Mineral Trioxide Aggregate: A Comprehensive Literature Review—Part II: Leakage and Biocompatibility Investigations

Mahmoud Torabinejad, DMD, MSD, PhD, and Masoud Parirokh, DMD, MS*[†]

Abstract

Introduction: Mineral trioxide aggregate (MTA) was developed because existing materials did not have the ideal characteristics for orthograde or retrograde root-end fillings. MTA has been recommended primarily as a root-end filling material, but it has also been used in pulp capping, pulpotomy, apical barrier formation in teeth with open apexes, repair of root perforations, and root canal filling. Part I of this literature review presented a comprehensive list of articles regarding the chemical and physical properties as well as the antibacterial activity of MTA. The purpose of part II of this review is to present a comprehensive list of articles regarding the sealing ability and biocompatibility of this material. **Methods:** A review of the literature was performed by using electronic and hand-searching methods for the sealing ability and biocompatibility of MTA from November 1993–September 2009. **Results:** Numerous studies have investigated the sealing ability and biocompatibility of MTA. **Conclusions:** On the basis of available evidence it appears that MTA seals well and is a biocompatible material. *(J Endod 2010;36:190–202)*

Key Words

Apical plug, biocompatibility, cytokine production, marginal adaptation, mineral trioxide aggregate, MTA, root-end filling, sealing ability, signaling molecule

From the *Department of Endodontics, School of Dentistry, Loma Linda University, Loma Linda, California; and [†]Department of Endodontics, School of Dentistry, Oral and Dental Diseases Research Center, Neuroscience Research Center, Iranian Center for Endodontic Research, Kerman University of Medical Sciences, Kerman, Iran.

Address requests for reprints to Mahmoud Torabinejad, DMD, MSD, PhD, Professor and Director, Endodontic Residency Program, Department of Endodontics, School of Dentistry, Loma Linda University, Loma Linda, CA 92350. E-mail address: mtorabinejad@llu.edu.

0099-2399/$0 - see front matter

doi:10.1016/j.joen.2009.09.010

Most endodontic failures occur as a result of leakage of irritants from pathologically involved root canals into the periradicular tissues; therefore, a repair material should provide a good seal to an otherwise unobturated root canal or improve the seal of an existing filling material. An adequate apical seal is a major factor for improving endodontic success (1). One of the most important criteria for an ideal endodontic material is its sealing ability and marginal adaptation (2). The sealing ability of original mineral trioxide aggregate (MTA), other types of MTA, and its new compositions has been tested by leakage studies (dye, fluid filtration, bacteria and bacterial by-products) and scanning electron microscopy (SEM). Because materials used in endodontics are frequently placed in close contact with the periodontium, they also must be biocompatible with host tissues. The purpose of this literature review is to present a comprehensive list of articles from November 1993–September 2009 regarding the sealing ability and biocompatibility of MTA.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for this literature review were identical to those used for Part I of the review (3).

Search Methodology

An electronic search was conducted in the PubMed and Cochrane databases with appropriate MeSH headings and key words related to the sealing ability and biocompatibility of MTA. The hand-searching methodology used in this literature review was identical to that used for Part I of the review (3).

Leakage Studies

Leakage investigations on MTA have evaluated the sealing ability of the material as a root-end filling material, perforation repair material, root canal filling, coronal and apical barrier material (4, 5–85).

Leakage of MTA as a Root-end Filling Material and Other Root-end Filling Materials to Materials Tested

The sealing ability of MTA and other root-end filling material has been tested by using dye, fluid filtration, protein leakage, and bacterial leakage methods.

Dye Leakage. Numerous dye leakage studies have been performed on MTA when used as a root-end filling material (4–20). Various types of dyes have been used to evaluate MTA's sealing ability, including methylene blue, fuchsin, rhodamine B, silver nitrate, India ink, and Pelikan ink.

Results from most of these investigations indicated that MTA exhibits significantly less dye leakage in comparison with Super EBA, amalgam (4–7, 9, 10), and intermediate restorative material (IRM) (5, 7, 11). An investigation compared dye penetration in roots filled with MTA as a root canal filling material (in an orthograde manner) with fresh MTA as a root-end filling material (in a retrograde manner). Results showed no significant difference between the 2 groups (8).

Gondim et al (17) investigated microleakage of three root-end filling materials with or without finishing. Their results revealed that Pro Root MTA displays significantly less mean dye microleakage as a root-end filling material than Super EBA and IRM.

Variation in the finishing techniques does not significantly affect dye leakage of the tested materials (17).

In contrast to these studies, 2 investigations showed the inferiority of MTA in terms of dye (India ink) penetration when compared with Super EBA and Geristore (15, 16). Tobón-Arroyave et al (16) attributed more leakage in MTA specimens to placing the white MTA (WMTA) samples in dye before complete setting.

Rahimi et al (85) compared dye leakage of different depths of MTA when used as a root-end filling material. They placed their samples in phosphate-buffered saline (PBS) for 48 hours before dye exposure. Dye penetration was not significantly different between 1-mm, 2-mm, or 3-mm thicknesses of MTA.

One investigation reported that the amounts of dye leakage of MTA without calcium phosphate cement (CPC) matrix samples was greater in acidic pH than in a neutral environment (19).

A dye leakage study testing different dental materials showed a decoloration effect of MTA with methylene blue (20). The formation of calcium hydroxide (CH) after the reaction of MTA with moisture (86, 87) might be the reason for methylene blue decoloration when the dye is used for leakage evaluation. The same finding was observed when the roots were filled with CH (20). A comparison of WMTA and a glass ionomer cement (GIC) by using rhodamine B (with varying pH values) showed that WMTA is affected less by changes in dye pH; however, more dye extension was observed through the material rather than at the tooth-to-material interface (21). Another dye leakage study with India ink showed penetration of dye through WMTA (16).

Storage of the teeth in formalin before a dye study might also affect leakage results. An investigation on various root-end filling materials revealed that storing the teeth in formalin for 4 weeks significantly decreases the amount of dye leakage in comparison to that observed with freshly extracted teeth (15). A recent investigation evaluated the effect of the presence of cracks on sealing ability and quality of filling with a GIC or WMTA as root-end filling materials. Both materials showed similar sealing ability, but WMTA had better obturation quality in comparison to Fuji IX (88).

On the basis of available information, it appears that MTA is one of the most resistant root-end filling materials to dye penetration. Different factors influence MTA leakage. They include thickness of the dentinal wall (18), the dye pH (19), the type of dye (12, 14, 20), pretreatment with chelating agents (13), the tooth storage environment before the experiment (15), and the setting status of MTA before its placement in the dye (16).

Fluid Filtration. Fluid filtration investigations showed the superiority of MTA compared with amalgam (22–25) and Super EBA (24).

In an investigation with 2 different cavity preparation techniques (erbium:YAG laser and ultrasonic), IRM, Super EBA, and MTA were used as root-end filling materials. MTA showed significantly less leakage than the other test materials when a laser was used for cavity preparation (26). Another fluid filtration study evaluated the sealing ability of MTA when used as a root canal filling material followed by root-end resection. No significant leakage was observed when at least 3 mm of MTA remained after root-end resection. However, the authors reported significantly more leakage when 2 mm or less thickness of MTA remained after root-end resection (27).

De Bruyne et al (28) used fluid filtration and capillary flow porometry for comparing leakage of WMTA with Fuji IX and IRM. After 6 months, Fuji IX leaked significantly less than IRM and MTA. The same investigators repeated the study with capillary flow porometry and reported that IRM and WMTA leak significantly less than Fuji IX (29). The authors attributed the conflicting results to the size of the root-end cavity preparations and the use of human teeth in the first study in contrast with bovine teeth in their second study (29). Nakamichi et al (30) compared the adhesive strength of 5 dental materials to bovine and human teeth. They found no statistically significant difference between human and bovine teeth, although the mean values were always slightly lower for bovine teeth.

Most fluid filtration investigations have shown the superiority of MTA as a root-end filling material in comparison to other currently used root-end filling materials.

Protein Leakage. Valois and Costa (31) used bovine albumin for evaluating the influence of the thickness of MTA on the sealing ability of this material as a root-end filling material. A 4-mm thickness of MTA leaks significantly less than lesser thicknesses of the material. Another study evaluated the effect of pH on protein leakage of WMTA (32). Teeth that were stored in acidic environments had significantly lower resistance to leakage than teeth that were stored under high pH conditions.

On the basis of limited available data and using protein as a tracer, it appears that a thin layer of MTA and acidic conditions adversely influence the leakage of MTA to protein leakage.

Bacterial Penetration. A large number of bacterial penetration investigations have been performed on MTA, comparing it with other currently used root-end filling materials (33–40). These studies have used different species of microorganisms to test bacterial penetration. The majority of the studies have compared amalgam and MTA (33–35, 40); most of them showed that MTA is more resistant to bacterial penetration than amalgam (33, 34, 40). In contrast, one investigation reported no significant difference in bacterial penetration between the 2 materials (35). Many bacterial penetration studies demonstrated the superiority of MTA to Super EBA (33, 34, 38). Conversely, others have shown no significant difference between the 2 materials (36, 37).

In an endotoxin leakage study, MTA was more resistant to leakage than amalgam, Super EBA, and IRM in most time intervals tested (41). Two investigations compared the bacterial penetration of IRM with MTA, showing the superiority of MTA (33, 34). Other studies showed no significant difference between MTA and Geristore (36), hydroxyapatite (HA) (37), a composite, amalgam with Pro-Bond dentin bonding agent (35), and Resilon (38).

In an investigation of WMTA as a root-end filling material, the material was contaminated with blood, saline, and saliva. The saliva-contaminated samples showed significantly more bacterial leakage in comparison with uncontaminated WMTA (39).

In an investigation simulating an environment similar to that of the human body, researchers immersed teeth with MTA as a root-end filling either in PBS or in normal saline for 1 month and showed formation of HA over MTA in all teeth placed in PBS and significantly higher resistance to *Enterococcus faecalis* penetration in this group in comparison to teeth placed in normal saline (43).

Available data showed that the type of microorganism and the length of leakage evaluation directly influence the results of bacterial leakage investigations. A meta-analysis of the results of current studies showed that MTA prevents bacterial and dye penetration better than Super EBA, amalgam, or IRM (44).

Leakage of MTA as a Perforation Repair Material

Many restorative materials have been used for repairing furcation perforations (45). Various *in vitro* methods have been used to compare MTA with these materials (46–55).

Dye Leakage Investigations. The superiority of MTA over IRM and amalgam was initially established in a study that used MTA as an endodontic filling material for repairing lateral root perforations (46). Gray MTA (GMTA) has superior sealing ability as a perforation