Comparative Evaluation of Endodontic Management of Teeth With Unformed Apices With Mineral Trioxide Aggregate and Calcium Hydroxide

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ABSTRACT

Purpose: The purpose of this study was to compare mineral trioxide aggregate (MTA) and calcium hydroxide ($Ca(OH)_2$) for their efficacies and time taken for formation of apical biological calcific barriers and resolution of periapical radiolucencies, if present at baseline, in teeth with unformed apices.

Methods: Twenty nonvital permanent maxillary incisors with unformed apices, stratified according to the size of periapical radiolucencies and stage of root development, were equally allocated to MTA and $Ca(OH)_2$ groups. In group 1 (MTA group), after 7 days of disinfection with $Ca(OH)_2$, MTA was packed into the apical one third of the root canals and obturation with gutta percha (GP) was performed in 90% (9/10) of cases within 15 to 30 days. In group 2 ($Ca(OH)_2$ group), obturation was performed following clinical and radiographic depiction of the apical stop.

Results: The mean time taken for apical biological barrier formation was 3±2.9 months for group 1 and 7±2.5 months for group 2 (*P*=.008). The periapical radiolucencies were resolved in 4.6±1.5 months for group 1 and 4.4±1.3 months for group 2 (*P*=.83). The total treatment was completed in 0.75±0.4859 months and 7±2.5 months for groups 1 and 2, respectively.

Conclusion: The 2 materials were found to be equally efficacious in the management of nonvital teeth with unformed apices. Time taken to complete the treatment and the biological barrier formation in group 1 was significantly less than that for group 2. The healing time for periapical radiolucencies was almost identical. (J Dent Child 2006;73:79-85)

KEYWORDS: MTA, CALCIUM HYDROXIDE, APEXIFICATION, BIOLOGICAL BARRIER, APICAL CALCIFIC STOP

Traumatic injuries in children involving young permanent teeth may, at times, result in devitalization of the pulp with concomitant arrest in further development of the immature roots of the involved teeth.[1-3] In such teeth, due to the lack of an apical constriction, hermetic seal of the root canal system during obturation is not possible. For such cases, the management technique has been apexification involving induction of a calcific barrier at the apex, with calcium hydroxide root canal dressings, which facilitate obturation of the root canal.[4,5]

The root end closure procedure using calcium hydroxide ($Ca(OH)_2$) is standardized but time consuming, requiring, on an average, 7 to 8 months[4,5] for apical bridge formation. Associated with long treatment time is the uncertainty of patients returning for follow-up, thus increasing the risk of failure in the management of these teeth.

An alternative to apexification with calcium hydroxide, which leads to a biological barrier at apex, is the creation of

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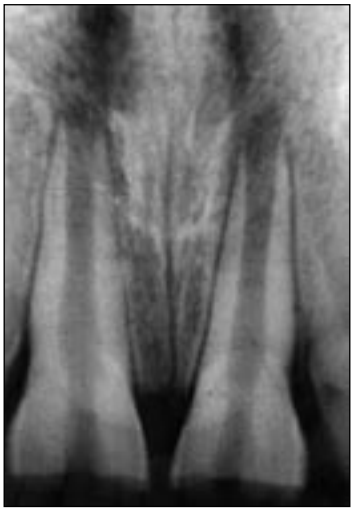

Figure 1. Preoperative views of maxillary right and left central incisors showing unformed apices.

an artificial apical barrier that enables immediate obturation of the root canal. For this purpose, various materials like Super-EBA, IRM, osteogenic protein-I, silver amalgam, and mineral trioxide (MTA) have been tried.[6,7] In an in vitro study,[6] evaluating the microleakage of the aforementioned materials, only MTA was found to prevent microleakage effectively. Introduced in 1993,[8] MTA has been reported to be a potential apical barrier material with good sealing ability,[9,10] and a high degree of biocompatibility.[11,12] Because of its alkaline pH of 12.5 and the presence of several mineral oxides in its composition,[8] it has been shown to possess antimicrobial properties.[13] It sets to a hard consistency about 4 hours after mixing and insertion, thus allowing early completion of final obturation of the root canal when used for apexification. To the best of the authors' knowledge, however, there are only a few case reports[8,14-22] on successful use of MTA for obtaining an artificial apical barrier in humans, with the longest follow-up being 20 months.[8] There is, as yet, no reported controlled longitudinal clinical trial on evaluation of MTA's role in achieving artificial root end closure and subsequent early obturation of root canals in humans.

The present investigation was planned to evaluate and compare calcium hydroxide and MTA with respect to:

1. their efficacies and time taken for the formation of an apical biological barrier;
2. resolution of periapical radiolucency if present at baseline; and
3. total time taken for completion of this treatment.

METHODS

The present study was reviewed and approved by the Departmental Human Studies Committee, Oral Health Sciences Centre, Postgraduate Institute of Medical Education and Research, Chandigarh, India The procedures, possible discomforts, and benefits were explained to the parents of the pediatric patients, and their informed consent was obtained prior to initiation of the study. Twenty nonvital, immature, permanent maxillary incisors with unformed apices (19 central incisors and 1 lateral incisor), with/without periapical infection, with minimum or no mobility, and adequate bone support involving 16 8- to 15-year-old children were selected from among those seeking treatment for traumatically injured anterior teeth at the Department of Pedodontics and Preventive Dentistry, Postgraduate Institute of Medical Education and Research, Chandigarh, India (example, Figure 1).

In 16 out of 20 teeth, the crowns were found to be fractured (Ellis Class III), the duration of exposure ranging from 2 to 24 months. In addition, 2 teeth presented with periapical sinus and another 2 were found to be discolored. The history of trauma to these teeth was positive in all cases. Radiographic examination revealed a presence of periapical radiolucencies in 11 out of 20 selected teeth. The size of the periapical radiolucency was recorded in millimeters at the maximum horizontal or vertical distance and graded as:

1. line radiolucency – an apparent widening of the periodontal ligament;
2. small – 0.1 to 1.9 mm;
3. medium – 2 to 3 mm;
4. large – more than 3 mm.

The 20 incisors selected were stratified according to presence/absence and size of periapical radiolucency and Nolla's stage of root development, followed by alternate distribution to: (1) experimental (MTA); or (2) control (calcium hydroxide) group. Each group comprised 10 teeth with matched radiological features.

All the patients were treated by the chief investigator (PDP), who was standardized by the chief supervisor (CHS) who has approximately 30 years experience in the field of apexification. Every case handled by PDP was checked by CHS. The assessment was conducted by 3 examiners (PDP, CHS, and GK) who were aware of the groups they were evaluating, as it was obvious from the radiograph, with MTA being more radio-opaque than $Ca(OH)_2$. All the examiners were calibrated, and the interexaminer variability was insignificant by using Cochran Q test (Q=2; P=.368). The patients were also aware of the treatment they were receiving.

Endodontic therapy in each case was carried out under local anesthesia and rubber dam isolation. The pulp was extirpated, and diagnostic radiographs were exposed. Biomechanical preparation was completed by circumferential filing and copious irrigation with 2.5% solution of sodium hypochlorite. After biomechanical preparation, the root canal was dried and calcium hydroxide paste (Reogan Rapid, Vivadent, Liechtenstein) was introduced into the canal with the help of engine-driven lentulospirals. The access cavity was sealed with quick setting ZOE (Kalsogen, DentPro, India). The adequacy of the $Ca(OH)_2$ push was checked with an immediate postoperative radiograph. If found to be inadequate, it was repeated. Up to this stage, the procedure was the same for both groups.

In the MTA group (group 1), after a period of 7 days, $Ca(OH)_2$ dressing was removed with reamers and irrigation of savlon (chlorhexidine gluconate 7.5%, cetrimide 15%, isopropyl alcohol 7%) as $Ca(OH)_2$ is dissolved in this solution. The MTA (Pro-Root, Dentsply, Tulsa, Okla) was inserted into the apical one third of the root canal. The method of insertion consisted of first selecting a gutta percha (GP) point so that, when inserted into the root canal with the butt end towards the apex to a length 3 to 4 mm

Table 1. Radiographic Assessment of Time Taken for Apical Barrier Formation in the 2 Groups

Time of evaluation	Group 1 (MTA) (n=7)	Group 2 (Ca(OH)2) (n=10)
Immediate post-push (mos)	0	0
1	3*	0
2	1†	0
3	1*	0
4	1 *	2 *
5	0	1*
6	0	3‡
7	0	0
8	0	0
9	1	2*
10	0	1‡
11	0	1*
Mean time taken (mos)	3.0±2.9	7.0±2.5
t test	t=3.025; P=.008	

***Adequately filled.**
†Underfilled.
‡Overfilled.

short of its actual length, it fit just snugly into the canal (a little loose was also accepted). In case it was loose, a few GP points, as required, were rolled onto a heated glass slab and joined together so that the aforementioned criterion of just "snugly fitting" was achieved. On this GP point, a mark was made with a permanent marker 3 to 4 mm short of the exact length of the root canal in reference to the incisal edge/point, and a silicon stopper was placed at this mark.

A freshly prepared granular mix of ProRoot MTA in distilled water was placed at the root canal opening with the help of a plastic filling instrument in small installments. Each increment of the mix was pushed apically by repeated vertical agitation of the marked GP point previously mentioned, taking care that it did not slip past the silicon stopper. By this method, a root end barrier of 3 to 4 mm was expected to be created. After inserting MTA, a moist cotton pellet was left in the canal in close contact with MTA to facilitate its setting and the access opening was sealed with ZOE. The adequacy of MTA's insertion was confirmed with an immediate postoperative radiograph. If needed, the procedure was repeated.

After 3 to 4 days, the wet cotton pellet was taken out and the apical plug of MTA was checked for its set and hardness with the help of a reamer. Obturation of the root canal was carried out over the hard set apical plug using thermoplasticised injectable GP (Obtura II, Tex EED Corp, Costa Mesa, Calif) with the vertical condensation technique. If the set and consistency of the MTA plug was not found to be satisfactory, the obturation was deferred until a later date. Thus, in 7 out of 10 cases, obturation was completed in 15 days. Two cases could be completed only after 1 month due to patients failing to keep appointments. In yet another case, due to persistence of the draining sinus, MTA push was repeated and obturation could be done after 2 months when the sinus healed. In the $Ca(OH)_2$ group (group 2), the dressing was kept as such.

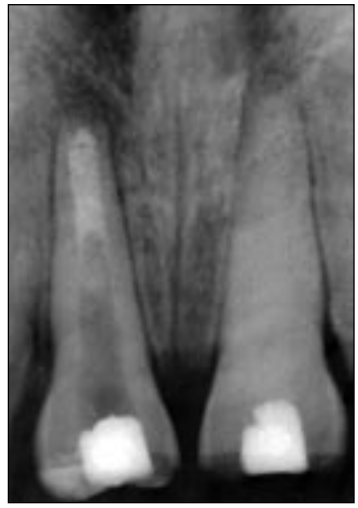

Figure 2. Immediate post MTA push in the maxillary right central incisor (left).

The teeth in both groups were assessed every 4 weeks according to the following clinical and radiographic parameters:

1. clinical: pain, tenderness to percussion, and intraoral sinus;
2. radiographic: extent of root canal filling and fate of overfilled material (if any), apical bridge formation, fate of periapical radiolucency (if present at baseline), and completion of lamina dura.

If $Ca(OH)_2$ in the root canal was found to have depleted more than half the length of the canal, it was pushed again. If noticed on radiographic examination, the apical barrier formation in group 2 was confirmed clinically, after cleaning the root canal of $Ca(OH)_2$, by introducing a sterile GP point into the canal and tapping it gently with a finger towards the apex.[23] If an obstruction was met without eliciting pain, it was presumed that a complete apical calcified bridge had formed. Root canal obturation was then accomplished with thermoplasticised GP. In group 1, it was not possible to check the barrier clinically because MTA present at the apex acted as an apical stop and provided obstruction to the GP point. The biological hard tissue barrier in this group was assessed radiographically by evaluating the radio-opaque bridge apically over the MTA plug, as it differed in its radio-opacity from MTA (Figure 1).

RESULTS

In groups 1 and 2, treatment was successful in all teeth. In group 1, the radiographic evidence of biological barrier formation apical to the MTA in the root canal was seen in 7 out of 10 cases. In these 7 teeth, the MTA was observed to be pushed to the apical end (6 flush and 1 short by 1 mm). In the remaining 3, however, it had been pushed too far and the biological barrier formation was not seen. This relationship between overfilling and nonformation of a biological barrier in group 1 was significant (chi-square test=10; *P*=.006). In group 2, the bridge formation was seen to form in both the flush-filled and overfilled root canals, with there being no under filling (Table 1).

The mean time taken for the apical biological barrier formation, as assessed radiographically (Table 1), was

Table 2. Intragroup Comparison of Fates of Medium and Large Periapical Radiolucencies in Group 1

Post-push follow-up	Medium (n=1)				Large (n=5)			
	Increasing	Decreasing	Static	Healed	Increasing	Decreasing	Static	Healed
Immediate post-push (mos)	0	0	1	0	0	0	5	0
1	0	1	0	0	0	4	1	0
2	0	0	0	1	0	2	3	0
3	0	0	0	0	0	2	1	2
4	0	0	0	0	0	3	0	0
5	0	0	0	0	0	2	0	1
6	0	0	0	0	0	0	0	2
Mean time taken for healing (mos)				2±0	4.6±1.5			
t test	t=3.8334; P=.018							

Table 3. Intergroup Comparison of Fates of Large Periapical Radiolucencies in Groups 1 and 2

Post-push follow-up	MTA (group 1) (n=5)				$Ca(OH)^2$ (group 2) (n=5)			
	Increasing	Decreasing	Static	Healed	Increasing	Decreasing	Static	Healed
Immediate post-push (mos)	0	0	5	0	0	0	5	0
1	0	4	1	0	0	5	0	0
2	0	2	3	0	0	4	1	0
3	0	2	1	2	0	2	1	2
4	0	3	0	0	0	2	1	0
5	0	2	0	1	0	1	0	2
6	0	0	0	2	0	0	0	1
Mean time taken for healing (mos)				4.6±1.5 4.4±1.3				
t test	t=0.221; P=.83							

significantly less in group 1 (3.0±2.9 months) compared to group 2 (7.0±2.5 months; t=3.025; *P*=.008; Figures 1-4).

FATE OF THE PERIAPICAL RADIOLUCENCIES (TABLES 2 AND 3)

In group 1, there initially were 5 large and 1 medium-sized periapical radiolucencies, whereas in group 2 all the radiolucencies (N=5) were large. These were assessed as increasing, decreasing, static, or completely healed. Upon evaluation of the fate of the periapical radiolucencies, it was found that all the radiolucencies eventually resolved over time, with the only difference found in the mean healing period. An intragroup comparative evaluation revealed that the one medium radiolucency in group 1 healed in a significantly shorter time (2 months), compared to large radiolucencies in the same group (4.6±1.5 months; t=3.8334; *P*=.018). Intergroup comparison, however, revealed that the mean healing period of large radiolucencies was found to be similar in the 2 groups (ie, 4.6±1.5 months in group 1 and 4.4±1.3 months in group 2; t=0.221; *P*=.83).

The total time taken for the management of teeth with unformed apices from the start to GP root canal filling (Table 4) was found to be significantly less in group 1 (0.75±0.49 months) vs group 2 (7 ±2.5 months).

DISCUSSION

Twenty maxillary teeth involving 16 children were selected for this controlled longitudinal clinical study, with 10 teeth in each of the 2 groups. The sample was confined to 10 teeth per group, keeping in mind the feasibility of collecting the required sample restricted to traumatized maxillary incisors with unformed apices within a specified time period. The authors who have studied the procedure of apexification using calcium hydroxide have also used a smaller sample size.

Table 4. Comparative Evaluation of Total Treatment Time from Root Canal Opening to Obturation With Gutta Percha in the 2 Groups

Total treatment time (mos)	MTA (group 1) (n=10)	Ca(OH)2 (group 2) (n=10)
0.5	7	0
1	2	0
2	1	0
3	0	0
4	0	2
5	0	1
6	0	3
7	0	0
8	0	0
9	0	2
10	0	1
11	0	1
Mean time (mos)	0.75±0.4859	7.0±2.5
t test	t=7.647; P=.000	

Chawla et al[24] in 1980 conducted an uncontrolled clinical study on 21 teeth to evaluate the induction of an apical barrier without using a catalyst paste. Chawla et al[23] in 1986 and Walia et al[25] in 2000 evaluated the efficacy of $Ca(OH)_2$ paste in inducing root end closure in 33 and 15 teeth, respectively. A larger sample size was, however, taken by Kleier and Barr[26] (41 incisors), Ghose[27] (51 central incisors), and Mackie et al[28] (112 incisors) in their respective studies for evaluation of $Ca(OH)_2$ apexification, but these samples were collected over a period of 4 to 11 years.

Moreover, none of these studies involved a control group. As far as the literature on the use of MTA in the apexification procedure is concerned, there are only a few reports of isolated case studies. Nevertheless, the relatively small sample is a limitation and a larger sample size would definitely be desirable.

The success rates in both the groups were comparable. The biological barrier formation over the periapical portion of the MTA approximating the periapical tissue, as assessed radiographically, was found to have been formed in 70% of cases. The 3 teeth on which an apical biological barrier was not formed were the ones in which MTA had been overpushed. In an experimental study on dog's teeth, Shabahang et al[7], after using 3 materials (osteogenic protein–I, $Ca(OH)_2$, and MTA) for root end induction, reported a radiographic appearance of hard tissue (biological barrier) in the apical area of 13 of 14 teeth treated with MTA after 12 weeks. The nonformation of a biological barrier in the remaining tooth was reported to be where MTA had been extruded 2 to 3 mm beyond the confines of the root. When the same cases were viewed in a histological examination under high magnification, however, a thin but complete band of calcified tissue was detected around the extruded material.

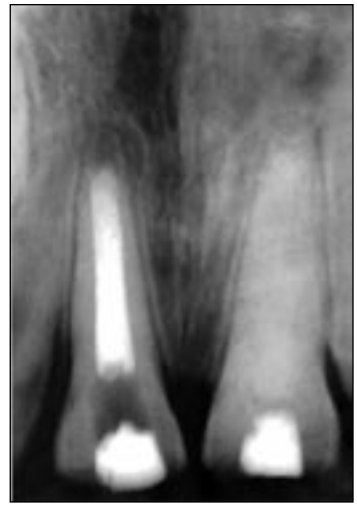

Figure 3. Apical calcific barrier formation in 8, 2 months after MTA push.

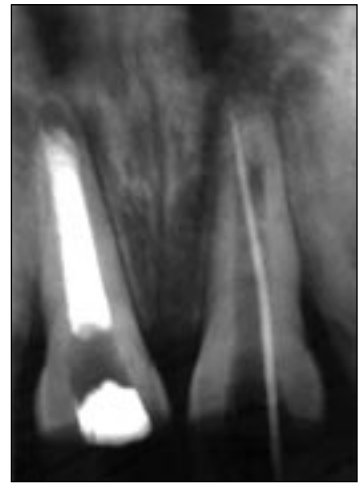

Figure 4. Apical calcific barrier formation in 9, 6 months after calcium hydroxide push.

In this study, it is probable that, in the 3 cases with overpushed MTA, a thin calcific bridge might have formed which was not dense enough to be detected radiographically. Benenati et al,[29] while studying sealing of iatrogenic root perforations with MTA, showed that extrusion of filling material can cause traumatic injury to the surrounding periodontal ligament, resulting in inflammation and delay in repair. This may be relevant in the present 3 cases where MTA was overpushed because the healing process in these teeth had been initiated, as evidenced by completion of lamina dura in all 3 teeth and complete resolution of periapical radiolucency in a case where it was present. Of the remaining 7 teeth in group 1, in which barrier formation had occurred, MTA was seen to have been slightly underfilled in one case and flush with the root apex in the remaining 6 teeth. It seems that the chances for biological calcific bridge formation are favorable when the root canal apices are flush or underfilled with MTA. Nevertheless, a study with a larger sample and a longer follow-up would be necessary to firmly establish the effect of MTA in the periapical region and on the tooth root tissues, especially when overpushed. Moreover, a foolproof method for MTA insertion should be devised to avoid overpushing.

In group 2, the radiographic evidence of biological apical barrier formation was observed in all 10 cases. The 100% success in achieving apical closure using calcium hydroxide, as in the present study, has also been reported by Chawla et al,[23] Kleier and Barr,[26] Mackie et al,[28] and Walia et al.[25] On the other hand, Heithersay[30] had reported closure in 90 percent of the treated teeth and Thater[31] reported a lower success rate (74%). The extent of root canal filling with $Ca(OH)_2$ does not affect bridge formation, as evidenced by 100% apical closure achieved in group 2, in spite of

overfilling in 4 out of 10 teeth. This is contrary to the findings of Holland et al.[32] They observed apical closure failing to occur in 18 of 20 root canals of dog teeth overfilled with $Ca(OH)_2$-iodoform paste, as opposed to hard tissue deposition occurring in 16 of 20 teeth where canals were adequately filled up to the apex. In their study, the unfavorable outcome in the overfilled cases may be attributed to the presence of iodoform in $Ca(OH)_2$, as it is cytotoxic[33,34] and may elicit an undesirable response from the periapical tissues.[35] In the present study, however, $Ca(OH)_2$, which is known to be biocompatible,[36] was used alone. Because of its paste form, the calcium hydroxide paste (Reogan Rapid, Vivadent, Liechtenstein) remains smooth upon setting and, thus, is not likely to traumatize the periapical tissues.

The time taken to form a biological apical barrier, as assessed radiographically, was significantly less for group 1 (3.0±2.9 months) than for group 2 (7.0±2.5 months; *P*=.008; Figures 1-4). In the present study, the biological barrier formation in group 1 occurred much earlier than that reported by Thom[15] (report of a case) and Giuliani et al[14] (report of 3 cases), who found biological apical hard tissue formation over the MTA after 1 year. In the present study, the average time taken for apical closure in group 2 was 7±2.5 months, with a range of 4 to 11 months. The results are concurrent with other authors who have used $Ca(OH)_2$[12,27,30,37-39] for apexification.

HEALING OF PERIAPICAL RADIOLUCENCY

Out of the 20 teeth taken up for apexification, 11 were found to be associated with periapical radiolucencies: 6 in group 1 (large=5; medium=1), and 5 in group 2 (large=5). During follow-up examinations, the time taken to completely heal large radiolucencies in both groups was the same: 4.6±1.5 months in group 1 and 4.4±1.3 months in group 2 (*P*=.83063). The healing was complete in all the cases in each group during the first 6 months. Thus, MTA was found to have healing ability comparable to $Ca(OH)_2$. This may be due to the fact that MTA also has an alkalinity (pH=12.5) similar to that of $Ca(OH)_2$ (pH=12)[40] and consists of several calcium salts in its composition.[8] The high pH is known to activate alkaline phosphatase and antibacterial activities. The presence of a high calcium concentration further increases the activity of calcium–dependent pyrophosphatase,[36] thus achieving asepsis of lesions and initiating the process of bone healing. In the single tooth with medium radiolucency in group 1 (MTA), complete healing was found to have occurred significantly earlier (2±0 months), compared to the large radiolucencies (4.6±1.5 months) in the same group (*P*=.01856). This is probably due to the relatively smaller area of bone destruction, which had to be repaired in the former.

As far as periapical healing in nonvital immature teeth treated with $Ca(OH)_2$ is concerned, Kleier and Barr[26] found an average healing period of 11 months. Cvek,[41] on the other hand, reported that an average of 13 months of follow-up is required for healing. In his study, Heithersay[30] found a wide range of 14 to 75 months or a mean of 36 months as the time required for healing of periapical radiolucency. MTA has been reported to bring about formation of bone and facilitate regeneration of the periodontal ligament[42] while treating lateral root perforations. Schwartz et al[8] have shown complete resolution of inter-radicular radiolucency within 6 months when MTA was used to repair a furcal perforation defect. Torabinejad and Chivian[43] found complete resolution of a periapical pathology associated with a central incisor within a period of 15 months after apexification was undertaken using MTA.

CONCLUSIONS

Based on this study's results, the following conclusions can be made:

1. The total treatment time taken for the management of teeth with unformed apices, from the start to GP root canal filling, was found to be much less in the mineral trioxide aggregate group than in the calcium hydroxide group.
2. The mean time taken for the biological barrier formation apical to mineral trioxide aggregate (group 1), as assessed radiographically, was significantly less than for group 2.
3. The mean healing time for large radiolucencies was found to be almost similar.

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