. Waplington M, Lumley PJ, Walmsley AD: Incidence of root face alteration after ultrasonic retrograde cavity preparation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83:387, 1997
26. Calzonetti KJ, Iwanowski T, Komorowski R, et al: Ultrasonic root end cavity preparation assessed by an in situ impression technique. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 85:210, 1998
27. Morgan LA, Marshall JG: A scanning electron microscopic study of in vivo ultrasonic root-end preparations. J Endod 25:567, 1999
28. Kim S: Principles of endodontic microsurgery. Dent Clin North Am 41:481, 1997
29. Bahcall JK, Di Fiore PM, Poulakidas TK: An endoscopic technique for endodontic surgery. J Endod 25:132, 1999
30. von Arx T, Hunenbart S, Buser D: Endoscope- and video-assisted endodontic surgery. Quintessence Int 33:255, 2002
31. Slaton CC, Loushine RJ, Weller RN, et al: Identification of resected root-end dentinal cracks: A comparative study of visual magnification. J Endod 29:519, 2003
32. von Arx T, Montagne D, Zwinggi C, et al: Diagnostic accuracy of endoscopy in periradicular surgery—a comparison with scanning electron microscopy. Int Endod J 36:691, 2003

33. Johnson BR: Considerations in the selection of a root-end filling material. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 87:398, 1999
34. Haumann CHJ, Love RM: Biocompatibility of dental materials used in contemporary endodontic therapy: A review. Part 2. Root-canal filling materials. Int Endod J 36:147, 2003
35. Torabinejad M, Pitt Ford TR: Root-end filling material: A review. Endod Dent Traumatol 12:161, 1996
36. Torabinejad M, Pitt Ford TR, McKendry DJ, et al: Histologic assessment of Mineral Trioxide Aggregate as a root-end filling in monkeys. J Endod 23:225, 1997
37. von Arx T, Britain S, Cochran DL, et al: Healing of periapical lesions with complete loss of the buccal bone plate: A histological study in the canine mandible. Int J Periodontics Restorative Dent 23:157, 2003
38. Zehnder M, Gold SI, Hasselgren G: Pathologic interactions in pulpal and periodontal tissues. J Clin Periodontol 29:663, 2002
39. Jansson L, Ehnevid H, Lindskog S, et al: Relationship between periapical and periodontal status. A clinical retrospective study. J Clin Periodontol 20:117, 1993
40. Jansson L, Ehnevid H, Lindskog S, et al: Radiographic attachment in periodontitis-prone teeth with endodontic infection. J Periodontol 64:947, 1993
41. Ehnevid H, Jansson L, Lindskog S, et al: Periodontal healing in teeth with periapical lesions. A clinical retrospective study. J Clin Periodontol 20:254, 1993
42. Jansson L, Ehnevid H, Lindskog S, et al: The influence of endodontic infection on progression of marginal bone loss in periodontitis. J Clin Periodontol 22:729, 1995
43. Jansson L, Sandstedt P, Laftman AC, et al: Relationship between apical and marginal healing in periradicular surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83:596, 1994
44. Hirsch JM, Ahlström U, Henrikson PA, et al: Periapical surgery. Int J Oral Surg 8:173, 1979
45. Skoglund A, Persson G: A follow-up study of apicoectomized teeth with total loss of the buccal bone plate. Oral Surg Oral Med Oral Pathol 59:78, 1985
46. von Arx T, Cochran DL: Rationale for the application of the GTR principle using a barrier membrane in endodontic surgery: A proposal of classification and literature review. Int J Periodont Restor Dent 21:127, 2001