Mineral Trioxide Aggregate

Excellent results have been reported\textsuperscript{1-4} with the use of mineral trioxide aggregate (MTA) (ProRoot MTA, Dentsply-Tulsa Dental, Tulsa, OK, USA) as a pulp capping agent. When compared with calcium hydroxide, MTA produced significantly more dentinal bridging in a shorter period of time with significantly less inflammation. Dentin deposition also began earlier with MTA.

MTA a biocompatible material has an antibacterial effect similar to that of calcium hydroxide, and has the property of providing a biologically active substrate for cell attachment. This feature makes it effective in preventing microleakage and improves treatment prognosis. MTA stimulated pulp healing with dentin bridge formation and minimal inflammatory reaction in exposed pulps in monkeys.\textsuperscript{4} Its dentinogenetic effect in short-term capping experiments was demonstrated in dogs.\textsuperscript{33} It was demonstrated\textsuperscript{5} that after direct pulp capping in dogs, the underlying pulp tissue was consistently normal. After 2 weeks, the beginning of a hard-tissue barrier was observed, and reparative dentinogenesis was observed after 3 weeks, associated with a firm fibrodentin matrix. This material has been approved for use by the ADA. A preliminary study in human teeth reported better results with MTA than with calcium hydroxide.\textsuperscript{6}

In studies\textsuperscript{7} of the effects of MTA on cementoblast growth and osteocalcin production in tissue cultures, the results showed MTA was cementoconductive with cementoblast attachment and growth as well as the production of mineralized matrix gene and protein expression.

Sarkar and associates\textsuperscript{8} reported the interactions of MTA with a synthetic tissue fluid composed of a neutral phosphate buffer saline solution and the dentin of extracted teeth. Endodontically prepared teeth filled with MTA and stored in this synthetic tissue fluid for 2 months produced an adherent precipitate interfaced with the dentin wall. This precipitate had the same composition and structure as hydroxyapatite. It was concluded that calcium, the dominant ion released from MTA, reacts with phosphate in tissue fluid, producing hydroxyapatite, and that the sealing ability, biocompatibility, and dentinogenic activity of the material occur because of these physiochemical reactions.

In the pulp capping or pulpotomy procedure MTA is placed directly over the exposure site. Because MTA requires 3 to 4 hours to set, a hard-setting material must be placed over it before the final restoration is completed. Following application of the MTA, a thin layer (1/2 to 1 mm thick) of flowable light curable composite resin is flowed over the
material and light cured. The remaining tooth structure is etched and a bonded restoration is placed. Although the flowable composite directly over the MTA is not bonded, by careful placement of the material, most of the prepared dentin and enamel is available for bonding, thus not weakening the seal of the restoration. In the event of failure of direct pulp capping, the option of endodontic therapy usually exists.

Pulp capping should not be considered for primary teeth with carious pulp exposures or for permanent teeth with a history of spontaneous toothache, radiographic evidence of pulpal or periapical pathosis, calcifications of the pulp chamber or root canals, excessive hemorrhage at the exposure site, or exposures with purulent or serous exudates.

**Apical Barrier Techniques**

While apexification with pastes has been highly successful, alternative treatments using artificial barriers that allow immediate obturation of the canal have replaced these procedures. The use of MTA as the apical barrier has become the standard as most of the inherent disadvantages of calcium hydroxide therapy, including increased cost, patient compliance with the multiple appointments and possible root fracture can be eliminated.

The use of MTA as an apical barrier was reported in 1996. Subsequent research showed that MTA induced apical hard tissue formation more often than osteogenic protein-1 or calcium hydroxide while producing less inflammation.

MTA is a hydrophilic material requiring the presence of moisture to set. Hydration of the powder produces a colloidal gel with a pH of 12.5 that solidifies into a hard structure requiring a setting time of approximately 4 hours. Dye and bacterial leakage studies have shown the seal of MTA to be superior or equal to amalgam, Super-EBA, and IRM, common materials used as root-end fillings. In a dye study in which the same materials were contaminated with blood, MTA leaked significantly less than the others. Also, the presence or absence of blood had no significant effect on the amount of dye leakage.

MTA is less cytotoxic than amalgam, IRM, or Super-EBA. Studies have demonstrated MTA to be biocompatible, free of inflammation, and demonstrated direct bony opposition on implanted specimens. MTA has been shown to be osteoconductive and promote osteogenesis when implanted intraosseously. MTA offers a biologically active substrate for bone cells and stimulates interleukin production. Torabinejad and coworkers have demonstrated a complete layer of cementum when using MTA as a root-end filling in monkeys. Further research has proven MTA to be cementoconductive.
in tissue cultures with cementoblast attachment to the material and production of mineralized matrix. When compared with Ketac-Endo (glass ionomer), MTA exhibited better biologic properties, was free of inflammation, and demonstrated total closure of the apical foramen with cementum.26

**MTA Barrier Technique**

In the apexification technique the canal is cleaned and disinfected as in any endodontic procedure. The use of a rubber dam is mandatory.

The length of the canal is established and the canal is cleaned as thoroughly as possible with frequent sodium hypochlorite irrigation to remove debris from the canal. Cleansing is complicated because the canal diverges apically. Sonic and ultrasonic devices are extremely helpful in debriding the canal. After thorough debridement the canal is dried and medicated with a slurry of calcium hydroxide paste and sealed with a temporary filling.

The physical environment has been shown27 to have an effect on MTA. Acidic environment of pH 5 adversely affects the physical properties and hydration of MTA as well as weakening the microhardness. Thus an acidic environment as would be present with infection or suppuration must be cleared up before application of MTA.

When the tooth is free of signs and symptoms of infection, it is reisolated with the rubber dam and the canal reentered. It is usually not necessary to anesthetize the tooth at this appointment. The canal is thoroughly flushed and cleansed of all the calcium hydroxide medicament. It is then dried and a plug of MTA is compacted into the apical 4 to 5 mm. Study28 of various thicknesses of MTA used as a root-end filling has shown 4 mm was significantly more effective than lesser amounts in preventing dye leakage. The properly mixed MTA is placed into the access opening with an amalgam carrier and condensed into the apical area with the blunt end of very large paper points. For the initial condensation, the paper points are measured 1 to 2 mm short of the working length to prevent apical extrusion of the MTA. Carefully measured large blunt ended pluggers may also be useful in packing the material. Assessment of the adequacy of the apical plug is verified radiographically. Once a plug of 4 mm is achieved, all excess MTA is removed from the canal. The walls of the canal are scrubbed with dampened large paper points and cotton tipped plastic applicators (normally used to apply bonding agents) to remove all MTA smear from the inner root surface. This is necessary because the
remainder of the canal will be obliterated with bonded composite resin to strengthen the root. Otherwise, there will not be a bonded resin-dentin interface.

Moisture to promote setting is provided by placing a very wet cotton pellet in the canal to provide moisture for the setting reaction. The pellet should not contact the MTA since fibers of the cotton will become impregnated into the material. Excess water in the access preparation is dried with cotton pellets and the opening sealed with cavit. At a subsequent appointment, the tooth is reisolated and the cavit and cotton removed. Hard set of the MTA is verified with an endodontic file or probe. If for some reason the MTA has not hardened, the canal can be recleansed and the procedure repeated.

**Restoration After Apexification**

Because of the thin dentinal walls there has traditionally been a high percentage of root fractures during and after apexification. Clinically, the placement of acid-etch bonded composite resin has virtually eliminated these fractures. Restoration of the immature tooth after placement of the apical plug of MTA must be designed to strengthen the tooth as much as possible. The use of newer dentinal bonding techniques has been shown to strengthen endodontically treated teeth to levels close to that of intact teeth. Another recent study demonstrated significantly greater resistance to root fracture after placement of a 4 mm thick apical plug of MTA followed by an intracanal composite resin when compared with MTA followed by gutta-percha and sealer. Other research using resin modified glass ionomer with a translucent curing post showed significantly increased resistance to root fracture as compared with gutta-percha alone in teeth with open apices.

Prior to placement of the composite resin, the dentin is acid etched, and a dentin bonding agent is applied to the internal surfaces of the canal and light cured. The etching and bonding is directly over the MTA plug and no gutta-percha is placed in the canal.

Unless a post is needed, the following technique is recommended for placement of the composite resin. Following acid etching and placement of the dentin bonding agent, 2 mm increments of condensable light cure composite resin Esthet-X (Dentsply Caulk, Milford, DE) or Alert (Pentron Clinical Technologies LLC, Wellingford, CT) are placed in the canal and cured until the canal and access opening are obliterated. Utilization of this technique strengthens the weak roots and has virtually eliminated fractures.
If a core is needed for crown placement, a Luminex post (Luminex System, Dentatus USA, New York, NY) without serrations is used to create post space. In this technique, a light-curing composite resin is placed in the canal, care being taken to avoid trapping of bubbles. The Luminex post is placed to the depth of the preparation and the composite cured by transmitting light through the post. Because the composite does not bond to the smooth post, it can be gently removed and a corresponding metal Dentatus post cemented into the space with a resin cement. A composite buildup for crown retention may then be completed.

REFERENCES


