Multifaceted Use of ProRoot™ MTA Root Canal Repair Material

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Abstract

Mineral Trioxide Aggregate (MTA) is a new material recently approved by the FDA for use in pulpal therapy. MTA has been reported to have superior biocompatibility and sealing ability and is less cytotoxic than other materials currently used in pulpal therapy. This report is a review of MTA's physical and biological properties and the clinical techniques of direct pulp capping, apexification, and repair of failed calcium hydroxide therapy. (Pediatr Dent 23:326-330, 2001)

One of the most difficult situations a dentist encounters is a deep carious lesion in an immature permanent molar exhibiting wide-open apices. While direct pulp capping with calcium hydroxide is an option, some calcium hydroxide bases have been shown to disintegrate over time, allowing for microleakage through tunnel defects evident after reparative dentin bridge formation.[1] The inability of calcium hydroxide to provide a permanent seal and the porous nature of the bridge allows the ingress of bacteria and inflammatory bacterial byproducts. These irritants can compromise pulpal vitality, often leading to dystrophic calcification, root canal therapy, or potential extraction.[1-4] 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.[5,6] MTA has been used experimentally for a number of years and was approved for human usage by the FDA in 1998.[7]

A major difficulty in obtaining successful results with pulp therapy is the prevention of recontamination by bacteria after treatment has been completed. Through improved visualization via magnification and the use of a caries detector, a dentist can effectively remove the carious lesion while preserving the uninfected dentin that has been shown to remineralize and therefore contribute to the maintenance of pulpal integrity.[8-10]

When pulp exposures are encountered, sodium hypochlorite has been shown to be an effective agent for disinfection, dentinal chip removal, and hemostasis. The most crucial area of concern is the inability to achieve a perfect seal to prevent marginal leakage of the medicament covering the pulp and or the final restoration. While bonding systems and composite resins have greatly improved sealability in recent years, there is clear evidence that, even with the best bonding system, there is microleakage of bacteria around the restoration. Therefore, it is imperative that the materials used to protect the pulp have an enhanced seal to compensate for potential marginal leakage of the restoration.

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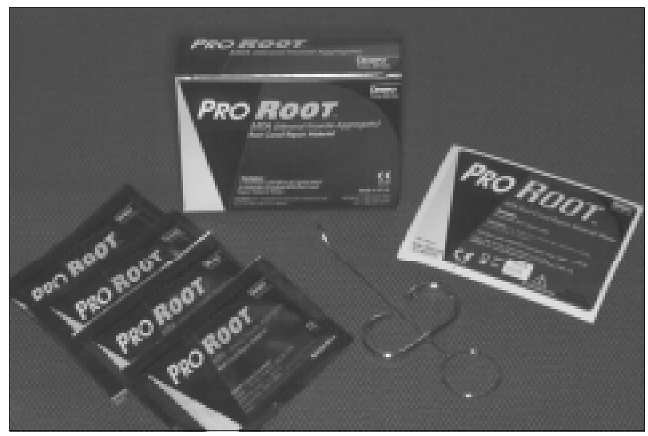

Fig 1. ProRoot™ MTA and delivery instruments

While MTA does allow some microleakage, it has been shown to have superior sealing ability to amalgam, ZOE, or IRM.[11-14] MTA has also been shown to have superior characteristics as a direct pulp capping agent when compared to calcium hydroxide using animal models.[6,16]

MTA is an ash-colored powder made primarily of fine hydrophilic particles of tricalcium aluminate, tricalcium silicate, silicate oxide, and tricalcium oxide[6,7,17] When the material is hydrated it becomes a colloidal gel.[7] The main components of MTA are calcium phosphate and calcium oxide. The material sets in approximately 3-4 hours, and, for radiopacity, bismuth oxide powder has been added, achieving a radiopacity similar to gutta percha.[6,18] The initial pH of MTA when hydrated is 10.2 and the set pH is 12.5, which is comparable to that of calcium hydroxide. 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).[6,17]

The biocompatibility of MTA has been found to be equal or superior to amalgam, IRM, and ZOE.[7,8,17,19,21] In a histologic study of perforation repair using MTA in the canine model, cementum was shown to grow over the MTA with minimal inflammation present, even when the material is extruded beyond the perforation site.[22] In a study on non-human primates where MTA was used as a root end filling material, results showed new bone formation and no periradicular inflammation. Histological sections of resected root dentin revealed that an intact layer of cementum had grown over the MTA and at five months there was a complete regeneration of the dento-alveolar apparatus in 5 out of 6 teeth.[23] Human os-

Fig 2. Pre-operative radiograph of a 7 year-old with a carious tooth #19 with open apecies.

teoblasts were studied in vitro and it was found that MTA stimulated the release of cytokines and the production of interleukin.[20,24,25] The material has also been show to have antimicrobial properties similar to that of amalgam, ZOE, and SuperEBA.[26] MTA has been found to have low cytotoxicity when compared with IRM and Super EBA.[6,14,27]

The setting ability of MTA is uninhibited by blood or water.[12] In fact, Arens et al recommended covering MTA with a wet cotton pellet and IRM to gain a better setting of the material.[18] Sluyk et al supported the use of the wet cotton pellet and showed that the resistance to dislodgement of the MTA was significantly higher at 72 h than it was at 24 h.[14] This slower setting time may also be an advantage in that it reduces the amount of setting shrinkage, which may help explain MTA's low microleakage.[11] It is important to note that because of the initial ease of displacement of MTA, all irrigation should be done prior to placing the MTA.

Tulsa Dental markets MTA as ProRoot™. ProRoot™ comes in a box of 5 one-gram packets with a carrier at a cost of approximately $300 (Fig 1). According to Tulsa Dental, each packet is intended for one time use only. However, if a treatment procedure requires only a small amount of MTA to be utilized, the authors recommend that the unused portion can be stored for future use in sterilized empty film canisters, preventing hydration. The manufacturers guidelines recommend that MTA should be mixed with the ProRoot liquid microampules (sterile water) included with the MTA packets. The material can be placed in the tooth with the included Tulsa carrier, an amalgam carrier, Messing gun, or a hand instrument.

MTA has been demonstrated to have diverse applications for all fields of dentistry. These indications include direct pulp capping, repair of internal resorption, root end filling, apexification, and repair of root perforations. From a pediatric standpoint, the most important indications are direct pulp capping and apexification.

The following illustrates the authors' recommendations on treatment procedures based on review of the literature and their previous clinical experience.

Direct pulp capping

The most important step is case selection. MTA has been highly clinically successful, but no restorative material will succeed if the pulp is irreversibly inflamed. The patient should be thoroughly interviewed to determine any history of symptoms in the tooth in question. Spontaneous pain or a constant dull aching pain is indicative of a necrosing pulp beyond repair.[28] A tooth with this type of symptomatology is not appropriate for capping with MTA. Asymptomatic teeth testing normal to the CO_2 ice test have been shown to attain the highest rate of clinical success. However, the use of MTA has been successful in teeth with a history of recent onset of mild sensitivity to chewing or temperature.

A study by Matsuo et al determined that the degree of hemorrhaging on pulpal exposure was the only statistically significant predictor of clinical success. The age or sex of the patient, history of spontaneous pain, hot or cold sensitivity, or the size of the exposure were all found to be statistically insigificant.[29] It should be left to the judgment of the clinician when it comes to determination of the survivability of the pulp.

There should be no purulent exudates, indicating pulpal necrosis, or excessive, uncontrollable hemorrhage on exposure. Clinical success is likely if hemostasis is achieved within approximately 5-10 minutes, using a cotton pellet soaked in 5.25% NaOCl. There should be no radiographic evidence of periapical or furcal lesion and the tooth should demonstrate only physiologic mobility (Fig 2).

Once the case has been selected, the tooth should be anesthetized and isolated with a rubber dam. The caries should be removed under magnification using a caries detector with slow speed round burs and spoon excavators. Once caries has been entirely removed, irrigate with 5.25% NaOCl for 5-10 minutes to achieve hemostasis and ensure complete debridement.[30,31] Rinse out the NaOCl and ensure that the chamber is debris free. Once MTA has been placed, no further irrigation can be accomplished, since the unset MTA can be easily washed out. Then place a 1-1.5 mm thick layer of freshly mixed MTA directly over the exposed pulp. Place a wet, thinned, flattened cotton pellet over the MTA. The cotton pellet provides the moisture MTA requires for a proper set. Due to its hygroscopic nature, Cavit absorbs water and can be inflammatory to vital pulp and therefore, should not be used as a temporary in vital teeth. Temporize with either light cured Photocore, IRM, or other suitable material (Fig 3).

The patient should return one week later for final restoration. At this time, the temporary and cotton pellet should be removed and vitality reassessed. Test for adequate setting of MTA using a spoon to carve around the edges of the material and remove residual cotton fibers, which frequently adhere to the set MTA. The instrument should be kept as far as possible from any previous exposure sites. The MTA should be the same

Fig 3. Immediate post-operative radiograph: MTA, Cotton pellet, Photocore Temporary placed.

Fig 4. 17 months post-treatment radiograph. Patient is asymptomatic.

hardness and consistency of a set concrete. Once proper setting of MTA has been ascertained, the tooth can be restored with bonded composite or another restoration of the clinician's choice. The final restoration should be bonded or placed directly over the set MTA.

The patient should be checked at six months via radiographs and cold test to monitor vitality (Fig 4).

Apexification

MTA may provide an improvement over standard calcium hydroxide therapy for immature, non-vital, permanent teeth that have been traumatized and which require pulp therapy. Although MTA and calcium hydroxide both exhibit similar alkaline pH levels, MTA also shows excellent marginal adaptability and is non-resorbable.[20] These important physical characteristics of MTA allow apexification cases to be restored after approximately two weeks as opposed traditional calcium hydroxide therapy, where apexification may require many months.[32] Another distinct advantage of treatment with MTA as noted by the authors is that follow-up radiographs may indicate continual apexogenesis of immature root apices.

After rubber dam isolation, extirpate the pulp and clean the root canal system using endodontic instruments and 5.25% NaOCl irrigation. Place calcium hydroxide paste in the root canal system for one week to fully disinfect the canal system. When the patient returns in one week, rinse the calcium hydroxide paste from the root canal system with NaOCl irrigation and dry with paper points. Place MTA in the canals and condense to apical end of the root to create a 3-4 mm apical plug. Radiographically, check the extension and quality of fill. Place a moist cotton pellet or cut paper point in the canal and close the access cavity with IRM or Cavit (Fig 5).

The patient can return in one week for obturation of the rest of the canal or the final obturation delayed until healing is completed. The canal can be obturated with thermoplastic gutta percha and sealer or with composite in thin walled teeth. A more expensive, but an effective, canal obturation technique in posterior teeth is to fill the entire canal with MTA.

However, filling the entire canal of anterior teeth with MTA should not be undertaken, as there is a risk of MTA leaching towards the clinical crown resulting in a dark appearance of the crown. Tulsa Dental is currently developing a lighter color MTA for use in anterior teeth. The patient should be recalled at 2-3 months intervals for radiographic and clinical assessment of periradicular healing (Figures 6 and 7).

Repair of failed calcium hydroxide therapy

Virtually the same technique can be used for traumatized teeth that show resorption in conjunction with failed calcium hydroxide therapy. The radiograph shows an immature maxillary central incisor replanted two hours post avulsion (Fig 8). The tooth was repositioned and stabilized with a semi-rigid splint. The patient was briefly lost to followup and returned to the clinic 4 weeks post trauma, at which time external resorption was noted on the radiograph (Fig 9). Calcium hydroxide was placed, but when the patient returned three weeks later, the resorption had increased. The calcium hydroxide was removed and MTA placed following the same clinical sequence as for apexification (Fig 10). By 14 weeks post trauma (7 weeks after MTA placement), the resorption was healing. On recall at 10 months, the external resorption had ceased and the periapical lesion was healing. The patient was asymptomatic (Fig 11).

Conclusion

Mineral trioxide is a new material that possesses numerous exciting possibilities for pulpal therapy. No longer are immature permanent teeth with deep carious lesions or traumatic pulp exposure destined for endodontic therapy. Although this material has not been on the market in the United States long enough for long-term studies to be completed, the animal studies and clinical results to this point are highly encouraging.

The next step is well-controlled clinical studies with long-term followup to verify the promising short-term outcomes. Certainly MTA cannot be used to save every tooth with pul-

Fig 5. MTA, Cotton pellet, photocore temporary.

Fig 6. 2 months post-trauma Apexogenesis.

Fig 7. 16 months post trauma patient asymptomatic.

Fig 8. Replantation of tooth left central incisor, 2 hours post-complete avulsion.

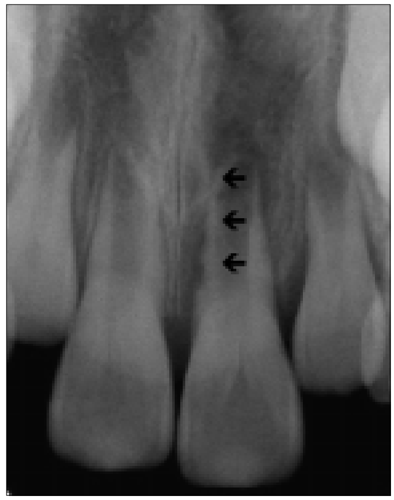

Fig 9. 1 month post-trauma. Note external resorption mesial of the left central incisor.

Fig 10. 8 weeks post-trauma radiograph. MTA placed.

Fig 11. 10 months post-trauma radiograph. External resorption has ceased and periapical lesion is healing. The patient is asymptomatic.

pal involvement; however with meticulous technique, it may serve as an advanced pulp medicament to add to a clinician's armamentarium.

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Abstract of the Scientific Literature

Human pulp response to direct pulp capping with an adhesive system

Recent publications have suggested that total etch/bonding treatment of pulp exposures and restoration with composite resin may lead to pulp repair with induction of a dentin bridge at the site of exposure. The objective of this *in vivo* study was to evaluate clinically and microscopically the response of human pulps capped directly with an adhesive system (ScotchBond Multi-Purpose, SBMP) or calcium hydroxide (Dycal) after a short (9-12 days) or long (53-204 days) experimental period. The authors found that human pulps capped with SBMP exhibited dilated and congested blood vessels associated with moderate inflammatory response in the short time periods evaluated. After 53-204 days, the SBMP-capped pulps presented responses varying from a persistent mild inflammatory response to microabcesses. No dentin bridge was observed in human pulps capped with SBMP. In contrast, calcium hydroxide stimulated early pulp repair and dentin bridging.

Comments: This study demonstrates that direct pulp capping with an adhesive resin system does not induce the development of dentin bridge at the site of pulp exposure, and does not allow for the resolution of inflammatory pulp responses. These histological findings may not be accompanied by clinical symptoms such as spontaneous or provoked pain. In contrast, the majority of the teeth capped with calcium hydroxide presented visible dentin bridges at the time of examination. **JN**

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Abstract of the Scientific Literature

Fracture strength of fragment-bonded teeth

The objective of this *in vitro* study was to measure the strength of intact teeth, and compare it with the strength of fracture-bonded teeth with or without preliminary lining with calcium hydroxide. Sheep incisors were fractured and the crown fragment was re-bonded with an adhesive system (One-Step + Æliteflo) after 3 weeks water storage. In one group, a layer of calcium hydroxide (Dycal) was applied to the dentin before storage in water. This layer of calcium hydroxide was completely removed with a hand instrument before bonding of the fragment. The authors found that the mean fracture strength of lined teeth (9.6 MPa) was significantly lower than that of intact teeth (17.8 MPa) or teeth that did not receive the calcium hydroxide lining before bonding (15.8 MPa).

Comments: This study demonstrates that the application of calcium hydroxide on the dentin of fractured teeth lowers the fracture strength of the bonded fragment, even if the liner is removed mechanically prior to final restoration. **JN**

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Fracture strength of fragment-bonded teeth. Effect of calcium hydroxide lining before bonding. Farik B, Munksgaard EC, Andreasen JO. Am J Dent 13: 98-100; 2000.

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