Comparison of Mineral Trioxide Aggregate and Calcium Hydroxide as Pulpotomy Agents in Young Permanent Teeth (Apexogenesis)

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Short title: Apexogenesis with MTA

Key words: Apexogenesis, Mineral Trioxide Aggregate, MTA

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Abstract

Purpose: This study was designed to compare mineral trioxide aggregate (MTA) with calcium hydroxide [Ca $(OH)_2$] clinically and radiographically as a pulpotomy agent in immature permanent teeth (apexogenesis).

Methods: Fifteen children, each with at least 2 immature permanent teeth requiring pulpotomy (apexogenesis) were selected for this study. All selected teeth were evenly divided into 2 test groups. In group 1, the conventional calcium hydroxide pulpotomy (control) was performed, whereas in group 2, the MTA pulpotomy (experimental) was done. The children were recalled for clinical and radiographic evaluations after 3, 6, and 12 months.

Results: The follow-up evaluations revealed failure due to pain and swelling detected at 6 and 12 months postoperative evaluation in only 2 teeth treated with calcium hydroxide. The remaining 28 teeth appeared to be clinically and radiographically successful 12 months postoperatively. Calcific metamorphosis was a radiographic finding in 2 teeth treated with $Ca(OH)_2$ and 4 teeth treated with MTA.

Conclusions: MTA showed clinical and radiographic success as a pulpotomy agent in immature permanent teeth (apexogenesis) and seems to be a suitable alternative to calcium hydroxide.

Although vital pulp capping and pulpotomy procedures of cariously exposed pulps in mature teeth remain controversial, it is universally accepted that vital pulp therapy is the treatment of choice for immature teeth (incompletely developed apices).[1] Such vital pulp therapy, often called apexogenesis, is defined as a vital pulp therapy of an immature tooth that permits continued root formation and apical closure.[2]

Calcium hydroxide [$Ca(OH)_2$] has been a popular pulpotomy agent for this type of vital pulp therapy and it is widely used clinically. It was introduced by Herman as a biologic dressing.[3] Despite its apparent success in vital pulp therapy, considerable confusion and condemnation of this material have long persisted because $Ca(OH)_2$, in the pure state and in the original formulations, actually kills a certain amount of tissue when placed in direct contact with the pulp rather than merely functioning as a biologic dressing. Because of its alkalinity (pH of 12), it is so caustic that when placed in contact with vital pulp tissue, the reaction produces a superficial necrosis of the pulp.[4] Studies have also shown that $Ca(OH)_2$ is extremely toxic to cells in tissue culture, also it has some tissue altering and dissolving effects.[5,6,7] Therefore, the search continues for procedures and materials that are more biocompatible while stimulating continued dentin formation and apical closure of immature teeth.

Mineral trioxide aggregate (Pro Root MTA, Tulsa Dental Products, Tulsa, OK), a newer material currently being used in pulp therapy, has been shown to provide an enhanced non-resorbable seal over the vital pulp.[8,9] MTA was used experimentally for a number of years and was approved for human use by the FDA in 1998.[10]

MTA is a powder consisting of tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium sulfate dehydrate, and bismuth oxide.[11] When the material is hydrated it becomes a colloidal gel that solidifies in approximately 3 hours.[10] It is available in 1 gm packets of MTA powder. The cost of a box of 5 packets with a carrier included is approximately $300.[12]

Like $Ca(OH)_2$, MTA also has a high pH (12.5) that causes denaturation of adjacent cells, tissue proteins, and some bacteria in the wound area but as the material sets, the pH changes and the cell injuries subside.[13] The set material has low solubility and a radiopacity slightly greater than that of dentin.[14] MTA has been found to have a set compressive strength of about 70 MPA. This is approximately equal to that of IRM but much less than amalgam (311 MPA).[9,14]

MTA has been shown to have superior sealing ability to amalgam, ZOE, or IRM.[15,16] Recent investigations using MTA as a direct pulp capping material seemed to stimulate natural dentin repair at pulpal exposure sites.[9,17,18] It was also found to produce less inflammation and better dentin bridge formation when compared with $Ca(OH)_2$ in monkeys.[15]

MTA was found to be biocompatible when implanted into guinea pigs, dogs and monkeys, and was more biocompatible than amalgam, super EBA, and IRM.[19,20,21] In animal studies, MTA was the only material that allowed cementum overgrowth.[20,22] In vitro studies of human osteoblasts showed that MTA stimulated cytokine release and interleukin production.[23,24] MTA has been also found to be nonmutagenic and less cytotoxic than super EBA and IRM.[25,26]

The setting ability of MTA is uninhibited by blood or water.[27] In fact, Arens and Torabinejad have recommended covering MTA with a wet cotton pellet and IRM to gain a better setting of the material.[28]

MTA has been used to manage many clinical problems, including successful pulp caps, pulpotomies, apexifications, root perforations repairs (surgical and non surgical), and root-end filings.[9,10] In all cases, MTA allowed bone healing and elimination of clinical symptoms. MTA showed high clinical and radiographic success rates as a pulpotomy dressing in immature permanent teeth.[29,30,31] MTA performed well as a pulptomy agent causing dentin bridge formation while simultaneously maintaining normal pulpal histology.[31,32]

The treatment of pulpal injury during the period of root maturation provides a significant challenge for the clinician. Depending on the vitality of the affected pulp, apexogenesis or apexification may be considered. Apexogenesis is 'a vital pulp therapy procedure performed to encourage continued physiological development and formation of the root end.' Apexification is 'a method to induce a calcified barrier in a root with an open apex or the continued apical development of an incomplete root in a tooth with a necrotic pulp.'[33]

The purpose of this study was to compare MTA with $Ca(OH)_2$ as a pulpotomy agent in immature permanent teeth. Postoperative clinical and radiographic evaluations of the treated teeth were done to make the comparison of the results with each agent.

Methods

This study was carried out on 30 traumatized or carious young permanent teeth of 15 children ranging in age from 6 to 12 years. The sample included 4 traumatized central incisors, 2 carious premolars, and 24 carious first molars. These children were selected from the Pediatric Dental Clinic at the Faculty of Dentistry, Alexandria University, Alexandria, Egypt. They were invited to participate over a period of 12 months. Each child had at least 2 contra-lateral qualifying teeth. The children were healthy and cooperative. Prior to treatment, an appropriate informed consent was obtained from the parents. This study was conducted in compliance with all policies of appropriate patient care at Alexandria University.

All patients selected for this study were free from any systemic diseases. Each tooth that was chosen for pulpotomy (apexogenesis) met the following criteria:[2]

1- Tooth was immature with incomplete root formation and damage to the coronal pulp but with a presumed healthy radicular pulp.
2- The crown was fairly intact and restorable.
3- There was no clinical evidence of extensive pulp degeneration or periapical pathology including spontaneous throbbing pain, tenderness to percussion, tooth mobility, swelling or fistulous tract.
4- There was no radiographic evidence of periapical pathosis or interradicular bone loss, internal resorption, pulp calcification, ankylsois, or pathologic external root resorption.

Preoperative periapical radiographs of the teeth considered for treatment in the study were made using the XCP extension cone paralleling technique.[34] The selected teeth were randomly assigned and divided into 2 test groups. Group 1 included 15 teeth treated with $Ca(OH)_2$ (control group). Group 2 included 15 teeth treated with MTA (experimental group). Each child received both treatments, $Ca(OH)_2$ on one side of the mouth and MTA on the other side of the mouth.

For both groups the following pulpotomy technique was followed:[2]

1- After local anesthesia, rubber dam isolation, a conventional access cavity was made with a high-speed bur using copious water spray.
2- Strands of pulp and debris were removed coronal to the amputation site. Amputation of the coronal pulp at the cervical level was performed with a sharp spoon excavator or a large sterile round bur.
3- Bleeding of the pulp stump was controlled with saline on a cotton pellet applied with gentle pressure.

For group 1 [$Ca(OH)_2$]: Calcium hydroxide powder was mixed with saline to a thick consistency. The paste was carefully placed on the pulp stump surface 1 to 2 mm thick. A layer of zinc oxide-eugenol cement was placed over the $Ca(OH)_2$ to protect it against leakage and to provide a rigid base prior to final restoration. Anterior teeth were restored with bonded composite resin. Posterior teeth were restored with amalgam.

For group 2 (MTA): The MTA powder was mixed with sterile water according to the manufacturer's directions. The mixture was placed on the pulp stump surface and patted with a moist cotton pellet. A damp cotton pellet was placed over the material and the remaining cavity was filled with fortified zinc oxide-eugenol cement (IRM). After a week, the IRM and the cotton pellet were removed and a final restoration was placed over set MTA (bonded composite for anterior teeth and amalgam for posterior teeth). The same operator provided these treatments to all 15 patients in this study.

The children were recalled for clinical and radiographic evaluations after 3, 6, and 12 months. Two examiners, who were blinded to treatment type, evaluated the teeth clinically and radiographically. The examiners were faculty colleagues from the Department of Pediatric Dentistry and Public Health, Alexandria University.

Clinically, the treatment was considered successful if there were no signs or symptoms of pulp or periapical disease (no history of pain and no clinical evidence of swelling or sinus tract). Radiographically, the treatment was considered successful if there was continued growth of the root and canal narrowing, and no widened periodontal ligament, no periapical radiolucency and no internal or external root resorption.[2] If calcific metamorphosis occurred it was noted, but it was not regarded as a treatment failure.

The clinical and radiographic data for the 2 groups were statistically analyzed using the chi-square test.

Results

All 30 teeth were available for examination at each of the 3-, 6-, and 12-month evaluations. The results of this study are divided into clinical and radiographic findings.

1- Clinical Findings

Table 1 shows the clinical findings of the 2 groups during the follow-up period. After 3 and 6 months, no clinical signs or symptoms of failure were observed in any of the 2 groups. After 12 months follow-up, 2 teeth in group 1 had a history of pain as reported by the patient and swelling of tissues associated with these teeth was noted during the clinical exam. In group 2, all 15 teeth were free of any clinical signs and symptoms. At the end of the study, 2 teeth in group 1 were considered to be clinical failures.

2- Radiographic findings

Table 2 shows the radiographic findings of the 2 groups during the follow-up period. After 3 and 6 months, no radiographic signs of failure were observed in any teeth of the 2 groups. After 12 months follow-up, 2 teeth in group 1 showed widening of lamina dura and periapical radiolucency. In group 2, the periradicular condition of all teeth appeared normal after 12 months. Calcific metamorphosis, though not a criterion for success or failure, was a radiographic finding in 2 teeth treated with $Ca(OH)_2$ and 4 teeth treated with MTA. At the end of the study, 2 teeth in group 1 were considered to be radiographic failures (same 2 teeth that were clinical failures).

The examiners agreed that assessing root growth and canal narrowing could not be reliably determined by observing the radiographs at the 3-month and 6-month observation periods even though no adverse radiographic signs were noted for these periods. Therefore assessing the radiographic evidence for root growth and canal narrowing was recorded only at the 12-month evaluations. After 12 months, 13 teeth in group 1 and all 15 teeth in group 2 demonstrated continued root growth and canal narrowing comparable to normal tooth maturation.

Clinical and radiographic success rates:

The 4 traumatized maxillary central incisors were treated successfully with both materials (2 teeth treated with $Ca(OH)_2$ and 2 teeth treated with MTA). Twenty four of the 26 carious posterior teeth were also treated successfully with the 2 pulpotomy agents (11 teeth treated with $Ca(OH)_2$ and 13 teeth treated with MTA). Only 2 posterior teeth treated with $Ca(OH)_2$ were considered to be failures at the end of the study. There were no disagreements between the examiners' evaluations throughout the study.

The clinical and radiographic success rates for the calcium hydroxide and MTA groups were 86.7% and 100% respectively. Figures (1-3) shows radiographs of one successful case for each of the 2 groups. There was no statistically significant difference between the 2 groups, either clinically or radiographically, using the chi-square test (chi-square=2.14; *P*=.16).

Table 1: Number of teeth exhibiting clinical findings in the 2 groups.

Post-treatment interval	Clinical Findings					
	History of pain		Swelling		Sinus tract	
	G1*	G2†	G1*	G2†	G1*	G2†
3 months	0	0	0	0	0	0
6 months	0	0	0	0	0	0
12 months	2	0	2	0	0	0

*G1: $Ca(OH)_2$ apexogenesis
†G2: MTA apexogenesis

Table 2: Number of teeth exhibiting radiographic findings in the 2 groups.

Post-treatment interval	Radiographic Findings							
	Widened PDL		Periapical radiolucency		Internal or external root resorption		Root growth and canal narrowing	
	G1*	G2†	G1*	G2†	G1*	G2†	G1*	G2†
3 months	0	0	0	0	0	0	NA‡	NA‡
6 months	0	0	0	0	0	0	NA‡	NA‡
12 months	2	0	2	0	0	0	13	15

*G1: Ca $(OH)_2$ apexogenesis
†G2: MTA apexogenesis

‡NA: No assessment

Figure (1): Preoperative periapical radiographs showing carious mandibular permanent first molars with open apices.

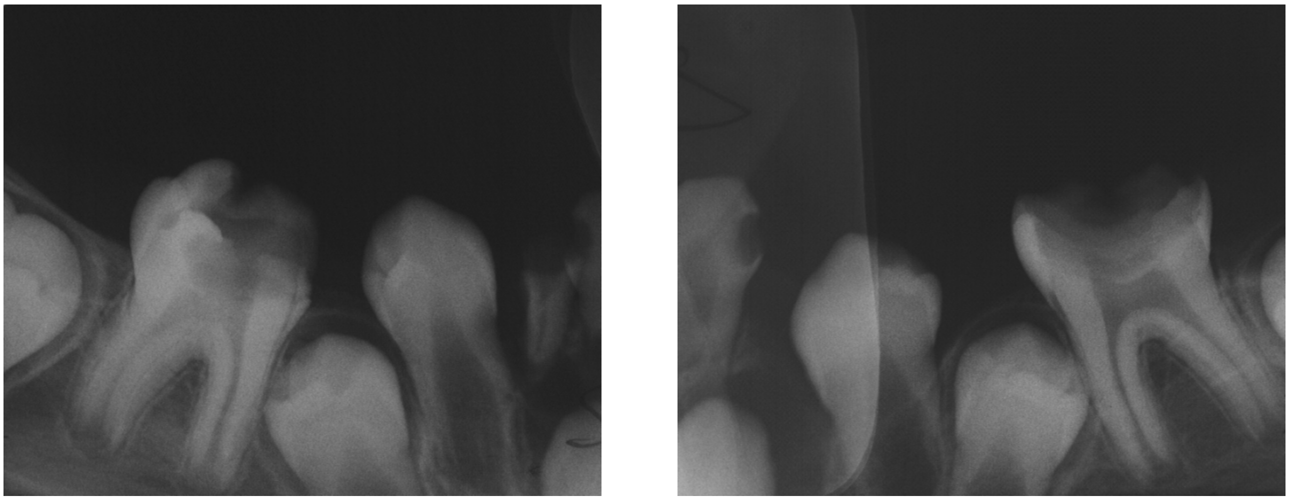


Figure (2): The same teeth 3 months after initiating apexogenesis. The mandibular right molar was treated with MTA (on reader's left) and the mandibular left molar was treated with calcium hydroxide. There were no signs of failure in either tooth.

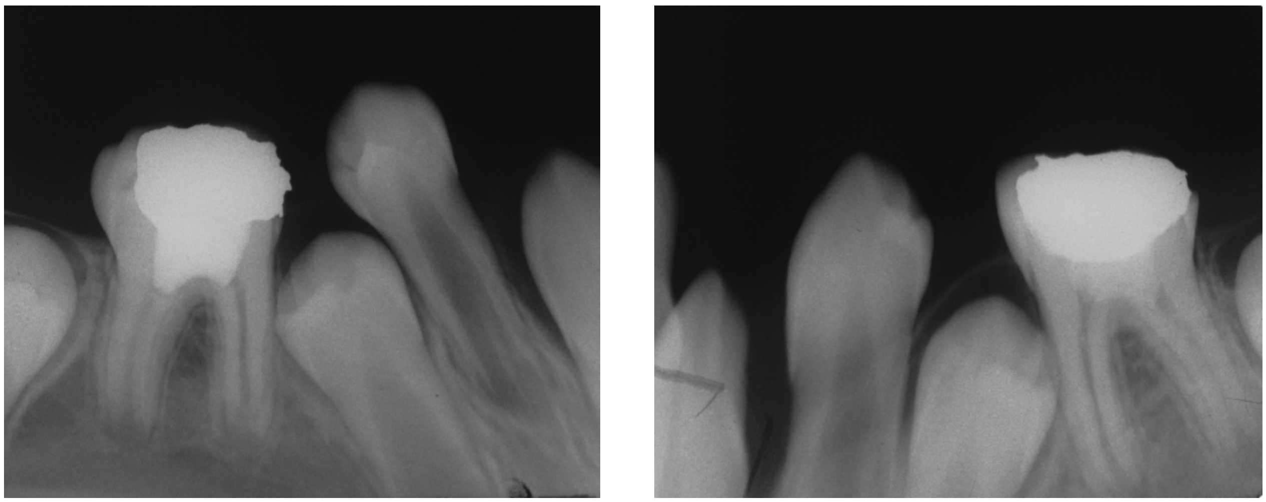
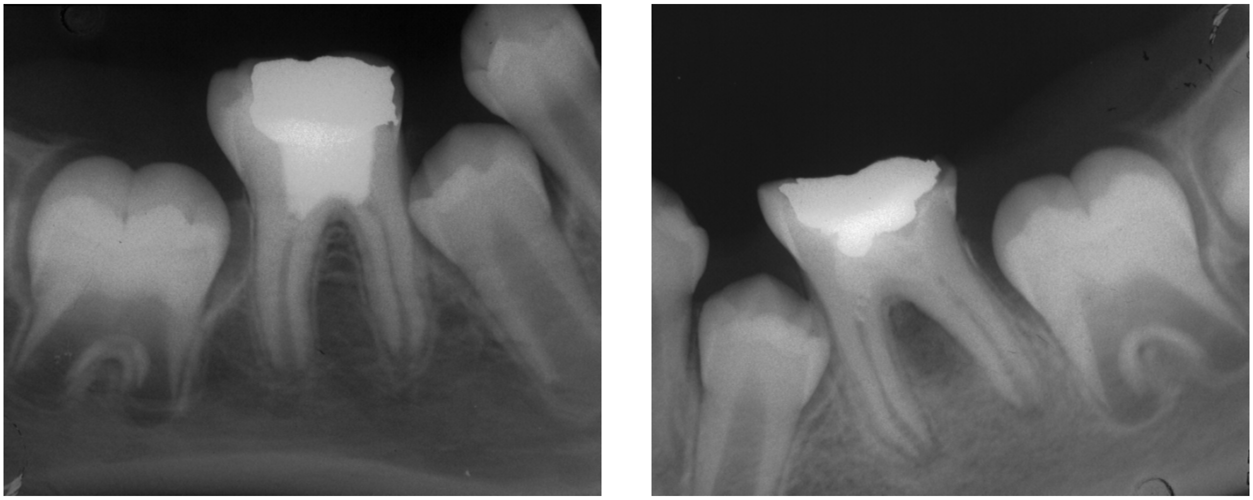


Figure (3): The same teeth 12 months postoperative. Notice continued normal root development in both teeth.



Discussion

This study examined the clinical and radiographic success rates of permanent tooth pulpotomies with MTA, a material with evidence-based success in many endodontic procedures. Several in vitro and in vivo studies have shown that MTA prevents microleakage, is biocompatible and nonresorbable, has low solubility and high comprehensive strength, and promotes tissue regeneration when it is placed in contact with dental pulp or periradicular tissues.[9,15,16,29,30]

However, using MTA as a pulpotomy agent is somewhat expensive. One suggestion to improve the cost effectiveness of using MTA is to carefully store unused portions of the powder from an opened packet in sterilized empty film canisters to keep it fresh and prevent hydration.[12]

Another noteworthy point when using MTA is that it needs to cure completely before placing a definitive restoration on the treated tooth. Therefore it is necessary to schedule 2 treatment appointments relatively close together, the first to perform the pulpotomy and place the MTA and the second to complete the restoration of the tooth after the MTA has cured.[29]

Ca $(OH)_2$ was selected as the control pulpotomy agent because it is currently considered the standard therapeutic agent for apexogenesis procedures in immature permanent teeth. $Ca(OH)_2$ has a long and proven record as an effective pulp therapy agent, including pulpotomies, and it is not expensive. On the other hand, $Ca(OH)_2$ has high solubility and low strength. $Ca(OH)_2$ has been reported to produce more inflammation and lower quality bridge formation when compared with MTA in monkeys and dogs.[15,17] Similar results were found when human third molars were used to compare the effect of pulp capping with MTA and $Ca(OH)_2$.[18]

The $Ca(OH)_2$ group in this study showed 2 teeth with pathologic signs and symptoms and they were regarded as failures at the 12-month evaluation. Walton and Torabinejad believe that failure usually results from bacterial contamination through microleakage around the restoration and through the porous bridge at the pulpotomy site.[2] $Ca(OH)_2$ offers no protection against microleakage while MTA remains stable and resists microleakage after it sets.[29]

Calcific metamorphosis was the most common noteworthy radiographic finding in both groups in this study, although it is not considered as a criterion for success or failure in the treated teeth. It results from vigorous odontoblastic activity and indicates pulpal vitality. Calcific metamorphosis is a common radiographic finding in pulpotomized teeth and in the present study, it was observed in 2 teeth treated with $Ca(OH)_2$ and in 4 teeth treated with MTA. Observing calcific metamorphosis in a portion of our sample was not surprising since both materials are known to promote hard tissue formation.

The success rate of MTA in this study was excellent; all 15 teeth in the experimental group were completely successful after 12 months, compared to 13 of 15 in the control group. Future material development may be expected to result in faster curing MTA. Further studies with a larger sample size and longer follow-up periods are recommended.

Conclusions

Based on the results of this study we conclude the following:

1. After a 12 month postoperative period, MTA proved very effective as a successful pulpotomy agent for apexogenesis in young permanent teeth.
2. MTA is a suitable replacement for $Ca(OH)_2$ as a pulpotomy agent for the apexogenesis procedure.
3. There was no statistically significant difference in the 2 treatment groups.

Acknowledgements

This study was partially supported by the Zawawi Pediatric Dentistry Fund of the Indiana University Foundation.

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