CLINICAL UPDATE

The management of periapical lesions in endodontically treated teeth

Marcus T. Yan, BDS (Syd), MDSc (QLD), FRACDS

Private Endodontic Practice, Sydney, New South Wales, Australia

Keywords
apicoectomy, dental cysts, retreatment, root canal medicaments, root canal irrigants, root canal therapy.

Correspondence
Marcus T. Yan, Level 11, 60 Park Street, Sydney, NSW 2000, Australia. Email: marcsyan@hotmail.com

doi: 10.1111/j.1747-4477.2006.00002.x

This article is based on a presentation to the 13th Asian Pacific Endodontic Confederation Scientific Meeting held in Kuala Lumpur on 25 May 2005.

Abstract

When root canal therapy is done according to accepted clinical principles and under aseptic conditions, the success rate is generally high. However, it has also been reported that 16% to 64.5% of endodontically treated teeth are associated with periapical radiolucent lesions. There are great variations among clinicians when suggesting treatment of these failed endodontic cases. This article will discuss factors influencing treatment decisions on these particular cases, and the pros and cons of nonsurgical retreatment versus surgical retreatment. The advancement of modern endodontic microsurgery will also be discussed.

Introduction

When endodontic treatment is performed to accepted clinical standards, a success rate of around 90% can be expected (1). However, in a recent cross-sectional study of populations in various countries, the prevalence of apical periodontitis associated with root-filled teeth was reported to be as high as 64.5% (2). The two most important factors that could relate the periapical lesion in association with root-filled teeth seem to be the qualities of the root fillings (3) and the coronal restorations (4).

In recent times many practitioners have replaced failed endodontically treated teeth with implants. Are implants a better treatment option for the patient? Are we condemning these teeth too quickly?

The aim of this article is to discuss the reasons for failure of endodontically treated teeth, the current concepts in their management and also the expected treatment outcome of each treatment strategy.

As understanding the disease process is the key to successfully treating the disease, it is important to understand the biological factors that are related to the failure of endodontically treated teeth. There are five main factors that may cause persistent periapical radiolucencies of endodontically treated teeth:

1. Intra-radicular infection (5);
2. Extraradicular infection (6–8);
3. Foreign body reaction (9,10);
4. True cyst (11,12); and
5. Fibrous scar tissue (12).

Among these factors, microorganisms persisting in the root canal should respond to orthograde retreatment. However, lesions associated with extraradicular bacteria, true cysts and foreign bodies can only be managed by periapical surgery. Periapical lesions that heal by fibrous scar tissue require no treatment.

Intra-radicular infection

In most cases, failure of endodontic treatment is due to microorganisms persisting in the root canal system, even in a seemingly well-treated tooth (5). In early studies, Engstrom and Frostell and Möller reported bacterial growth in root-filled teeth with apical radiolucencies (13,14). Nevertheless, the microflora in a previously root-treated tooth that has failed differs markedly from that in an infected but previously untreated root canal system. In teeth that have been previously treated, there appears to be a very limited assortment of microorganisms (14). Usually only a few species are recovered (15,16), with a predominance of Gram-positive microorganisms and facultative anaerobes (more than obligate anaerobes) (17,18). *Enterococcus faecalis* was the most frequently recovered bacterial species (15–17,19) with streptococci also relatively common. Other species found in high numbers are lactobacilli (17), actinomyces species and peptostreptococci (18).

Coronal leakage

If the root canal had been unsealed at some point during the treatment, enteric bacteria are found more frequently than in canals with an adequate seal between the appointments. A third of *E. faecalis* cases in pure culture have also been reported (20). Pinheiro *et al.* reported a significant positive relationship between the absence of a coronal restoration and the presence of streptococcus spp. and candida spp. in the root canal (15). In 2004, Adib *et al.* attempted to identify the bacterial flora in root-filled teeth with persistent periapical lesions and a history of coronal leakage. They found the predominant group of bacteria was Gram-positive facultative anaerobes of which staphylococci followed by streptococci and enterococci were the most prevalent. Their results also showed a polymicrobial flora existed (with the number of species recovered per tooth ranging from six to 41 species) when the canal was poorly root filled (21).

Technically unsatisfactory root fillings with periapical lesions

In the root canals of teeth with technically inadequate root fillings and asymptomatic periapical lesions, but with an acceptable coronal restoration, one or more obligate anaerobes are usually found and the situation is similar to the infected but previously untreated teeth (22). Peciuliene *et al.* confirmed that there is a significant association between poorly obturated canals and polymicrobial infections (23). This is in agreement with Sundqvist *et al.* who reported in 1998 that the polymicrobial flora in a poorly root-filled tooth was similar to the flora found in untreated cases (16). Polymicrobial infections and obligate anaerobes were also frequently found in the canals of symptomatic root-filled teeth (15).

In summary, the microorganisms causing the initial infection persisted in poorly treated root-filled teeth with periapical lesions. In theory, if these root canals are retreated adequately under a strict treatment regimen, the success rate should be as good as endodontic treatment of the previously untreated teeth with apical periodontitis. We should expect a healing rate of around 85% to 94% (24). Periapical surgery can be avoided if orthograde retreatments are carried out in these cases. Replacement

Figure 1 Periapical lesion associated with endodontically treated tooth 36.

Figure 2 Regression of periapical lesion 6 months after orthograde retreatment of tooth 36.

of these teeth that have a reasonable endodontic outcome with implants cannot be justified (Figs 1,2).

However, in teeth with adequate root fillings but with apical periodontitis (with or without history of coronal leakage), there is a higher chance that the pathogens would include *E. faecalis* and *Candida albicans*. The treatment regimen in these cases should be viewed differently from the initial endodontic therapy with apical periodontitis. This will be discussed later.

Extra-radicular infection

Histologically, there are generally two types of extra-radicular infection:

1. Acute periapical abscess – purulent inflammation in the periapical tissue in response to the egress of virulent bacteria from the root canal. This is dependent on the intra-radicular infection; once the intra-radicular infection is treated, the extra-radicular infection should subside (25). In most cases, orthograde endodontic retreatment would thus be indicated.

2. Microorganisms become established in the periapical tissues either by adhering to the apical root surface in the form of biofilm-like structures (26) or within the body of the inflammatory lesion, usually as cohesive colonies (27). The microorganisms involved are usually members of the genus actinomyces, *propionibacterium propionicum* and bacteroides species (7,8,28). Once microoganisms are established in the periapical area, the infection can only be successfully treated by periapical surgery.

Foreign body reaction

Periapical lesions often contain cholesterol crystals, as seen in histopathological sections. These endogenous crystals, which are believed to be released from disintegrating host cells such as erythrocytes, lymphocytes, plasma cells and macrophages in the inflamed periapical connective tissue and/or circulating plasma lipids (29) can act as foreign bodies and provoke a giant cell reaction. Other materials that may elicit a foreign body reaction in the periapical tissues are usually exogenous in nature and include talc-contaminated gutta-percha (9), the cellulose component of paper points, cotton wool and food material of vegetable origin (30,31). Therefore, the initiation of a foreign body reaction in the periapical tissues can be either by exogenous materials or endogenous cholesterol. This is the only non-microbial factor associated with periapical lesions of endodontically treated teeth.

Currently, there are no clinical tests to diagnose the existence of these extraradicular agents associated with post-treatment periapical radiolucencies. Surgical treatment is the only way to remove these agents that can sustain the disease process. Therefore, periapical surgery should be considered a part of the treatment plan, especially in cases that do not respond to conventional orthograde retreatment.

Periapical cyst

Clinically, periapical lesions cannot be differentially diagnosed as cystic or non-cystic lesion based on conventional radiographs (32–34). An accurate diagnosis of radicular cyst is possible only histopathologically through serial sectioning of the lesion (35). In 1980, Simon described two categories of radicular cyst: true cyst, containing cavities completely enclosed in epithelial lining; and Bay cyst or pocket cyst, containing epithelium-lined cavities that are open to the root canals (36). Nair *et al.*, in analysing 256 periapical lesions, found 35% to be periapical abscesses, 50% to be periapical granulomas, and only 15% to be periapical cysts. Among this group of 15%, 9% were true cysts and 6% were pocket cysts (35). Unlike true cysts, periapical pocket cysts may heal after non-surgical root canal therapy. The prevalence of true cysts associated with endodontically treated teeth with periapical lesion may be higher, with Nair *et al.* reporting about 13% of post-treatment apical lesions to be true cystic lesions (9,11,12).

Current thoughts on retreatment

The main cause of failure of endodontic treatment is generally accepted to be the continuing presence of microorganisms in the root canal system that have either resisted treatment (5) or have reinfected the root canal system through coronal leakage (4,37,38). Conventional orthograde retreatment is thus indicated in many cases to try to eliminate this persistent intra-radicular infection before surgical intervention is contemplated (Figs 3–5).

Irrigants and medicaments

Numerous studies have shown that many of our current irrigating solutions and intra-canal medicaments, including sodium hypochlorite (NaOCl) and calcium hydroxide are ineffective against *C. albicans* and *E. faecalis* (39–41) Molander *et al.* (17) questioned the use of calcium hydroxide in retreatment cases and Peciuliene suggested a different treatment regimen should be used to target *E. faecalis* in retreatment cases (23).

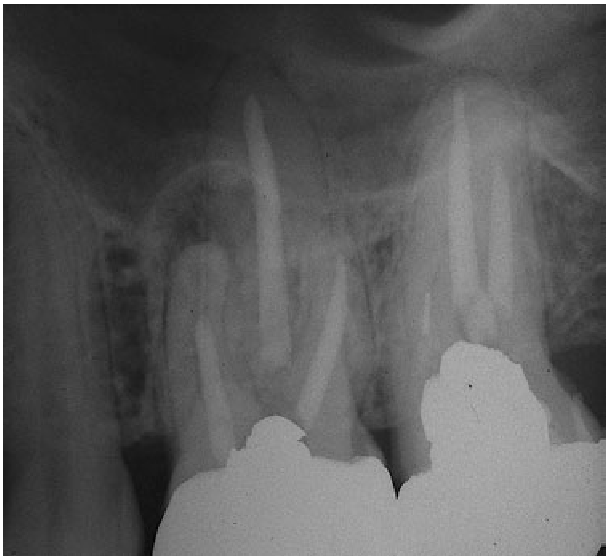

Figure 3 Endodontically treated tooth 26 presented with periapical lesion associated with mesiobuccal root.

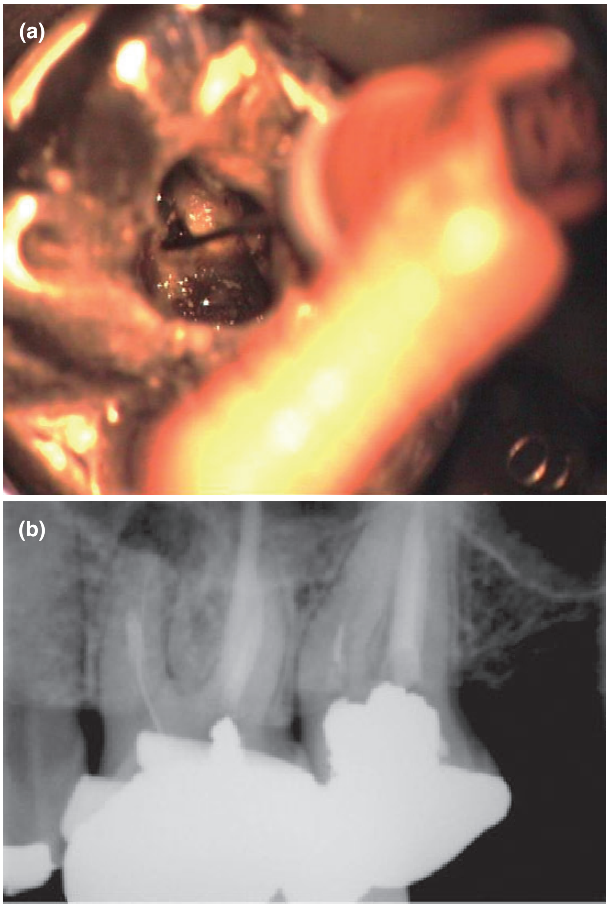

Figure 4 (a) and (b). Location of the unfilled second mesiobuccal canal of tooth 26.

Figure 5 Healing of the periapical lesion associated with tooth 26 (mesiobuccal root) 1 year after orthograde retreatment.

Chlorhexidine gluconate (CHX)

Chlorhexidine gluconate (CHX) has been proposed for use both as an irrigant and as a medicament especially in endodontic retreatment. As a medicament, it is more effective than calcium hydroxide in eliminating *E. faecalis* infection inside dentinal tubules (42). As an irrigant, it appears as effective or superior to sodium hypochlorite (NaOCl) (43–45), especially in the elimination of *E. faecalis* (45,46). Irrigating solutions of 0.5% CHX were reported to be more effective at killing *C. albicans* than calcium hydroxide, 0.5% and 5% NaOCl and 2% iodine potassium iodide (IKI) (47). Chlorhexidine also has the added advantage of substantivity with the antimicrobial activity of 2% CHX found to be retained in root canal dentine and effective against *E. faecalis* for up to 12 weeks (48).

Two per cent CHX in both gel and liquid forms performed as well as 5.25% NaOCl against *C. albicans* and *E. faecalis* (44,45,49). However, Dametto *et al.* demonstrated that 2% CHX gel and liquid were more effective than 5.25% sodium hypochlorite in preventing regrowth of *E. faecalis* for 7 days after biomechanical preparation of the root canals. Two per cent CHX is also less toxic than 0.5% NaOCl (50).

One *in vitro* study found 2% CHX gel produced cleaner dentine walls when compared with 5.25% NaOCl and 2% CHX liquid used as an endodontic irrigant. The viscosity of the CHX gel seemed to compensate for its inability to dissolve pulp tissue by promoting a better mechanical cleansing of the root canal and aiding the removal of dentine debris and tissue remnants (51). Other studies also suggest CHX gel has more clinical advantages than the liquid (45,51,52).

However, CHX is unable to dissolve organic matter or pulp tissue (53) and it does not remove smear layer (54). Therefore, White *et al.* suggested the combination of CHX and NaOCl as an irrigant to takes advantage of each individual irrigant's properties, without impairing or compromising the substantivity of CHX and the tissue-dissolving action of NaOCl (55). This is further supported by Kuruvilla and Kamath, who showed that the combination of 2.5% NaOCl and 0.2% CHX resulted in significantly greater bacterial reduction than when each irrigant was used alone (56). Zamany *et al.* showed that a better disinfection of the root canals occurred when CHX was used as a final rinse after chemo-mechanical preparation with NaOCl (57).

Calcium hydroxide and chlorhexidine as a combined medicament

As calcium hydroxide is ineffective against *E. faecalis*, combining calcium hydroxide with CHX has been advocated in recent years (58,59). CHX as an aqueous vehicle may raise the pH of the mixture during the first 2 days (60,61). However, calcium hydroxide could decrease the antibacterial activity of the CHX because of the competition between the positive charge of the CHX and calcium ions for common binding sites (negatively charged phosphate groups) on the bacterial cell wall (47,62). Therefore, calcium hydroxide powder might reduce the immediate antimicrobial efficacy of CHX (63). The substantive antimicrobial activity of CHX in human root dentine in killing *E. faecalis* could also be affected when it is mixed with calcium hydroxide (60,64,65). Gomes *et al.* reported that 2% CHX gel alone was more effective against *E. faecalis* than calcium hydroxide and its antibacterial activity depended on how long it remained inside the root canal (60). Waltimo *et al.* reported the combination of calcium hydroxide and 0.05% CHX to be more effective in killing *C. albicans* than pure calcium hydroxide. However, this combination was less effective than 0.05% CHX alone in killing *C. albicans* (47).

Iodine potassium iodide (IKI)

This iodine-based medicament was suggested as an endodontic medicament in the early 1970s, but its use is not widespread owing to its ability to discolour teeth. There has been renewed interest in IKI in recent years owing to its seemingly superior antibacterial properties compared with calcium hydroxide. Studies have shown that IKI was able to penetrate the dentinal tubules and was more effective than calcium hydroxide in killing *E. faecalis* in both *in vitro* (66), and *in vivo* studies (17,67). It was also more effective than calcium hydroxide against *C. albicans*. The efficacy of IKI was reduced when combined with calcium hydroxide but was still more effective than calcium hydroxide alone (47). Recently, a study also reported that calcium hydroxide mixed with iodoform and silicone oil was more effective than calcium hydroxide plus IKI and calcium hydroxide alone in killing *E. faecalis* (68).

MTAD

MTAD is a mixture of a tetracycline isomer, citric acid and a detergent. MTAD has been reported to be more effective than NaOCl in killing *E. faecalis in vitro* (69,70). Its effectiveness seems to be further enhanced when used in combination with NaOCl (71).

Rotary instrumentation

Studies have clearly shown that mechanical instrumentation alone will not predictably eliminate bacteria from an infected root canal. Rotary nickel-titanium (NiTi) instrumentation has gained popularity owing to its efficiency and ability to maintain the original canal curvature better, especially in the apical third of the root canal compared with hand instruments made of stainless steel (72,73). However, from a biological perspective, rotary instrumentation does not seem to have produced significant real advantages over hand instrumentation (74). Dalton *et al.* compared intra-canal bacterial reduction in teeth instrumented with 0.04 tapered NiTi rotary instruments to teeth prepared using stainless-steel K-files with the step-back technique. The study found no significant difference between the two techniques in their ability to reduce intra-canal bacteria (75). Shuping *et al.* used a similar experimental model to Byström and Sundqvist in 1983 (39) to evaluate the extent of bacterial reduction with nickel-titanium rotary instrumentation and 1.25% NaOCl irrigation. Their results indicate the use of NaOCl irrigation with rotary instrumentation during endodontic treatment is the more important factor in reducing bacterial numbers. However, the authors were still unable to consistently remove all the bacteria in the root canals and thus suggested the use of calcium hydroxide as an intra-canal medicament to attain the goal of total bacterial elimination more predictably (76).

In summary, the use of intra-canal medicament is still the most predictable way to eliminate bacteria in the root canal system in orthograde retreatment cases. As the use of chlorhexidine as a medicament or irrigant has clearly shown to be more effective in killing *E. faecalis* and *C.albicans in vitro*, it should therefore be used in retreating failed endodontic cases. IKI and MTAD appear promising in early *in vitro* studies and they may be the medicament/irrigant of choice in the future.

Outcome of endodontic retreatment

Many studies looking at the outcome of endodontic retreatment have been published but there are probably only a handful of published studies that have met the evidence-based dentistry (EBD) criteria which were defined by American Dental Association (77). These studies reported the success rate of endodontic retreatment to be around 74–88% (78,79). Interestingly, the percentage of teeth still in 'function' ranged from 78% to 97%. This is a similar term to 'implant survival' which many implant studies have used as a measure of implant treatment outcomes. The survival rate of dental implants has been reported as ranging from 76% to 94% (80,81). 'Survival' or 'functional', however, do not necessarily equate to biological success.

Based on the literature, the factors affecting the outcome of retreatment are as follows:

1. Teeth with root canal morphology altered by previous endodontic treatment have a lower success rate (82).
2. Teeth with periapical pathosis have considerably less predictable treatment outcome (1,83).
3. The greater the size of the peripical lesion, the lower the success rate of treatment (84).
4. Preoperative perforation results in a poorer prognosis (79).
5. The outcome in 'failed' teeth with an adequate root filling was poorer (16,79).
6. The outcome was better if retreatment was performed to an adequate length (79).
7. The outcome was poorer when teeth had not been definitively restored (4).
8. Over-instrumentation and overfilling could delay periapical healing (85,86).

Periapical surgery

Periapical surgery attempts to contain any microorganisms within the canal by sealing the canal apically (at the same time the periapical lesion, if present, can be curetted and histologically investigated further). The objective is to optimise the conditions for periapical tissue healing and regeneration of the attachment apparatus.

The indications for surgical treatment can be summarised as:
1 Where retreatment is impossible owing to fractured instruments, ledges, blockages, filling material impossible to remove and so on.
2 With failure of orthograde retreatment: bacteria located in areas such as isthmuses, ramifications, deltas, irregularities and dentinal tubules may be unaffected by endodontic disinfection procedures (87,88). Bacteria may also remain in the space created by dentinal resorption owing to the periapical lesion having eluded intra-canal irrigation and medicament, as well as systemic antibiotics (89).
3 Where the prognosis of non-surgical retreatment is unfavourable or impractical (such as an extensive coronal restoration that may have to be sacrificed and remade).
4 With patients who may not prefer the routine retreatment owing to financial and/or time constraints.
5 Where biopsy is needed.

There have been great improvements in endodontic surgery in the past 20 years owing to advances in techniques, equipments and materials (90–94). The advancement of modern endodontic surgery as compare with traditional endodontic surgery is summarised in Table 1. The operating microscope enhances visibility and provides the surgeon with a better understanding of canal anatomy, a better surgical view and the ability to undertake more complex but predictable apical resection techniques. The advancement of surgical ultrasonic instruments has also allowed a more conservative, precise and coaxial root-end preparation (Figs 6–10).

Table 1. Comparison of traditional and microsurgery in endodontics (95)

Procedure	Traditional surgery	Microsurgery
Identification of the apex	Difficult	Precise
Osteotomy	Large (10 mm)	Small <5 mm
Root surface inspection	None	Always
Bevel angle	Large (45°)	Small <10°
Isthmus identification	Nearly impossible	Easy
Retropreparation	Approximate	Precise
Root-end fillings	Imprecise	Precise

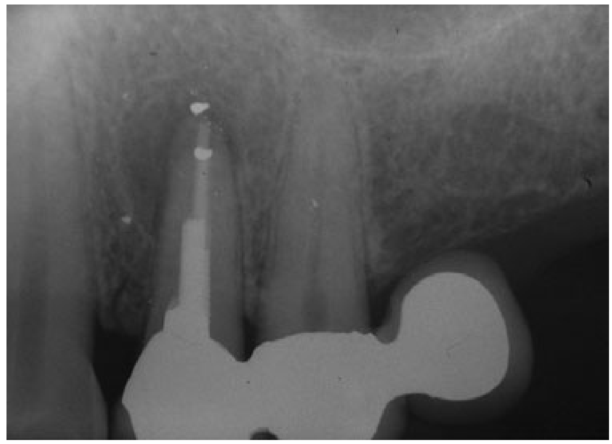

Figure 6 Periapical lesion associated with tooth 14 which had a history of previous periapical surgery.

Mineral trioxide aggregate (MTA)

Mineral trioxide aggregate was introduced as a retrograde filling material in the mid-1990s (96–98) and its use appears to have improved the clinical success of periapical surgery. The success rate for periapical surgery with MTA as the retrograde filling material has been reported to be around 84% after 12 months and 92% after 24 months, which is higher than IRM (99).

Mineral trioxide aggregate has been shown to induce hard tissue formation (100), including deposition of cementum (101,102). MTA also has an antibacterial effect on some facultative bacteria (freshly mixed and 24 h set) and *C. albicans* (103).

Apaydin *et al.* found no significant difference in the quantity of cementum or osseous healing associated with freshly placed or set MTA when used as a root-end filling material and thus even suggested using MTA to root-fill teeth prior to surgery (and subsequent root-end resection without the retrofilling procedure) to simplify the surgical process (104).

Prognosis of endodontic surgery

A summary of studies with an adequate level of evidence reporting on the outcome of endodontic surgery is outlined in Table 2 (105).

These studies suggest that the healing rates of periapical surgery range from 60% to 91%. Important factors that may significantly affect the outcome are summarised as follows:

1. Retrofilling: Hirsch *et al.* stated the retrograde filling is a major prognostic factor (112). If we accept that apical lesions result primarily from bacterial infection in the root canal, the presence/absence of an apical barrier will therefore affect the long-term prognosis of surgical treatment. The success rate can be increased by 10% to 13% if a retrograde filling is used (113–115).

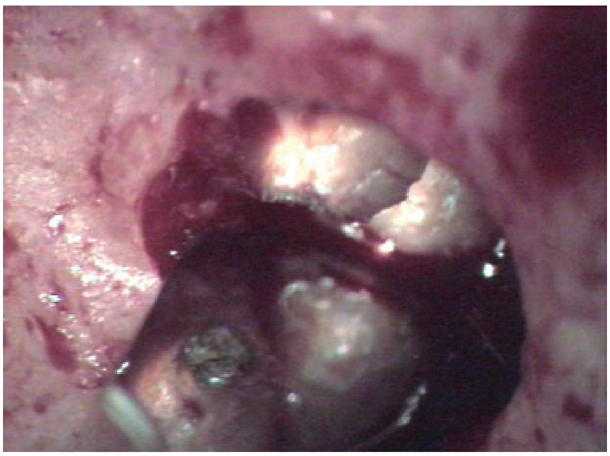

Figure 7 Leakage around the amalgam retrofilling in the buccal root apices of tooth 14.

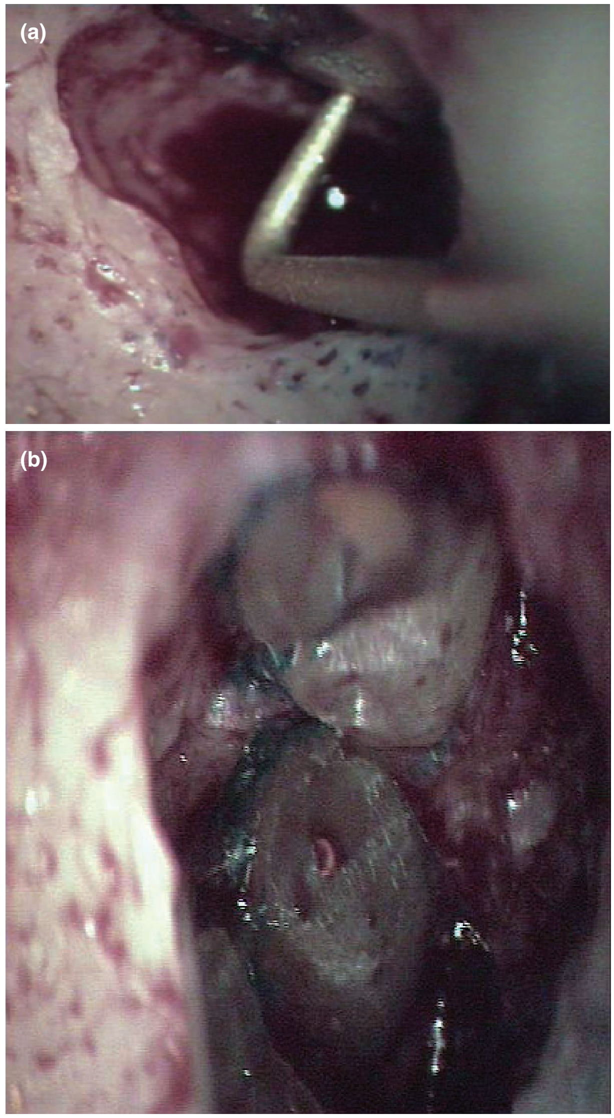

Figure 8 (a) and (b) – Retropreparation on the palatal root apices of tooth 14 with ultrasonic retrotips.

Table 2. Summary of studies with an adequate level of evidence reporting on the outcome of endodontic surgery

	Follow-up years	No. of cases observed	Orthograde and surgery (%)	Surgery only (%)	Healed (%)	Healing (%)	Functional (%)
Molven *et al.* (106)	1–8	222	50		96	3	99
				50	73	14	87
Jansson *et al.* (107)	0.9–1.3	62		100	31	55	86
Kvist and Reit (108)	4	45		100	60		60
Zuolo *et al.* (109)	1–4	102		100	91		91
Rahbaran *et al.* (110)	>4	129		100	37	33	70
Wang *et al.* (111)	4 to 8	155		100	74		91

Figure 9 The buccal and palatal root apices of 14 retrofilled with mineral trioxide aggregate.

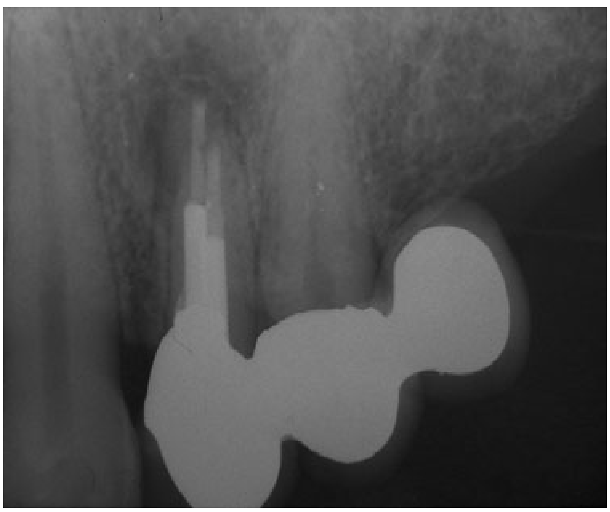

Figure 10 Healing of periapical lesion associated with tooth 14, 6 months after endodontic microsurgery.

2. Size of the apical lesion: The healing rate is significantly higher for teeth with smaller (<5 mm) rather than larger preoperative lesions (106,111,116).
3. Quality of root fillings: Teeth with preoperative long or short root fillings have a higher healing rate compared with those with adequate root fillings (111,117).
4. Tooth location: Maxillary lateral incisors demonstrate the highest rate of healing by scar tissue (116,118). There appear to be poorer outcomes with maxillary premolars than with anterior teeth (119); better outcomes occur for posterior teeth compared with anterior teeth (mandibular incisors have the worst outcome) (120).
5. Alveolar bone loss: Considerable loss of the bony plate or marginal bone impairs the successful outcome of periapical surgery (112,118,121,122).
6. The outcome of treatment is significantly impaired in the presence of temporary restorations (114), posts (117) and crowns (123).

Prognosis of surgical treatment versus non-surgical retreatment

There seems to be a general view that surgical retreatments have a higher failure rate (113,124) than orthograde retreatment; however, recent studies have shown no significant difference in outcome when treating endodontic failures either by surgery or conventional retreatment (125).

In 1999, Kvist and Reit studied 95 incisors and canines that were classified as failures and which were treated either by surgical or non-surgical retreatment. They found the cases which were treated surgically had a significantly higher healing rate at 12 months. But at the final 48-month examination, no difference was found in the healing rate between teeth that were treated surgically and those treated non-surgically (108).

Importantly though, it has been shown that when teeth are retreated conventionally before periapical surgery, there is a 24% higher success rate compared with teeth where only periapical surgery is performed (116). Therefore, if orthograde retreatment can be done immediately prior to surgery, then an approximately 90% success rate can be expected (106,118).

Recent developments in endodontic surgery such as the use of the surgical microscopes, ultrasonic retrotips and new retrofilling materials should enable us to achieve a more predictable surgical treatment outcome and thus a higher success rate. Maddalone and Gagliani reported modern surgical endodontic procedures with EBA root-end fillings were successful over 3 years in 92.5% of cases (126). Rubinstein and Kim (127) reported a 91.5% success rate over 5–7 years. These percentages are significantly better than those quoted in the earlier studies of endodontic periapical surgery (94,99,126,128).

In summary, the best success rate can be achieved if orthograde retreatment is done first followed by periapical surgery, if indicated. Endodontic surgery should be carried out with the aid of a surgical microscope, micro-instruments and ultrasonic instrumentation, and a retrograde filling material should be placed.

Retreatment, surgery or extraction?

Once the initial diagnosis is established, the clinician should undertake the appropriate treatment based on the understanding of the disease process. As persistent intraradicular infection appears to be the major cause of post-treatment disease, conservative orthograde retreatment should be our first treatment choice. However, as the bacterial flora is different from the flora found in a previously untreated tooth, we should establish a different medicament regimen to achieve a better outcome. An even better outcome would also be achieved for surgical treatment if the tooth can be retreated conservatively first.

However, retreatment might be time-consuming and costly if replacement of an extensive restoration is required. Periapical surgery may be the most practical treatment option for managing these cases. With the advances of our surgical techniques, the outcome of surgical endodontic treatment appears to be more promising and more predictable than before (Figs 11–15).

Our patients should also provide an input in the decision process. Friedman in 2000 emphasised the important role of the clinician in providing the patient with information and facilitating their choice of the appropriate treatment option (129). This is important, as the involved treatment may be lengthy and expensive. For example, the surgical option would be favoured if the patient is reluctant to undergo a retreatment process which could be relatively more complex and time-consuming. However, the patient should also understand and accept the possible compromised long-term prognosis of a surgical procedure

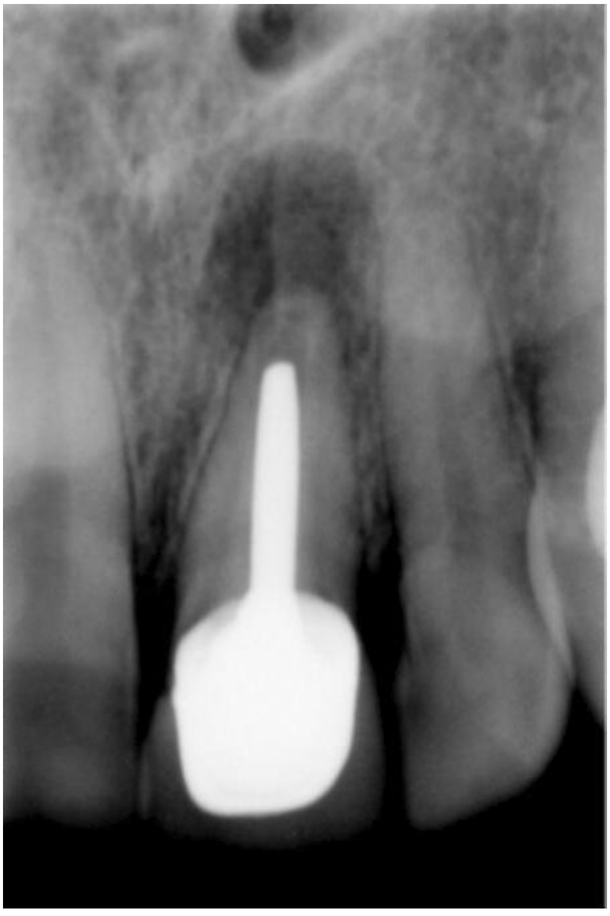

Figure 11 Periapical lesion associated with tooth 21 restored with a post-core crown.

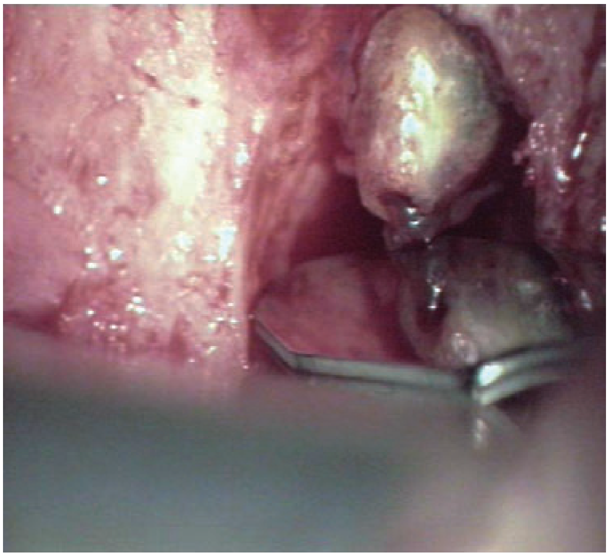

Figure 12 Surgical access to the infected root apex of tooth 21.

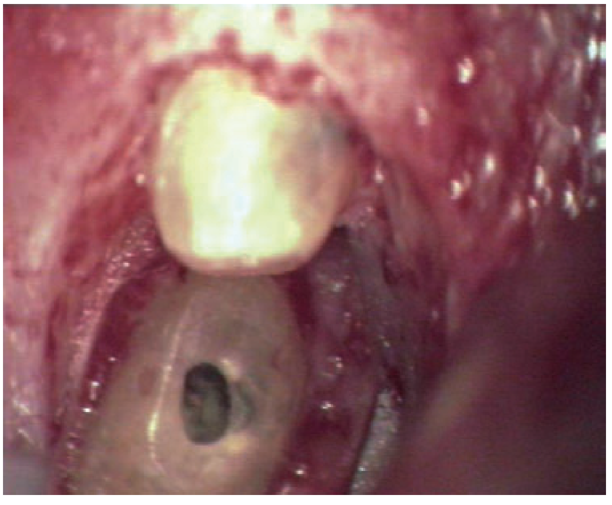

Figure 13 Surgical retrograde preparation of the root apex of tooth 21, showing the apical end of the post. The image was taken under high magnification through a microscope with the help of a surgical micro-mirror.

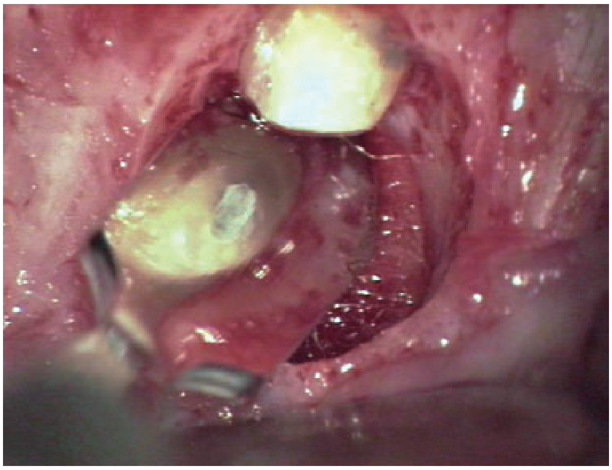

Figure 14 Tooth 21 retrofilled with Super EBA.

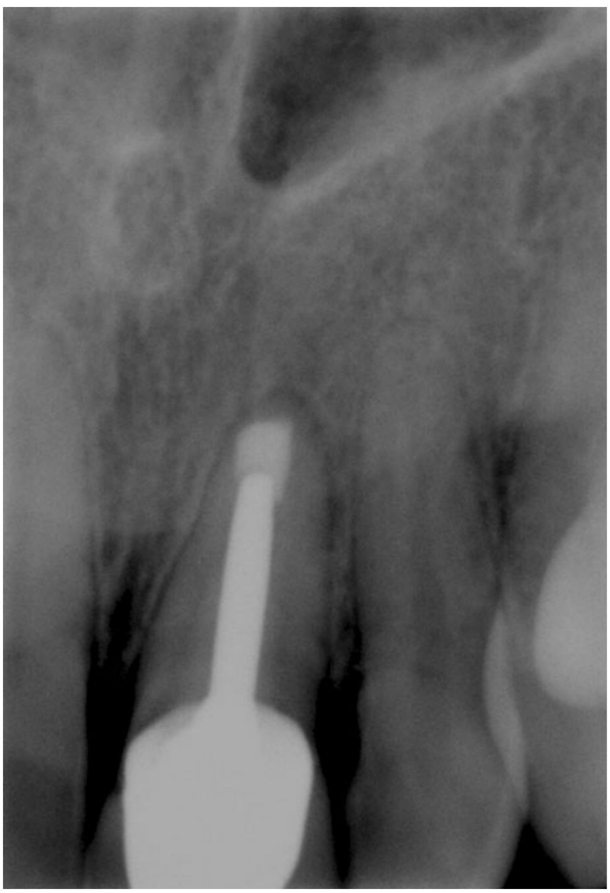

Figure 15 Healing of periapical lesion associated with tooth 21, 6 months after periapical surgery.

Table 3. Patient considerations governing treatment options

No.	Consideration	Yes
Extraction	Motivation to retain tooth	Retreatment or surgery
Surgery	Motivation to pursue best long-term outcome	Retreatment
Retreatment	Time concern	Surgery
Retreatment	Financial concerns	Surgery

alone. When the motivation for retaining the tooth is lacking, then extraction and perhaps replacement with an implant maybe the most appropriate treatment option (Table 3). Effective communication before treatment decisions will avoid future misunderstandings, disappointment and possible litigation.

Conclusion

Our greater understanding of post-endodontic treatment disease and technological advances has enabled us to manage these cases more effectively. Many endodontically treated teeth that have failed still have a reasonable chance of success if they are managed appropriately. The extraction of these teeth and subsequent replacement by implants does not seem justified when one considers the favourable prognosis of retreatment and the biological costs of implant replacement. A more careful and thoughtful approach in assessing and treatment planning each case, with the patient being involved in the decision-making, is strongly recommended.

Acknowledgement

The author would like to express his gratitude to Dr Alexander Lee for his assistance and review of this paper.

References

1. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990; 16: 498–504.
2. Jimenez-Pinzon A, Segura-Egea JJ, Poyato-Ferrera M, Velasco-Ortega E, Rios-Santos JV. Prevalence of apical periodontitis and frequency of root-filled teeth in an adult Spanish population. Int Endod J 2004; 37: 167–73.
3. Dugas NN, Lawrence HP, Teplitsky PE, Pharoah MJ, Friedman S. Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. Int Endod J 2003; 36: 181–92.
4. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 1995; 28: 12–18.

5. Nair PN, Sjogren U, Krey G, Kahnberg KE, Sundqvist G. Intraradicular bacteria and fungi in root-filled, asymptomatic human teeth with therapy-resistant periapical lesions: a long-term light and electron microscopic follow-up study. J Endod 1990; 16: 580–8.
6. Bystrom A, Happonen RP, Sjogren U, Sundqvist G. Healing of periapical lesions of pulpless teeth after endodontic treatment with controlled asepsis. Endod Dent Traumatol 1987; 3: 58–63.
7. Sjogren U, Happonen RP, Kahnberg KE, Sundqvist G. Survival of Arachnia propionica in periapical tissue. Int Endod J 1988; 21: 277–82.
8. Sundqvist G, Reuterving CO. Isolation of Actinomyces israelii from periapical lesion. J Endod 1980; 6: 602–6.
9. Nair PN, Sjogren U, Krey G, Sundqvist G. Therapy-resistant foreign body giant cell granuloma at the periapex of a root-filled human tooth. J Endod 1990; 16: 589–95.
10. Yusuf H. The significance of the presence of foreign material periapically as a cause of failure of root treatment. Oral Surg Oral Med Oral Pathol 1982; 54: 566–74.
11. Nair PN, Sjogren U, Schumacher E, Sundqvist G. Radicular cyst affecting a root-filled human tooth: a long-term post-treatment follow-up. Int Endod J 1993; 26: 225–33.
12. Nair PN, Sjogren U, Figdor D, Sundqvist G. Persistent periapical radiolucencies of root-filled human teeth, failed endodontic treatments, and periapical scars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999; 87: 617–27.
13. Engstrom B, Frostell G. Experiences of Bacteriological root canal control. Acta Odontol Scand 1964; 22: 43–69.
14. Möller AJ. Microbiological examination of root canals and periapical tissues of human teeth. Methodological studies. Odontol Tidskr 1966; 74 (Suppl): 1–380.
15. Pinheiro ET, Gomes BP, Ferraz CC, Sousa EL, Teixeira FB, Souza-Filho FJ. Microorganisms from canals of root-filled teeth with periapical lesions. Int Endod J 2003; 36: 1–11.
16. Sundqvist G, Figdor D, Persson S, Sjogren U. Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998; 85: 86–93.
17. Molander A, Reit C, Dahlen G, Kvist T. Microbiological status of root-filled teeth with apical periodontitis. Int Endod J 1998; 31: 1–7.
18. Hancock HH 3rd, Sigurdsson A, Trope M, Moiseiwitsch J. Bacteria isolated after unsuccessful endodontic treatment in a North American population. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001; 91: 579–86.
19. Siqueira JF Jr, Rocas IN. Polymerase chain reaction-based analysis of microorganisms associated with failed endodontic treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004; 97: 85–94.
20. Siren EK, Haapasalo MP, Ranta K, Salmi P, Kerosuo EN. Microbiological findings and clinical treatment procedures in endodontic cases selected for microbiological investigation. Int Endod J 1997; 30: 91–5.
21. Adib V, Spratt D, Ng YL, Gulabivala K. Cultivable microbial flora associated with persistent periapical disease and coronal leakage after root canal treatment: a preliminary study. Int Endod J 2004; 37: 542–51.
22. Cheung GS, Ho MW. Microbial flora of root canal-treated teeth associated with asymptomatic periapical radiolucent lesions. Oral Microbiol Immunol 2001; 16: 332–7.
23. Peciuliene V, Balciuniene I, Eriksen HM, Haapasalo M. Isolation of Enterococcus faecalis in previously root-filled canals in a Lithuanian population. J Endod 2000; 26: 593–5.
24. Sjogren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Int Endod J 1997; 30: 297–306.
25. Siqueira JF Jr, Rocas IN, Souto R, de Uzeda M, Colombo AP. Actinomyces species, streptococci, and Enterococcus faecalis in primary root canal infections. J Endod 2002; 28: 168–72.
26. Tronstad L, Kreshtool D, Barnett F. Microbiological monitoring and results of treatment of extraradicular endodontic infection. Endod Dent Traumatol 1990; 6: 129–36.
27. Figdor D. Apical periodontitis: a very prevalent problem. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002; 94: 651–2.
28. Tronstad L, Barnett F, Riso K, Slots J. Extraradicular endodontic infections. Endod Dent Traumatol 1987; 3: 86–90.
29. Nair PN, Sjogren U, Sundqvist G. Cholesterol crystals as an etiological factor in non-resolving chronic inflammation: an experimental study in guinea pigs. Eur J Oral Sci 1998; 106: 644–50.
30. Simon M, Mullem PJ, Lamers AC. Formocresol: no allergic effect after root canal disinfection in non-presensitized guinea pigs. J Endod 1982; 8: 269–72.
31. Koppang HS, Koppang R, Solheim T, Aarnes H, Stolen SO. Cellulose fibers from endodontic paper points as an etiological factor in postendodontic periapical granulomas and cysts. J Endod 1989; 15: 369–72.
32. Bhaskar SN. Periapical lesions-types, incidence, and clinical features. Oral Surg Oral Med Oral Pathol 1966; 21: 657–71.
33. Priebe WA, Lazansky JP, Wuehrmann AH. The value of the roentgenographic film in the differential diagnosis of periapical lesions. Oral Surg Oral Med Oral Pathol 1954; 7: 979–83.
34. Lalonde ER, Luebke RG. The frequency and distribution of periapical cysts and granulomas. An evaluation of 800 specimens. Oral Surg Oral Med Oral Pathol 1968; 25: 861–8.
35. Nair PN, Pajarola G, Schroeder HE. Types and incidence of human periapical lesions obtained with extracted teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996; 81: 93–102.
36. Simon JH. Incidence of periapical cysts in relation to the root canal. J Endod 1980; 6: 845–8.

37. Madison S, Swanson K, Chiles SA. An evaluation of coronal microleakage in endodontically treated teeth. Part II. Sealer types. J Endod 1987; 13: 109–12.
38. Swanson K, Madison S. An evaluation of coronal microleakage in endodontically treated teeth. Part I. Time periods. J Endod 1987; 13: 56–9.
39. Byström A, Sundqvist G. Bacteriologic evaluation of the effect of 0.5 percent sodium hypochlorite in endodontic therapy. Oral Surg Oral Med Oral Pathol 1983; 55 (3): 307–12.
40. Bystrom A, Claesson R, Sundqvist G. The antibacterial effect of camphorated paramonochlorophenol, camphorated phenol and calcium hydroxide in the treatment of infected root canals. Endod Dent Traumatol 1985; 1 (5): 170–5.
41. Byström A, Sundqvist G. The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. Int Endod J 1985; 18: 35–40.
42. Heling I, Steinberg D, Kenig S, Gavrilovich I, Sela MN, Friedman M. Efficacy of a sustained-release device containing chlorhexidine and Ca(OH)2 in preventing secondary infection of dentinal tubules. Int Endod J 1992; 25: 20–4.
43. Ohara P, Torabinejad M, Kettering JD. Antibacterial effects of various endodontic medicaments on selected anaerobic bacteria. J Endod 1993; 19: 498–500.
44. Jeansonne MJ, White RR. A comparison of 2.0% chlorhexidine gluconate and 5.25% sodium hypochlorite as antimicrobial endodontic irrigants. J Endod 1994; 20: 276–8.
45. Gomes BP, Ferraz CC, Vianna ME, Berber VB, Teixeira FB, Souza-Filho FJ. In vitro antimicrobial activity of several concentrations of sodium hypochlorite and chlorhexidine gluconate in the elimination of Enterococcus faecalis. Int Endod J 2001; 34: 424–8.
46. Menezes MM, Valera MC, Jorge AO, Koga-Ito CY, Camargo CH, Mancini MN. In vitro evaluation of the effectiveness of irrigants and intracanal medicaments on microorganisms within root canals. Int Endod J 2004; 37: 311–19.
47. Waltimo TM, Ørstavik D, Siren EK, Haapasalo MP. In vitro susceptibility of Candida albicans to four disinfectants and their combinations. Int Endod J 1999; 32: 421–9.
48. Rosenthal S, Spangberg L, Safavi K. Chlorhexidine substantivity in root canal dentin. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004; 98: 488–92.
49. Vianna ME, Gomes BP, Berber VB, Zaia AA, Ferraz CC, de Souza-Filho FJ. In vitro evaluation of the antimicrobial activity of chlorhexidine and sodium hypochlorite. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004; 97: 79–84.
50. Tanomaru Filho M, Leonardo MR, da Silva L. A. Effect of irrigating solution and calcium hydroxide root canal dressing on the repair of apical and periapical tissues of teeth with periapical lesion. J Endod 2002; 28: 295–9.
51. Ferraz CC, Figueiredo de Almeida Gomes BP, Zaia AA, Teixeira FB, de Souza-Filho FJ. In vitro assessment of the antimicrobial action and the mechanical ability of chlorhexidine gel as an endodontic irrigant. J Endod 2001; 27: 452–5.
52. Vivacqua-Gomes N, Ferraz CC, Gomes BP, Zaia AA, Teixeira FB, Souza-Filho FJ. Influence of irrigants on the coronal microleakage of laterally condensed gutta-percha root fillings. Int Endod J 2002; 35: 791–5.
53. Okino LA, Siqueira EL, Santos M, Bombana AC, Figueiredo JA. Dissolution of pulp tissue by aqueous solution of chlorhexidine digluconate and chlorhexidine digluconate gel. Int Endod J 2004; 37: 38–41.
54. Tucker JW, Mizrahi S, Seltzer S. Scanning electron microscopic study of the efficacy of various irrigation solutions: urea, Tubulicid Red and Tubulicid Blue. J Endod 1976; 2: 71–8.
55. White RR, Hays GL, Janer LR. Residual antimicrobial activity after canal irrigation with chlorhexidine. J Endod 1997; 23: 229–31.
56. Kuruvilla JR, Kamath MP. Antimicrobial activity of 2.5% sodium hypochlorite and 0.2% chlorhexidine gluconate separately and combined, as endodontic irrigants. J Endod 1998; 24: 472–6.
57. Zamany A, Safavi K, Spangberg LS. The effect of chlorhexidine as an endodontic disinfectant. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003; 96: 578–81.
58. Estrela C, Bammann LL, Pimenta FC, Pecora JD. Control of microorganisms in vitro by calcium hydroxide pastes. Int Endod J 2001; 34: 341–5.
59. Zehnder M, Grawehr M, Hasselgren G, Waltimo T. Tissue-dissolution capacity and dentin-disinfecting potential of calcium hydroxide mixed with irrigating solutions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003; 96: 608–13.
60. Gomes BP, Souza SF, Ferraz CC et al. Effectiveness of 2% chlorhexidine gel and calcium hydroxide against Enterococcus faecalis in bovine root dentine in vitro. Int Endod J 2003; 36: 267–75.
61. Barbosa SV, Spangberg LS, Almeida D. Low surface tension calcium hydroxide solution is an effective antiseptic. Int Endod J 1994; 27: 6–10.
62. Rolla G, Melsen B. On the mechanism of the plaque inhibition by chlorhexidine. J Dent Res 1975; 54 (Spec No B): B57–62.
63. Haenni S, Schmidlin PR, Mueller B, Sener B, Zehnder M. Chemical and antimicrobial properties of calcium hydroxide mixed with irrigating solutions. Int Endod J 2003; 36: 100–5.
64. Basrani B, Santos JM, Tjaderhane L et al. Substantive antimicrobial activity in chlorhexidine-treated human root dentin. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002; 94: 240–5.

65. Schafer E, Bossmann K. Antimicrobial efficacy of chlorhexidine and two calcium hydroxide formulations against Enterococcus faecalis. J Endod 2005; 31: 53–6.
66. Safavi KE, Spangberg LS, Langeland K. Root canal dentinal tubule disinfection. J Endod 1990; 16: 207–10.
67. Peciuliene V, Reynaud AH, Balciuniene I, Haapasalo M. Isolation of yeasts and enteric bacteria in root-filled teeth with chronic apical periodontitis. Int Endod J 2001; 34: 429–34.
68. Cwikla SJ, Belanger M, Giguere S, Progulske-Fox A, Vertucci FJ. Dentinal tubule disinfection using three calcium hydroxide formulations. J Endod 2005; 31: 50–2.
69. Shabahang S, Torabinejad M.Effect of MTAD on Enterococcus faecalis-contaminated root canals of extracted human teeth. J Endod 2003; 29: 576–9.
70. Torabinejad M, Shabahang S, Aprecio RM, Kettering JD. The antimicrobial effect of MTAD: an in vitro investigation. J Endod 2003; 29: 400–3.
71. Torabinejad M, Cho Y, Khademi AA, Bakland LK, Shabahang S. The effect of various concentrations of sodium hypochlorite on the ability of MTAD to remove the smear layer. J Endod 2003; 29: 233–9.
72. Schafer E, Lohmann D. Efficiency of rotary nickel-titanium FlexMaster instruments compared with stainless steel hand K-Flexofile – Part 1. Shaping ability in simulated curved canals. Int Endod J 2002; 35: 505–13.
73. Schafer E, Lohmannm D. Efficiency of rotary nickel-titanium FlexMaster instruments compared with stainless steel hand K-Flexofile – Part 2. Cleaning effectiveness and instrumentation results in severely curved root canals of extracted teeth. Int Endod J 2002; 35: 514–21.
74. De Rossi A, Silva LA, Leonardo MR, Rocha LB, Rossi MA. Effect of rotary or manual instrumentation, with or without a calcium hydroxide/1% chlorhexidine intracanal dressing, on the healing of experimentally induced chronic periapical lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005; 99: 628–36.
75. Dalton BC, Ørstavik D, Phillips C, Pettiette M, Trope M. Bacterial reduction with nickel-titanium rotary instrumentation. J Endod 1998; 24: 763–7.
76. Shuping GB, Ørstavik D, Sigurdsson A, Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. J Endod 2000; 26: 751–5.
77. American Dental Association ADA Policy on Evidence-based Dentistry. Available from URL: http://www.ada.org/prof/resources/positions/statements/evidencebased.asp
78. Paik S, Sechrist C, Torabinejad M. Levels of evidence for the outcome of endodontic retreatment. J Endod 2004; 30: 745–50.
79. Farzaneh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phases I and II: orthograde retreatment. J Endod 2004; 30: 627–33.
80. Karoussis IK, Bragger U, Salvi GE, Burgin W, Lang NP. Effect of implant design on survival and success rates of titanium oral implants: a 10-year prospective cohort study of the ITI Dental Implant System. Clin Oral Implants Res 2004; 15: 8–17.
81. Adell R, Lekholm U, Rockler B, Branemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981; 10: 387–416.
82. Gorni FG, Gagliani MM. The outcome of endodontic retreatment: a 2-yr follow-up. J Endod 2004; 30: 1–4.
83. Bergenholtz G, Lekholm U, Milthon R, Engstrom B. Influence of apical overinstrumentation and overfilling on re-treated root canals. J Endod 1979; 5: 310–14.
84. Chugal NM, Clive JM, Spangberg LS. A prognostic model for assessment of the outcome of endodontic treatment: effect of biologic and diagnostic variables. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001; 91: 342–52.
85. Fristad I, Molven O, Halse A. Nonsurgically retreated root filled teeth – radiographic findings after 20–27 years. Int Endod J 2004; 37: 12–18.
86. Molven O, Halse A, Fristad I, MacDonald-Jankowski D. Periapical changes following root-canal treatment observed 20–27 years postoperatively. Int Endod J 2002; 35: 784–90.
87. Siqueira JF Jr, De Uzeda M, Fonseca ME. A scanning electron microscopic evaluation of in vitro dentinal tubules penetration by selected anaerobic bacteria. J Endod 1996; 22: 308–10.
88. Lin LM, Skribner JE, Gaengler P. Factors associated with endodontic treatment failures. J Endod 1992; 18: 625–7.
89. Vier FV, Figueiredo JA. Internal apical resorption and its correlation with the type of apical lesion. Int Endod J 2004; 37: 730–7.
90. Kim S. Principles of endodontic microsurgery. Dent Clin North Am 1997; 41: 481–97.
91. Pecora G, Andreana S. Use of dental operating microscope in endodontic surgery. Oral Surg Oral Med Oral Pathol 1993; 75: 751–8.
92. Gray GJ, Hatton JF, Holtzmann DJ, Jenkins DB, Nielsen CJ. Quality of root-end preparations using ultrasonic and rotary instrumentation in cadavers. J Endod 2000; 26: 281–3.
93. Adamo HL, Buruiana R, Schertzer L, Boylan RJ. A comparison of MTA, Super-EBA, composite and amalgam as root-end filling materials using a bacterial microleakage model. Int Endod J 1999; 32: 197–203.
94. Rud J, Rud V, Munksgaard EC. Periapical healing of mandibular molars after root-end sealing with dentine-bonded composite. Int Endod J 2001; 34: 285–92.
95. Kim S. Color atlas of microsurgery in endodontics. New York: W.B. Saunders; 2001.
96. Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. J Endod 1995; 21: 349–53.

97. Torabinejad M, Smith PW, Kettering JD, Pitt Ford TR. Comparative investigation of marginal adaptation of mineral trioxide aggregate and other commonly used root-end filling materials. J Endod 1995; 21: 295–9.
98. Torabinejad M, Pitt Ford TR, McKendry DJ, Abedi HR, Miller DA, Kariyawasam SP. Histologic assessment of mineral trioxide aggregate as a root-end filling in monkeys. J Endod 1997; 23: 225–8.
99. 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 2003; 36: 520–6.
100. Yaltirik M, Ozbas H, Bilgic B, Issever H. Reactions of connective tissue to mineral trioxide aggregate and amalgam. J Endod 2004; 30: 95–9.
101. Regan JD, Gutmann JL, Witherspoon DE. Comparison of Diaket and MTA when used as root-end filling materials to support regeneration of the periradicular tissues. Int Endod J 2002; 35: 840–7.
102. Economides N, Pantelidou O, Kokkas A, Tziafas D. Short-term periradicular tissue response to mineral trioxide aggregate (MTA) as root-end filling material. Int Endod J 2003; 36: 44–8.
103. Torabinejad M, Hong CU, Pitt Ford TR, Kettering JD. Antibacterial effects of some root-end filling materials. J Endod 1995; 21: 403–6.
104. Apaydin ES, Shabahang S, Torabinejad M. Hard-tissue healing after application of fresh or set MTA as root-end-filling material. J Endod 2004; 30: 21–4.
105. Mead C, Javidan-Nejad S, Mego ME, Nash B, Torabinejad M. Levels of evidence for the outcome of endodontic surgery. J Endod 2005; 31: 19–24.
106. Molven O, Halse A, Grung B. Surgical management of endodontic failures: indications and treatment results. Int Dent J 1991; 41: 33–42.
107. Jansson L, Sandstedt P, Laftman AC, Skoglund A. Relationship between apical and marginal healing in periradicular surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997; 83: 596–601.
108. Kvist T, Reit C. Results of endodontic retreatment: a randomized clinical study comparing surgical and nonsurgical procedures. J Endod 1999; 25: 814–17.
109. Zuolo ML, Ferreira MO, Gutmann JL. Prognosis in periradicular surgery: a clinical prospective study. Int Endod J 2000; 33: 91–8.
110. Rahbaran S, Gilthorpe MS, Harrison SD, Gulabivala K. Comparison of clinical outcome of periapical surgery in endodontic and oral surgery units of a teaching dental hospital: a retrospective study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001; 91: 700–9.
111. Wang N, Knight K, Dao T, Friedman S. Treatment outcome in endodontics-The Toronto Study. Phases I and II: apical surgery. J Endod 2004; 30: 751–61.
112. Hirsch JM, Ahlstrom U, Henrikson PA, Heyden G, Peterson LE. Periapical surgery. Int J Oral Surg 1979; 8: 173–85.
113. Friedman S, Lustmann J, Shaharabany V. Treatment results of apical surgery in premolar and molar teeth. J Endod 1991; 17: 30–3.
114. Rapp EL, Brown CE Jr, Newton CW. An analysis of success and failure of apicoectomies. J Endod 1991; 17: 508–12.
115. August DS.Long-term, postsurgical results on teeth with periapical radiolucencies. J Endod 1996; 22: 380–3.
116. Grung B, Molven O, Halse A. Periapical surgery in a Norwegian county hospital: follow-up findings of 477 teeth. J Endod 1990; 16: 411–17.
117. Lustmann J, Friedman S, Shaharabany V. Relation of pre- and intraoperative factors to prognosis of posterior apical surgery. J Endod 1991; 17: 239–41.
118. Rud J, Andreasen JO, Jensen JF. A multivariate analysis of the influence of various factors upon healing after endodontic surgery. Int J Oral Surg 1972; 1: 258–71.
119. Ericson S, Finne K, Persson G. Results of apicoectomy of maxillary canines, premolars and molars with special reference to oroantral communication as a prognostic factor. Int J Oral Surg 1974; 3: 386–93.
120. Rud J, Munksgaard EC, Andreasen JO, Rud V. Retrograde root filling with composite and a dentin-bonding agent 2. Endod Dent Traumatol 1991; 7: 126–31.
121. Finne K, Nord PG, Persson G, Lennartsson B. Retrograde root filling with amalgam and Cavit. Oral Surg Oral Med Oral Pathol 1977; 43: 621–6.
122. 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 1985; 59: 78–81.
123. Mikkonen M, Kullaa Mikkonen A, Kotilainen R. Clinical and radiologic re-examination of apicoectomized teeth. Oral Surg Oral Med Oral Pathol 1983; 55: 302–6.
124. Frank AL, Glick DH, Patterson SS, Weine FS. Long-term evaluation of surgically placed amalgam fillings. J Endod 1992; 18: 391–8.
125. Danin J, Stromberg T, Forsgren H, Linder LE, Ramskold LO. Clinical management of nonhealing periradicular pathosis. Surgery versus endodontic retreatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996; 82: 213–17.
126. Maddalone M, Gagliani M. Periapical endodontic surgery: a 3-year follow-up study. Int Endod J 2003; 36: 193–8.
127. Rubinstein RA, Kim S. Long-term follow-up of cases considered healed one year after apical microsurgery. J Endod 2002; 28: 378–83.
128. von Arx T, Gerber C, Hardt N. Periradicular surgery of molars: a prospective clinical study with a one-year follow-up. Int Endod J 2001; 34: 520–5.
129. Friedman S. Management of post-treatment endodontic disease: a current concept of case selection. Aust Endod J 2000; 26: 104–9.