Retrospective Analysis of Open Apex Teeth Obturated with Mineral Trioxide Aggregate

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Abstract

This study is a retrospective analysis of the outcome of initial nonsurgical root canal treatment of teeth with open apices, obturated with mineral trioxide aggregate when no apical barrier existed. One hundred sixteen patients from a single private endodontic office were treated between 1999 and 2006. Treatments on 144 teeth were completed either in one (92/144) or two visits with an interim calcium hydroxide interappointment medication (52/144). Fifty-four percent (78/144) of the teeth were available for recall (60.3% one visit and 39.7% two visits). The maximum time to recall was 4.87 years. The mean time to recall was 19.4 months. Of the cases recalled for period of 1 year or longer, 93.5% of teeth treated in 1 visit healed, and 90.5% of teeth treated in 2 visits healed. *(J Endod 2008;34: 1171–1176)*

Key Words

Apexification, mineral trioxide aggregate, obturation, open apex

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Apexification has traditionally formed an integral part of the treatment of teeth with necrotic pulps with open apices. Apexification is defined as "a method of inducing a calcified barrier in a root with an open apex or the continued apical development of an incompletely formed root in teeth with necrotic pulp" (1). One aim of an apexification procedure is to establish a root canal space that can be successfully obturated. Numerous procedures and materials have been recommended to facilitate this by inducing root-end barrier formation. These include no treatment (2), infection control (3), induction of a blood clot in the periradicular tissues (4), antibiotic pastes (5), and calcium hydroxide mixed with various materials (6).

Historically, calcium hydroxide has been the material of choice used to induce the formation of an apical hard tissue barrier before placing a long-term root filling. Granath (7) (1959) was the first to describe the use of calcium hydroxide for apical closure. Before this, nonvital immature teeth were often extracted (8). Frank (6) (1966) popularized the technique in which the canals are debrided and packed with a paste made by mixing calcium hydroxide with camphorated *p*-chlorophenol. The Frank technique required the replacement of the calcium hydroxide paste every 3 months until a barrier formed. This could take up to 24 months (6, 9). Many studies have reported favorable outcomes when calcium hydroxide is used alone or in combination with other materials (10–17).

However, despite a long history of use in apical closure procedures, there are several problems relating to the use of calcium hydroxide for apexification. These include the long time required for root apices to close, the number of "dressings" necessary to complete closure, the role of infection, and the fracture resistance of teeth after the long-term application of calcium hydroxide. Depending on the study, barrier formation is reported to take anywhere from 3–24 months (6, 9). These studies also vary in the number of recommended reapplications of calcium hydroxide. Changes of the dressing material at 1 month and then 3 months or 1 month and 6-8 months have been suggested until apical barrier formation takes place (14, 18–21). The role of infection is also not universally agreed on. Some studies report an increase in the time for apexification when infection is present (12, 17), and others have demonstrated no statistically significant differences (22–24). Cvek (25) (1992) noted that immature teeth are weakened by filling of the root canals with a calcium hydroxide dressing and a subsequent gutta-percha obturation. Subsequently, the long-term application of intracanal calcium hydroxide has been shown to decrease the fracture resistance of open apex teeth (26–29). The results indicate that the fracture strength of calcium hydroxide–filled immature teeth will be halved in a year (26–29). In addition to these difficulties, poor patient compliance has been shown to have a negative influence on outcomes of traditional apexification procedures (30).

Recently an alternative material, mineral trioxide aggregate (MTA), has been introduced. MTA is composed of dicalcium and tricalcium silicate, tricalcium silicate, bismuth oxide, and calcium sulfate. Hydration of the powder results in a fine crystalline gel. This solidifies to a hard structure in less than 3 hours (31). It has a compressive strength equal to intermediate restorative material (IRM) and Super-EBA but less than that of amalgam. It is commercially available as ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK) and has been advocated for use in the immediate obturation of open apex teeth (32–40). MTA has the ability to induce cementum-like hard tissue when used adjacent to the periradicular tissues (33, 41–44). MTA is a promising material as a

result of its superior sealing property, its ability to set up in the presence of blood, and its biocompatibility (44–50). Moisture contamination at the apex of the tooth before barrier formation is often a problem with other materials typically used in apexification. As a result of MTA's hydrophilic property, the presence of moisture, specifically blood, does not affect its sealing ability (45). Because of the encouraging results reported for MTA when used as a root-end filling material (45, 46, 50), investigation of its use as an apexification material is warranted.

Shabahang et al. (33) examined hard tissue formation and inflammation histomorphologically after treating open apices in canine teeth with osteogenic protein-1, MTA, and calcium hydroxide. MTA induced hard tissue formation with the most consistency, but the amount of hard tissue formation and inflammation was not statistically different among the 3 materials. The tissue response to MTA used under the same conditions, however, has yet to be characterized at the molecular level. Because the histologic response to calcium hydroxide has been highly variable and described in terms such as osteodentin, osteocementum, or cementum, the response of the periradicular tissues and cells to the material placed at the root end is unpredictable. MTA has demonstrated the ability to stimulate cells to differentiate into hard tissue–forming cells and to produce a hard tissue matrix. The use of MTA to obturate open apex teeth has shown a greater degree of hard tissue formation when compared with calcium hydroxide. A number of animal studies have demonstrated a more predictable healing outcome when MTA is used to obturate open apex teeth when compared with teeth treated with calcium hydroxide (33, 51, 52). In a human outcome study that compared the clinical and radiographic results of apexification with either MTA or calcium hydroxide, all the cases obturated with MTA were successful at the 12-month recall, whereas 2 of the15 calcium hydroxide cases had persistent disease (38). In a prospective human outcome study, 57 teeth with open apices were obturated with MTA in one appointment. Forty-three of these cases were available for recall at 12 months, of which 81% of cases were classified as healed (39).

It would appear that MTA has several advantages when compared with the combination of calcium hydroxide–induced apical closure followed by compacted gutta-percha. These are (1) a reduction in treatment time, thereby facilitating the timely restoration of the tooth; (2) the tooth is less likely to fracture; and (3) the patient requires fewer visits to the dental office.

The purpose of this article is to report on the clinical and radiographic outcome when MTA is used to obturate teeth with open apices.

Material and Methods

All patients were treated in a specialist endodontic private practice setting. All authors provided treatment. There were no contraindications to dental treatment for any of the patients. All radiographs were taken by using the DEXIS digital radiographic system (Alpharetta, GA) in accordance with the manufacturer's recommendations. Pulpal vitality tests were performed to establish a pulpal diagnosis.

TABLE 1. Distribution of Tooth Type

Tooth Type	No. of Teeth
Maxillary molars	3
Maxillary premolars	3
Maxillary canines	1
Maxillary anterior	113
Mandibular molars	13
Mandibular premolars	7
Mandibular canines	1
Mandibular anterior	2

TABLE 2. Patient Demographics

Sex demographics	
Male	84
Female	60
Age demographics (y)	
Range	7.5–68.9
Average	18.6
Mode	13.0
Median	13.0

The teeth were treated in either 1 or 2 visits. A tooth was treated in 2 visits if the periradicular drainage through the canal could not be controlled, or if external root resorption was present.

One Visit Treatment

Treatment followed a standard nonsurgical root canal treatment protocol. After local anesthesia, rubber dam was applied. The root canal systems were accessed; the canals were cleaned and shaped by using nickel-titanium rotary instruments with 6% sodium hypochlorite as the irrigant. At the completion of cleaning and shaping, the smear layer was then removed by using a combination of 17% ethylenediaminetetraacetic acid (EDTA) and 6% sodium hypochlorite. All canals received a final flush of 2% chlorhexidine before obturation. The canals were dried with paper points.

Two Visit Treatment

The treatment procedure for teeth treated in 2 visits was essentially the same as for 1 visit, with the exception that calcium hydroxide paste was used as an interappointment intracanal medicament. Injectable calcium hydroxide paste (UltraCal, South Jordan, UT) was delivered to the entire length of the root canal system; the teeth were temporized by using a cotton pellet and IRM. The patients were then scheduled for obturation of the root canal system approximately 3 weeks later. At the second appointment the calcium hydroxide was removed from the canal by using a combination of rotary files and irrigation with 17% EDTA and 6% sodium hypochlorite. All canals received a final flush of 2% chlorhexidine before obturation. The canals were dried with paper points.

Obturation

Once the root canal systems were dried, a series of pluggers were prefitted so that the smallest plugger fit loosely ~1 mm from the working length. MTA was placed in the middle to apical third of the root canal system by using an MTA gun (MAP System; Roydent Dental Products, Johnson City, TN) and compacted by using ultrasonically vibrated pluggers to encourage compaction and flow of MTA to the apex. Once the MTA layer was adequately compacted to working length and confirmed with a radiograph, the excess was removed from the coronal third of the canal system by irrigating with sterile water, and the remaining fluid was removed with paper points. The remainder of the canal system was restored with a bonded composite material applied directly to the MTA (53). The composite layer was placed into the coronal third of the canal and access cavity. A final radiograph was exposed after removal of the rubber dam.

Recall intervals were set at approximately 6 months, with all cases being followed for as long as possible. At the recall visit a subjective history was ascertained. Percussion, palpation, and radiographic evaluation were performed. All radiographs were viewed on a single 20-inch high-resolution monitor. All radiographs were initially assessed by

TABLE 3. Results for All Teeth Recalled

Treatment	No. of Teeth Treated	No. of Teeth Recalled	Healed	Healing	Persistent Disease	Treatment Not Completed
All teeth	144	78	59	13	2	4
One visit	92	47	36	10	1	0
Two visits	52	31	23	3	1	4

one endodontist and rated accorded to the categories outlined below. The examiner was blinded to the operator. If the recall category was unclear, cases were then examined in consultation with 2 other endodontists, and the outcome category was established through consensus (54, 55).

Cases were categorized as healed, healing, or persistent disease. The criteria for healed were (1) no history of pain, discomfort, or altered sensation; and (2) radiographic appearance of normal periodontal ligament space ($\leq$2 times normal width) and lamina dura. The criteria for healing were (1) no history of pain, discomfort, or altered sensation; and (2) a decrease in the size of a radiolucency that was previously present, but the appearance of the periodontal ligament space and lamina dura is not within normal limits. The criteria for persistent disease were (1) a history of pain, discomfort, or altered sensation; and (2) an increase or no decrease in the size of a radiolucency that was previously present.

Statistical Analysis

To evaluate the effect of the presence of a periapical lesion on probability of treatment success and the effect of treatment with 2 visits versus 1 visit on probability of treatment success, multivariate survival analysis with the marginal method was used.

Results

One hundred forty-four teeth in 116 patients were treated as outlined above between 1999 and 2006. Ninety-two of the teeth were treated in 1 visit, and 52 of the teeth were treated in 2 visits. The distribution by tooth types is shown in Table 1. Patient demographics are shown in Table 2. Seventy-eight of the 144 teeth (54.2%) in 63 patients were available for recall (Tables 3 and 4). The mean age of patients recalled for this study was 18.6 years (standard deviation, 15.1; median, 13.0 years; range, 7.5–68.9 years). In the study 62.3% of teeth (48/77) had a periapical lesion, and 60.3% of teeth (47/78) were treated in 1 visit, whereas 39.7% (31/78) were treated in 2 visits, and 7.7% of treated teeth (6/78) had persistent disease. The results of the multivariate survival analysis evaluating the effect of the presence of a periapical lesion and the number of treatment visits are shown in Table 5. The probability of tooth survival for differing number of treatment visits and when a periradicular lesion was present, as predicted by Kaplan-Meier statistical analyses, is shown in Figs. 1 and 2, respectively.

Fifty-two of the 78 teeth (66.7%) had at least a 1-year recall. Forty-eight of 52 teeth (92.3%) that had a postoperative recall period of 1 year or longer were healed. Three of 52 (5.8 %) teeth were healing, and 1 (1.9%) had persistent disease. Four of the 78 cases (5.1%) returned when the teeth became symptomatic, and in all these cases the teeth had to be extracted. The maximum time to recall was 4.87 years. The mean time of recall was 19.4 months.

One Visit

Forty-seven of the 92 teeth (51%) treated in 1 visit were available for recall. Of these, 36 (76.6%) were healed (Fig. 3), 10 (21.3%) were healing, and 1 of the 47 teeth (2.1%) was considered to have persistent disease. Thirty-one of 47 teeth had a recall period of 1 year or longer. Twenty-nine of these 31 teeth (93.5%) were classified as healed; the remaining 2 (6.5%) were considered to be healing (Tables 3 and 4).

Two Visits

Thirty-one of the 52 teeth (61.5%) treated in 2 visits were available for recall. Of these, 23 (74.2%) were healed (Fig. 4), 3 of 31 teeth (9.7%) were healing, and 1 of 31 teeth (3.2%) was considered to have persistent disease. Four of the 31 returned to have treatment completed only when the teeth became symptomatic. The time lapse between the initial visit and when these patients returned to complete treatment ranged from 1.25–6.36 years. In all 4 of these cases, the teeth had to be extracted.

Twenty-one of 31 teeth had a recall period of 1 year or longer. Nineteen of these 21 teeth (90.5%) were classified as healed. Of the remaining 2 cases, 1 (4.8%) was considered to be healing, and the other (4.8%) had persistent disease (ankylosis) (Tables 3 and 4).

Discussion

The primary objective of nonsurgical root canal therapy in teeth with incomplete root formation is long-term tooth retention. The traditional approach of using calcium hydroxide to facilitate obturation of the root canal space has provided a high degree of success (11, 15, 16, 18, 22, 36, 56–59). There are, however, several disadvantages to this treatment modality. Any treatment requiring several visits during a long period of time risks patient attrition as a result of patient fatigue and geographic relocation. If a child moves away during the course of treatment, it is difficult to ensure that the integrity of the coronal seal is maintained, and that the treatment is completed. Likewise, patient compliance can be a problem when multiple visits are necessary (30). Repeated visits to the dentist can be disruptive and difficult in a busy schedule for both the parent and child. In addition, these appointments are easily forgotten because the patient usually remains asymptomatic, and the tooth looks clinically normal. Another problem avoided by a

TABLE 4. Results for Recalled Teeth with a 1-year or Longer Follow-up

Treatment	No. of Teeth with 1 y+ Recall	Healed	Healing	Persistent Disease
All teeth	52	48	3	1
One visit	31	29	2	0
Two visits	21	19	1	1

TABLE 5. Hazard Ratios for Periapical Lesion and Number of Treatment Visits

	Hazard Ratio	95% Confidence Interval	*P* Value
Periapical lesion			
Absent	1.00	—	
Present	0.67	0.13–3.45	.635
Treatment visits			
1	1.00	—	
2	6.32	0.69–57.7	.103

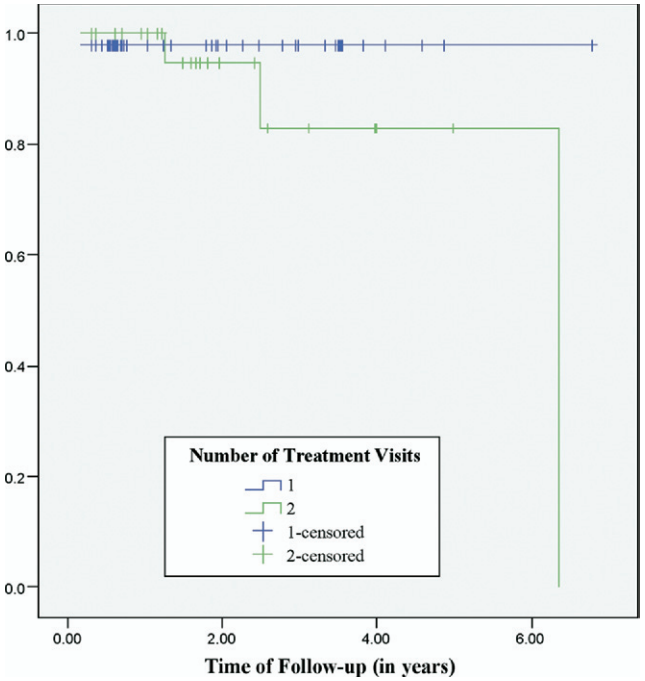

Figure 1. Probability of tooth survival; number of treatment visits.

single-visit procedure with MTA is that of subjecting an unwilling child to multiple treatment visits that might be very unpleasant for the patient. Many children who fear trips to the dentist are even more traumatized by repeated visits (60–63). The younger the child, the worse this response might be, and these are frequently the very patients with wide apices that require a greater number of treatments (64). The long-term application of calcium hydroxide has been shown to weaken the tooth and increase the likelihood of tooth fracture (25–29). Thus, a treatment alternative that has a higher rate of long-term success, avoids the use of extended

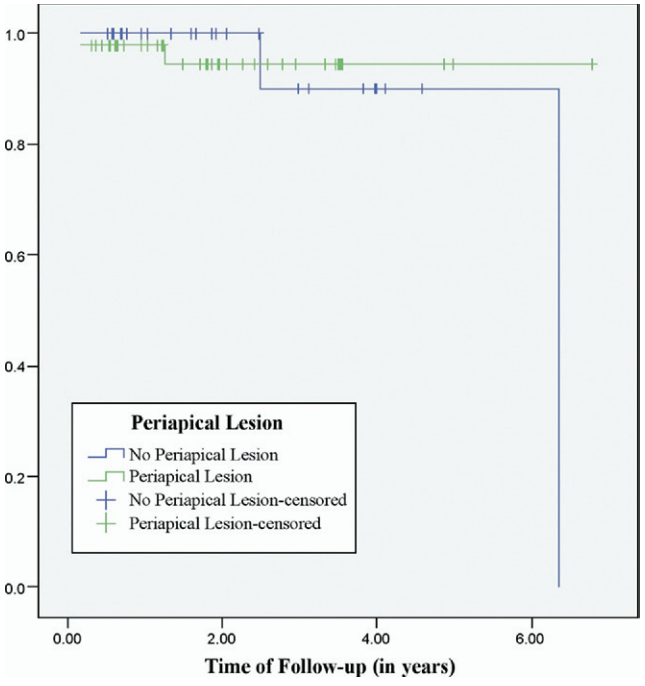

Figure 2. Probability of tooth survival; periapical lesion.

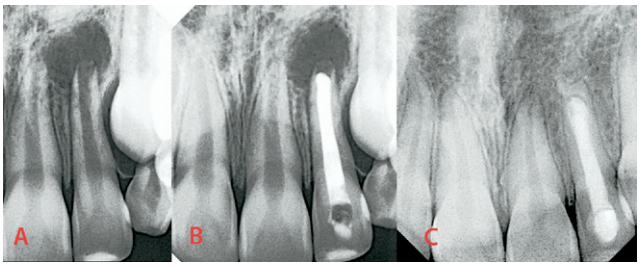

Figure 3. Representative example of a case treated in 1 visit. (*A*) Preoperative radiograph; (*B*) immediate postoperative radiograph; (*C*) 4-year recall radiograph showing completely healed periapical tissues.

applications of calcium hydroxide, and minimizes the number of patient visits would be a desirable alternative. MTA obturation of teeth with open apices avoids many of the problems associated with traditional apexification procedures. MTA is a viable option and should be considered as a good alternative.

In addition, in in vitro leakage studies (65–67) MTA has been shown to resist leakage to a greater degree than the traditional obturating materials of gutta-percha and sealer. In short-term animal studies, MTA consistently induced the formation of cementum with a high degree of structural integrity and more complete periradicular architecture. Histologically, MTA is considerably better at stimulating reparative periradicular periodontal tissues (33, 51, 52).

In an outcome assessment of calcium hydroxide in apexification treatment, success rates ranged from 79%–96% (25, 68). In human outcomes studies of open apex teeth, MTA demonstrated healed rates that ranged from 81%–100% (38, 39, 69). Compared directly with the calcium hydroxide technique, there is less persistent disease (38). In this study the healed rate at the 1-year or longer recall time period was 93.5% for 1 appointment and 90.5% for 2 appointments, and the healing rate at the 1-year or longer recall time period was 6.5% for 1 appointment and 4.8% for 2 appointments. At the 1-year or longer recall period of cases that had treatment completed either in 1 or 2 visits, the rate of persistent disease was 1 case in 52 or 1.9%. In addition, all cases that were initially observed to be healing at shorter recall times (less than 1 year) were subsequently observed to undergo complete healing at later recalls. Furthermore, a high rate of success was observed in both 1- and 2-appointment treatments, regardless of whether a periradicular lesion was present.

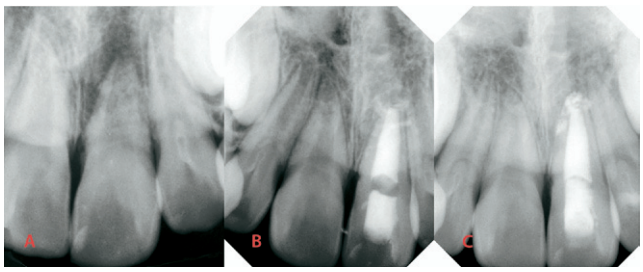

Figure 4. Representative example of a case treated in 2 visits. (*A*) Preoperative radiograph; (*B*) immediate postoperative radiograph; (*C*) 4-year recall radiograph showing completely healed periapical tissues.

Conclusion

MTA obturation of canals with open apices is a viable alternative to the use of calcium hydroxide to induce apical closure.

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