Clinical Assessment of Mineral Trioxide Aggregate (MTA) as Direct Pulp Capping in Young Permanent Teeth

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Carious pulp exposure in permanent molars of children is a common incident. Mineral trioxide aggregate is a new material that possesses numerous exciting possibilities for pulp therapy.

Aim: *The purpose of this study was to evaluate the efficiency of MTA as a direct pulp capping agent in young permanent teeth.*

Methods: *Thirty asymptomatic permanent molars with pulp exposures were treated by pulp capping using MTA. At each recall (6, 12, 18 and 24 months), the teeth were assessed clinically, through pulpal sensitivity tests, as well as radiographically to evaluate periapical healing.*

Results: *None of the cases reported spontaneous pain at the six months follow up and the pulp showed signs of vitality and absence of periapical radiolucency. At 24 months, the clinical and radiographic success rate was 93% with evidence of continued root growth.*

Conclusion: *Pulp capping with MTA is recommended for teeth with carious pulp exposures specially immature teeth with high potential for healing.*

Key words: *Mineral trioxide aggregate, Pulp capping*

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INTRODUCTION

One of the most difficult situations a dentist encounters is a deep carious lesion in an immature permanent molar exhibiting wide-open apices. Although indirect pulp therapy will reduce incidence of direct pulp exposures encountered, pediatric dentists will still be faced with situations where vital pulp exposure is unavoidable.

A major difficulty in obtaining successful results when dealing with pulp therapy is the prevention of bacterial recontamination after treatment has been completed. Improving visualization via magnification and using caries detectors, can help dentists to effectively remove the infected dentin and maintain the affected but uninfected layer that can be remineralized. This procedure has been shown to be successful in maintaining the pulp integrity.[1,2]

When pulp exposures are encountered, sodium hypochlorite has been shown to be an effective agent for hemostasis, disinfection, and removal of remaining dentinal chips. The most crucial factor in direct pulp capping is the inability to achieve a perfect seal to prevent marginal leakage of the medicament covering the pulp and or the final restoration. While direct pulp capping with calcium hydroxide is an option, some studies have shown that calcium hydroxide bases disintegrate over time, and that microleakge can take place through tunnel defects in the reparative dentin bridge.[3] Some authors generally report that calcium hydroxide disappears with time.[4] The inability of calcium hydroxide to provide a permanent seal and the porous nature of the reparative dentin bridge allows the access of bacteria and eventually inflammatory pulpal reaction will take place. These irritants can compromise pulpal vitality, often leading to dystrophic calcification, root canal therapy, or potential extraction.[3,5-7]

Although the sealing ability of bonding systems and composite resins have been greatly improved over the last decade, there is still no clear evidence on the durability and efficiency of bonding systems in preventing microleakage of bacteria around the restoration.[8] Therefore, it is imperative that the materials used to protect the pulp should have an enhanced seal to compensate for potential marginal leakage of the restoration.

Mineral trioxide aggregate (MTA), a new material currently being used in pulp therapy, has been demonstrated to provide an enhanced seal over the vital pulp and is non-resorbable.[9,10] MTA has been used experimentally for a number of years and was approved for human usage by the FDA in 1998.[11]

MTA has been shown to have superior sealing ability to amalgam, ZOE, or IRM.[12-14] It has also been shown to have a superior characteristic as a direct pulp capping agent when compared to calcium

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hydroxide using animal models.[15,16]

The biocompatibility of MTA has been found to be equal or superior to amalgam, IRM, and ZOE.[11,17-19] In an histological study of perforation repair using MTA in the canine model, MTA was shown to permit cementoblast attachment and the production of mineralized matrix gene.[20]

Accordingly, MTA has been proposed as a potential medicament for various pulpal procedures like pulp capping with reversible pulpitis, apexification, repair of root furcations and pulpotomy in primary teeth.

In a recent preliminary report, MTA was used as a pulp dressing agent in pulpotomized primary molars and it seemed to be a suitable replacement for formocresol.[21] The study of Farsi *et al*[22] on 120 primary molars confirmed the superiority of MTA in pulpotomized primary teeth. MTA has also been compared to calcium hydroxide as pulp capping agents in 14 human permanent teeth throughout a period of six months. Although the results favored the use of MTA, it suggested a larger sample and a longer follow-up.[23]

Although MTA has not been on the market long enough for long-term studies to be completed, the animal studies and the available clinical results are highly encouraging, and suggest that endodontic treatment is no longer the only modality for immature permanent teeth with carious exposures.

METHODS AND MATERIALS

The purpose of this study was to evaluate clinically and radiographically the efficacy of MTA as a predictable pulp capping material in young permanent teeth. After obtaining a written consent to participate in the study, 30 children with an age range of 9 to 12 years participated according to the proposed inclusion criteria. Each child had at least one permanent molar involved with deep caries. The lesion was evaluated radiographically and diagnosed as having a potential pulp exposure. The carious teeth were exposed to the same surgical protocol of pulp capping with MTA. The efficacy of MTA material as a therapeutic modality for preserving pulpal vitality was assessed through a strict recall program.

1. Inclusion criteria:

According to the American Academy of Pediatric Dentistry guidelines on pulp therapy for young permanent teeth[24] only teeth with signs and/or symptoms of reversible pulpitis were included. Teeth with reversible pulpitis were those exhibiting provoked pain of short duration, which was relieved upon the removal of the stimulus, taking analgesics, or by brushing. Teeth exhibiting signs and/or symptoms of irreversible pulpitis such as history of spontaneous unprovoked toothache, a sinus tract, periodontal inflammation (not resulting from gingivitis or periodontitis,) excessive mobility (not associated with trauma), furcation/apical radiolucency, or radiographic evidence of internal/external resorption were excluded from the study.

2. Clinical Evaluation:

Symptoms of reversible pulpitis were then confirmed clinically by carrying out the following tests:

i. Thermal test: The test included applying a cold cotton pellet sprayed with ENDO-ICE frozen gas (Coltene/Whaledent Inc, Mahwah, NJ, USA) for five seconds on the buccal surface of the involved tooth as well as the adjacent tooth to characterize the patient's normal response and to compare it to that of the offended tooth. Exaggerated response and/or lingering response after removal of the cotton pellet was indicative of irreversible pulpitis and qualified the tooth for exclusion.

ii. Percussion test: the purpose of this test was to predict the periradicular involvement of the offended tooth which was an indication of irreversible changes in the pulp and hence disqualified the tooth for inclusion. This test included percussion applied vertically to three normal teeth and then to the suspected tooth. Positive result was indicated when pain on percussion was recorded.

iii. Palpation test: another test to predict the extent of the periradicular bone involvement. This test was carried out by bi-manual palpation of two quadrants at the depth of the buccal sulcus. Pain on palpation was indicative of spread of infection. Softness in one side indicated spread of infection into bone and soft tissues.

3. Radiographic Evaluation:

Standardized radiographic projection using the parallel cone technique with the aid of a Rinn holder (Dentsply Rinn) was taken at the screening time and at each follow up visit. The aim of radiographic evaluation was to characterize the continued root formation of the involved tooth and the presence or absence of radiographic signs of periradicular bone destruction.

4. Operative procedure:

Under the rubber dam isolation, the carious enamel and dentin were removed using sterile carbide bur #245. The convenience form was obtained and the remaining decay was scooped out with a sterile spoon excavator. Teeth without pulp exposure were excluded from the study.

Bleeding was controlled with moistened cotton pellet with sterile saline.[25] Haemostasis was achieved within approximately 5-10 minutes. Teeth with excessive uncontrollable bleeding were excluded from the study. The tooth was rinsed out with saline. Then fresh mix of MTA (ProRoot®, Dentsply Tulsa, Tulsa, OK, USA) was applied to the exposure site. MTA powder was mixed with saline in a 3:1 ratio and then placed over the exposure site with a plastic instrument. Once MTA had been placed, no further irrigation was accomplished.

A moistened cotton pellet with sterile saline was placed on the MTA mix gently. The cotton pellet provided the moisture MTA required for a proper set. The tooth was then temporized with IRM. After two weeks, the patient was screened for any symptoms that were indicative of irreversible pulpal changes. The IRM was replaced with composite. The patient was then followed up at 6, 12, 18 and 24 months.

RESULTS

All data for the tested teeth are summarized in Table 1. At the baseline evaluation none of the treated teeth showed any sign or symptom of irreversible pulpitis. Twenty two teeth (73%) had immature root development, while eight had closed apices.

Six-month observation visit:

At this visit four cases reported sensitivity to thermal stimulation upon clinical examination but without lingering pain. None of the subjects had tenderness to either percussion nor palpation tests. Radiographic findings showed no detectable periradicular changes. The state of root development remained the same as in the screening visit.

Twelve-month observation visit:

At this visit 26 cases showed normal pain response to thermal testing, two cases reported slight sensitivity that disappeared upon

removal of stimulus and two cases reported lingering pain. Those two cases reported pain to percussion and palpation as well. Radiographically the cases were considered normal except for the two cases, who had history of pain; periapical pathoses were evident. At this stage sixteen cases had complete root development; four cases showed narrowing of at least one root canal. The failed cases were subjected to root canal treatment and were excluded from the study.

Eighteen-month observation visit:

No sensitivity or tenderness to percussion and palpation were found in any of the remaining teeth. Radiographic examination showed that all of the 28 teeth were free from periradicular pathology. Root apices were fully formed and closed in 20 teeth, whereas, in eight cases roots closure was not evident. Narrowing of the root canal could be detected in six cases.

Twenty-four month observation visit:

Clinical examination showed normal pain response of the vitality tests. Radiographic examinations presented no signs of abnormality. Root end closure were evident in all teeth. Narrowing of root canal was detected in six teeth. Figure 1 shows a case of a first permanent molar treated with MTA as a capping material throughout a 24 month follow up period in the screening and the follow up visits. Notice the onset of calcification in the mesial root at 12 months.

DISCUSSION

Dentists, on a routine basis, frequently perform vital pulp-therapy procedures. Predominantly, these procedures are taught in dental schools as a temporary treatment modality for cariously exposed teeth. However, some authors[26,27] have suggested that vital pulp therapy can be considered a permanent treatment because the young pulp has a vast blood supply. Stanley[27] advocated that pulp-capping procedures could be performed successfully on an asymptomatic carious exposure. The development of newer materials that are biocompatible, bactericidal, inductive of a reparative process and have good sealing properties could render these treatments long-term quality.

Traditionally, the treatment of carious pulpal exposures involved direct pulp capping with calcium hydroxide based materials. However, recently, the dental literature presents some negative opinions on calcium hydroxide based on the material associated with low mechanical strength, poor adhesion to dentin and dentin bonding agents and potential resorption.[25,28]

A number of new pulp capping agents have been tested during the last two decades as potential materials of choice. Several studies reported use of dentin bonding agents for direct pulp capping in permanent teeth.[29,30] Accorinte *et al*[30] reported lack of pulp healing after capping with adhesive which could be due to the application of cytotoxic components over the pulp. Even when haemorrhage control was achieved, several studies found no dental bridge formation after adhesive capping.[31-33] It is interesting to note that most of the articles reporting acceptable biocompatibility of adhesive agents over exposed pulps were conducted in monkeys or rats[29,34]; however, these findings were not reported in human teeth studies.[30,31,33]

MTA is one of the newest materials that have appeared recently. Faraco and Holland[35] emphasized the advantages of MTA over calcium hydroxide for pulp capping. Thirty teeth of three dogs were capped with either calcium hydroxide or MTA. More inflammation and less frequent dentinal bridging were observed in the calcium hydroxide group in addition to material resorption and microleakage of microorganisms. Later Aeinehchi *et al*[3] reported similar results. In a case report, MTA was used as pulp capping material to preserve the vitality of the pulpal tissue in two permanent teeth with complicated crown fracture and followed up for 18 months. MTA was successful in preserving pulp vitality and continued development of teeth.[36]

The present study shows that the treatment of the symptomless exposed permanent teeth with MTA is a clinically and radiographically effective procedure. In this study, 28 out of 30 pulpally exposed young permanent teeth capped with MTA showed normal pulpal responses with evidence of continuing apical root development at 24 months after capping. Severe non-reversible pulpal changes were present at 12 months after capping in only two teeth. In each of those two cases the filling material was partially lost and microleakage through coronal portion was unavoidable. The presence of bacteria and their by-products is one of the most important reasons for pulp capping failure.[13] Microleakage could be an explanation for this adverse pulp reaction. This is supported by the conclusion reported by Swift *et al*[37] that along with pulpal health, provision of a seal against bacterial access is probably the most critical factor in the success of vital pulp therapy.

In the present study teeth after capping were temporized using IRM (Caulk), because, when a practitioner caps and fills the cavity with MTA it is necessary to use gentle pressure to pack the MTA and minimize harmful effect to the pulp tissues which could have been assaulted during cavity preparation. If amalgam was used as a final restoration just after pulp capping, pressure during condensation would dislodge MTA before it has hardened or set. The use of acid etchants for composite material placement has been also disregarded because it requires washing which might easily wash out MTA. IRM was the material of choice to temporize the capped teeth until proper setting of MTA was achieved and then was replaced with composite. In fact, Arens and Torabinejad[38] recommended covering MTA with a wet cotton pellet and IRM to gain a better setting of the material. Sluyk *et al*[14] supported the use of the wet cotton pellet and showed that the resistance to dislodgement of the MTA was significantly higher at 72 than it was at 24 hours. This slower setting time may also be an advantage as it reduces the amount of setting shrinkage, which may help explain MTA's low microleakage.[13]

Reparative dentin can be easily identified in histological studies. In the present study, dentin bridge formation was not reported because they are usually observed adjacent to areas of pulp exposure and it was not always possible to have the radiographic beam perfectly perpendicular to the axis of the tooth and the exposure site at the same time. This could explain the fact that many of the samples could not be scored positively for the presence of dentin bridge formation. Consequently, the dentin bridge formation could not be categorized as one of the success criteria. Nevertheless, the teeth were scored as successful according to the other described criteria.

Narrowing of root canal was evident in 21% of the cases by the end of the study period. MTA might induce dentin formation along the entire walls of dental pulp. Previous histological studies reported that MTA induced cytological and functional changes in pulpal cells, resulting in formation of fibro-dentin and reparative dentin.[9,10] Human osteoblasts were studied *in vitro* and it was found that MTA stimulated the release of cytokines and the production of interleukin.[39,40] Other researchers suggested that mid-pulp calcification

Figure 1A

Figure 1B

Figure 1C

Figure 1D

Figure 1E

Table 1:
Distribution of clinical and radiographic findings of MTA on capped permanent molars

		Pre-operative	Post operative			
			6 months	12 months	18 months	24 months
Thermal Test	No pain	30	26	26	28	28
	Slight sensitivity	-	4	2	-	-
	Lingering pain	-	-	2	-	-
Percussion test	No pain	30	30	28	28	28
	Pain	-	-	2	-	-
Palpation test	No pain	30	30	28	28	28
	Pain	-	-	2	-	-
Peri-radicular Radiographic changes	Absent	30	30	28	28	28
	Present	-	-	2	-	-
Narrowing of pulp canal	Present	-	-	4	6	6
	Absent	30	30	26	22	22
Root development	Immature	22	22	14	8	0
	Fully formed	8	8	16	20	28
Total		**30**	**30**	**30**	**28**	**28**

may be a consequence of MTA and dentinal chips being pushed into the subjacent pulp during the mechanical exposure.[35,41] Evaluation of the literature on pulp responses to irritants revealed that the reduction in coronal pulp space followed by a gradual narrowing of the root canal is not considered to be a pathology and does not require treatment.[42]

CONCLUSIONS

Mineral trioxide aggregates can be recommended to be used as the material of choice for pulp capping of permanent teeth with carious exposure.

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