Mineral Trioxide Aggregate: A Wondrous Savior

A.K.M. Shafiul Kadir[1]
Mahfuzur Rahman[2]
Najmul Haque Sajib[3]
Abdullah Al Rabbi[4]
Jannatun Naim Nipun[5]

[1]University of Rajshahi, Rajshahi, Bangladesh
[2]Marks Medical College, Dhaka, Bangladesh
[3]Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh
[4]University of Rajshahi, Rajshahi, Bangladesh
[5]Private Practitioner, Chittagong, Bangladesh

Abstract. From the beginning of advancements in dentistry, various materials are being tested for their repair ability of perforation but none seem to fulfill the criteria perfectly. MTA is a miracle in the recent advancements in dentistry and have shown versatility and potentiality among other materials. As it is derived from Portland cement material, it has biocompatibility and is non-toxic in nature. Unlike other perforation repair materials, MTA materials are proved to be better and tend to be micro-leakage proof. Various treatments like pulp capping, pulpotomy, apexogenesis and apexification treatments can be done excellently by MTA. In this present article the versatility of MTA in endodontic practice will be discussed.

Key words: mineral trioxide aggregate, biocompatibility, uses in dentistry.

Introduction

Different endodontic procedures like apical surgery, perforation repair, apexification treatment are done every year. Sometimes it becomes difficult to treat the inflammation of the apical region of the tooth along with surrounding periapical areas conventionally because of the complex anatomy of the root apex and/or canal morphology. Procedural accidents like root perforation may occur during biomechanical preparation of the root canal system or during post-space preparation also demands for surgical procedures. Endodontic surgery is one of its kind for the resolution. An important step in surgical treatment is to place the material which can seal the root canal contents from the periradicular tissues and repair root defects. However, external inflammatory processes can lower the success rate of endodontic surgery (Chong, 2004: 123-47). The criteria of an ideal endodontic repair material should meet the following points: 1) well adherence to the tooth structure, 2) maintenance of a sufficient seal, 3) insolubility in tissue fluids, 4) dimensional stability, 5) non-resorbability, 6) radiopacity, and 7) biocompatible rather than bioactive (Johnson, 1999: 398-404, Kratchman,2004: 291-307). A number of materials such as amalgam, zinc-oxide-eugenol cements, composite resin, and glass-ionomer cements were used but none of these materials fulfill the criteria of an ideal retrograde fillings and perforation repair material (Johnson, 1999: 398-404, Bryan, et al., 1999, 274-280). Mineral trioxide aggregate (MTA), a new root-end filling endodontic material, was introduced by Mahmoud Torabinejad at the university of Loma Linda, in 1990. The first study on this material was published by Lee et al in 1993 and It received acceptance by the U.S. Food and Drug Administration in the year 1998 (Torabinejad: white tooth filling and material use,1995; Lee et al, 1993: 541-544; Schwartz et al., 1999: 967-975) and became commercially available as ProRoot MTA (Tulsa Dental Products, Tulsa, OK, USA).

MTA has been found to be fulfilling the above requirements of an ideal retrograde root canal filling material because it is micro-leakage proof, biocompatible, has an osteo-inductive property and has an ability to set in the presence of moisture (Hegde et al., 2012: 171-173). MTA is now most widely used in endodontics for pulp capping, pulpotomy, repair of root perforations, root end filling, root canal filling, and apical barrier formation in teeth with necrotic pulps and open apices (Varghese et al., 2014: 19-22).

Types and Composition of MTA

MTA comprises of fine hydrophilic particles like Tri-calcium silicate, Tri-calcium aluminate, Tri-calcium oxide, Silicate oxide and bismuth oxide. It also contains trace amounts of mineral oxides, which acts and changes its physical and chemical properties.

Based on the color, MTA is available in two types:

1. Grey MTA (GMTA).
2. White MTA (WMTA).

The difference between these two types is described in the Table 1.

Table 1. Compositional differences between Grey and White MTA

Components (phases) in Grey MTA	Components (phases) in White MTA
Tricalcium silicate $(CaO)_3.SiO_2$	Tricalcium silicate $(CaO)_3.SiO_2$
Dicalcium silicate $(CaO)_2.SiO_2$	Dicalcium silicate $(CaO)_2.SiO_2$
Tricalcium aluminate $(CaO)_3.Al_2O_3$	Tricalcium aluminate $(CaO)_3.Al_2O_3$
Tetracalcium aluminoferrite $(CaO)_4.Al_2O_3.Fe_2O_3$	Gypsum $CaSO_4 \cdot 2\ H_2O$
Gypsum $CaSO_4 \cdot 2\ H_2O$	Bismuth oxide Bi_2O_3
Bismuth oxide Bi_2O_3	

Source: (Asgary et al., 2005: 101-103; Torabinejad: white tooth filling and material use, 1995)

Manipulation and Mechanism of Action of MTA

To obtain putty like consistency, MTA can be mixed on mixing pad or, on a glass slab using a plastic or metal spatula in the powder-water ratio of 3:1. Mixing time should be less than 4 minutes. This mix is then quickly placed in the desired location using ultrasonic condensation, plugger, paper point or specially designed carriers and messing gun and condensed lightly with a moistened cotton pellet as because if the mix is left open on the glass slab after mixing, it undergoes dehydration and dries into a sandy mixture (Sluyk et al., 1998: 768-771; Torabinejad and Chivian, 1999: 197-205). Because of the hydrophilic nature of MTA, moisture is needed for setting, that’s why it is strongly advised to place a wet cotton pellet over the MTA in the first visit to improve the flexural strength of the set cement followed by replacement by a permanent restoration at the second visit (Aminoshariae, 2003: 679-82). Excess moisture results in a mix that is ‘soupy’ and difficult to use. Hand condensation has better adaptation of MTA to the walls with fewer voids when compared to the ultrasonic method as the condensation pressure may affect the strength and hardness of MTA (Nekoofar et al., 2007: 453-61).

When MTA is placed in direct contact with human tissues, it appears that the material does the following (Ravichandra et al., 2011; Varghese et al., 2014: 19-22):

- forms the releases of calcium ions for cell attachment and proliferation.
- an antibacterial environment is created by its alkaline pH.
- cytokine production is modulated.
- migration and differentiation of hard tissue-producing cells is encouraged.
- provides a biologic seal by the formation of Hydroxy apatite, HA (or carbonated apatite) on the MTA surface.

Properties of Mineral Trioxide Aggregate:

1. pH: MTA has a pH of 10.2 immediately after mixing and increases to 12.5 after 3 hours of setting which is almost similar to calcium hydroxide (Torabinejad et al., 1995: 349-353).

2. Compressive strength: The compressive strength of MTA is 40.0MPa at 24 hours and 67.3MPa at 21 days. Compressive strength of Grey MTA is more than White MTA (Torabinejad et al., 1995: 349-353).

3. Radio-opacity: The mean radio opacity of MTA is 7.17 mm which is easy to visualize radiographically (Torabinejad et al., 1995: 349-353). MTA is less radio opaque than IRM, Super EBA, amalgam or gutta-percha and has similar radio-density as Zinc Oxide Eugenol (Islam, 2006: 220-225).

4. Solubility: If excess water is used during mixing, solubility may increase. Calcium hydroxide is released if the set MTA is exposed to water which induces cementogenesis property of MTA. Acidic environment does not interfere in the setting reaction (Danesh et al., 2006: 213-219).

5. Marginal adaptation and sealing ability: In presence of moist environment, setting expansion occurs which enhances the sealing ability of MTA. MTA thickness of about 4 mm is sufficient to provide a good seal. Residual calcium hydroxide, Ca(OH)2 particle may interfere with the adaptation of MTA to dentinal wall which causes reduced sealing ability (Torabinejad et al., 1995: 295-299).

6. Antibacterial and antifungal property: MTA has antibacterial effect especially against Enterococcus faecalis and Streptococcus sanguis but no antimicrobial action against any of the anerobes. However, it showed certain effects on facultative bacteria like Streptococcus mitis, Streptococcus mutans, Streptococcus salivarius, Lactobacillus and Streptococcus epidermidis (Al-Hazaimi et al., 2006: 1053-1056; Torabinejad et al., 1995: 403-406). MTA may not be beneficial as a direct antibacterial agent in endodontic practice, since most of the microflora in the root canal is strict anaerobic bacteria with few facultative anaerobes.

7. Reaction with other dental materials: MTA does not react or interfere with any other restorative materials like glass ionomer cements or composite resins. When they are used as permanent filling material, do not affect the setting of MTA when placed over it (Nandini et al., 2007: 167-172).

8. Biocompatibility: MTA is found non- mutagenic, less cytotoxic, well tolerated by the tissues and biocompatible when compared with Super EBA and IRM (Kettering andTorabinejad, 1995: 537-542). MTA has good interaction with periapical and periradicular tissues when treated furcation perforations and osseous repair with MTA (Arens and Torabinejad, 1996: 84-88).

9. Tissue regeneration: MTA has become a potential regenerative material because of its facilitation of consistent cementum overgrowth by activating

cementoblasts and regeneration of periodontal ligament. It also allows bone healing and eliminates symptoms in many cases (Pelliccioni et al., 2004: 167-173).

10. Mineralization: MTA has tri-calcium oxide which interacts with tissue fluids to form calcium hydroxide, Ca(OH)2 resulting in hard tissue formation in a similar manner to that of Ca(OH)2 but the structure is well integrated and faster in MTA than Ca(OH)2. MTA also proves to be better at stimulating reparative dentin formation and maintaining the integrity of the pulp (Tziafas et al., 2002: 245-254).

Application of MTA in Dentistry

In Primary Tooth:

A. Direct Pulp Capping: MTA is a very reliable material for direct pulp capping teeth especially with reversible pulpitis, as analysed by various histological studies. MTA appears to be more effective than calcium hydroxide for maintaining long-term pulp vitality after direct pulp capping and shows much promise in the long term health of pulps that have been capped using MTA (Dominguez et al., 2003: 324-333).

B. Pulpotomy: pulpotomy procedure involves removing only part of the pulp, eliminating tissues that have inflammatory or degenerative changes and leaving intact the underlying healthy pulp. MTA was tested and found to be an ideal material with low toxic effects, increased tissue regenerating properties and good clinical results (Naik and Hegde, 2005: 13-16).

In Immature Tooth:

Apical Barrier in Open Apices (Apexification): The purpose of apexification is to obtain an apical barrier so that the obturation material can be prevented from extrusion in the periapical space. The disadvantage of using calcium hydroxide is the extended time taken for the completion of the procedure and reduction in fracture resistance. When the effectiveness of Ca(OH)2 versus MTA was compared, MTA has been found effective for the treatment an open apex cases due to lesser period of time with effective and predictable results (Kratchman,2004: 291-307).

In Permanent Tooth:

A. Obturation of the Canal (Root Canal Sealer): When compared with glass ionomer root canal sealer, MTA leads to the closure of main foramen by the formation of new cementum with the absence of inflammatory cells after several months (Torabinejad and Chivian, 1999: 197-205). Dentin- MTA interfacial layer is formed in the presence of phosphate when MTA is used as a root canal sealer when it is compacted against the dentin. This dentin-MTA interstitial layer has a close resembles with the hydroxy-apatite of dentin in its structure and composition when it is seen under x-rays diffraction and analysis (Islam, 2006: 220-225).

B. Root-End Filling: Endodontic surgery followed by root-end filling may be necessary at times for certain teeth where routine endodontic treatment is not possible. This procedure involves surgical exposure of the root apex, root resection and plugging the apical foramen with a suitable material that provides complete apical seal, is nontoxic, non-resorbable, dimensionally stable and radio opaque (Torabinejad et al., 1995: 295-299). Many materials have been used as root-end filling agents but the main disadvantage is their failure to prevent leakage and the lack of biocompatibility. Amalgam was routinely used as a root-end filling material but proved to be much inferior when tested with MTA. MTA treated teeth exhibited significantly less inflammation, more cementum formation and regeneration of periradicular tissues (Torabinejad et al., 1995: 603-608).

C. Repair of Perforation: Root perforation can be iatrogenic or due to severe extension of internal resorption leading to a communication between the root canal and the periodontium. There may be severe inflammation and granulation tissue formation with extensive hemorrhage. Repairing such a communication requires a material that should be biocompatible, should withstand moisture without dissolving and should have good sealing ability. The antimicrobial properties and high pH (12.5) of MTA leads to its repair capacity and numerous other characteristic of MTA also leads to the growth promotion of the cementum and bone formation (Lee, 1993: 541-544).

D. Repair of Fracture:

- horizontal Root Fracture: In case of 3° mobility in upper central incisor with horizontal root fracture, after applying MTA by leaving the apical portion of pulp intact along with removing the coronal fragment, dressing the canal with calcium hydroxide, $Ca(OH)2$ and splinting and then removing the $Ca(OH)2$ and replacing it with MTA and obturating with gutta percha, the tooth becomes asymptomatic (Schwartz et al., 1999: 967-975).

- vertical Root Fracture: By intentional re-implantation or, by flap surgery, the vertical root fracture can be corrected by making a groove along the fracture line and placing MTA in the prepared groove and by instructing to maintain proper oral hygiene (Torabinejad and Chivian, 1999: 197-205).

Conclusion

MTA is a new biocompatible material and exhibits excellent biologic performance when used for root-end fillings, perforations repair, pulp-capping and pulpotomy, and apexification treatment. The favorable biologic performance exhibited by MTA materials is due to hydroxy-apatite formation when these materials are exposed to physiologic solutions. MTA also have a high pH similar to calcium hydroxide and also induces the hard tissue formation often after the use of this substance. As MTA materials are compositionally different than Portland cement, it is not recommended that Portland cement can serve as a suitable MTA substitute. GMTA has been investigated more than the more esthetic WMTA and GMTA showed more desirable biologic response than WMTA. Though the overall results in human studies involving MTA materials are very positive, MTA can be of a great choice in various treatment aspects of endodontics as well as dentistry.

Acknowledgement

We would like to extend our gratitude to Dr. UmmeKulsum, Associate Professor and Head of the Department of Conservative Dentistry in Dhaka Dental College and Hospital, Dhaka, Bangladesh from whom we got our inspiration to write this review article. Without her immense support, it could not be possible.

References

Al-Hazaimi, K., Al-Shalan, T.A., Naghshbandi, J., Oglesby, S., Dimon, J.S.H., Rotstein, I. (2006). Antibacterial effect of two Mineral Trioxide Aggregate (MTA) preparations against Enterococcus *faecalis*and Streptococcus *sanguis*in vitro. *J Endod*,1053-1056.

Aminoshariae, A., Hartwell, G.R., Moon, P.C. (2003). Placement of mineral trioxide aggregate using two different techniques. *J Endod*, 29, 679-82.

Arens, D.E., Torabinejad, M. (1996). Repair of furcal perforations with mineral trioxide aggregate: Two case reports. *Oral Surg., Oral Med., Oral Pathol., Oral Radiol.*, 82, 84-88.

Asgary, S, Parirokh, M, Eghbal, M.J., Brink, F. (2005). Chemical differences between white and grey mineral trioxide aggregate. *J Endod*, 31, 101-103.

Bryan, E.B, Wollard, G., Mitchell, W.C. (1999). Nonsurgical repair of furcal perforations: a literature review. *Gen Dent*, 47, 274-280.

Chong, B.S. (2004). *Managing endodontic failure in practice*. Chicago: Quintessence Publishing Co., Ltd., pp. 123-47.

Danesh, G., Dammaschke, T., Gerth, H.U.V., Zandbiglari, T., Schafer, E.A. (2006). Comparative study of selected properties of ProRoot mineral trioxide aggregate and two Portland cements. *IntEndod J,* 39, 213-219.

Dominguez, M.S., Witherspoon, D.E., Gutmann, J.L., Opperman, L.A. (2003). Histological and scanning electron microscopy assessment of various vital pulp-therapy materials. *J Endod*, 29, 324-333.

Hegde, M.N., Bhat, G., Shetty, P., Thatte, S. (2012). Revascularization of non-vital immature tooth: A case report. *Indian J Dent*, 3(1-3), 171-173.

Islam, I., Chang, H.K., Yap, A.U.J. (2006). X-Ray diffraction analysis of mineral trioxide aggregate and Portland cement. *IntEndod J*, 39, 220-225.

Johnson, B.R. (1999). Considerations in the selection of a root-end filling material. *Oral Surg Oral Med Oral Pathol Oral RadiolEndod*, 87, 398-404.

Kettering, J.D., Torabinejad, M. (1995). Investigation of mutagenicity of mineral trioxide aggregate and other commonly used root-end filling materials. *J Endod*, 21, 537-542.

Kratchman, S.I. (2004). Perforation repair and one-step apexification procedures. *Dent Clin N Am*, 48, 291-307.

Lee, S.J., Monsef, M., Torabinejad, M. (1993). Sealing ability of mineral trioxide aggregate for repair of lateral root perforations. *J Endod*, 19, 541-544.

Naik, S., Hegde, A.M. (2005). Mineral trioxide aggregate as a pulpotomy agent in primary molars, An in vivo study. *Jn.IndianSocPedodPrev Dent*, 23, 13-16.

Nandini, S., Ballal, S., Kandaswamy, D. (2007). Influence of glass ionomer cement on the interface and setting reaction of mineral trioxide aggregate when used as a furcal repair material using laser Raman spectroscopic analysis. *J Endod*, 33,167-172.

Nekoofar, M.H., Adusei, G., Sheykhrezae, M.S., Hayes, S.J., Bryant, S.T., Dummer, P.M. (2007). The effect of condensation pressure on selected physical properties of mineral trioxide aggregate. *IntEndod J*, 40, 453-61.

Pelliccioni, G.A., Ciapetti, G., Cenni, E., Granchi, D., Nanni, M., Pagani, S. (2004). Evaluation of osteoblast-like cell response to Proroot MTA (mineral trioxide aggregate) cement. *J. Mater Sci Mater Med*, 15, 167-173.

Ravichandra, P.V., Jayaprada, R.S, Harikumar, V., Kavita, A. (2011). Mineral Trioxide Aggregate: A Review. Indian Journal of Dental Advancements, 03, 593-597. Available at: https://www.researchgate.net/publication/265730242_Mineral_Trioxide_Aggregate_A_Review

Schwartz, R.S., Mauger, M., Clement, D.J., Walker, W.A. (1999). Mineral Trioxide Aggregate: A new material for endodontics. *J Am Dent Assoc*,130(7), 967-975.

Sluyk, S.R., Moon, P.C., Hartwell, G.R. (1998). Evaluation of setting properties and retention characteristics of Mineral Trioxide Aggregate when used as a furcation perforation repair material. *J Endod*, 24, 768-771.

Torabinejad M, Chivian N. (1999). Clinical applications of mineral trioxide aggregate. *J Endod*, 25, 197-205.

Torabinejad M., Hong, C.U., McDonald, F., Pitt Ford, T.R. (1995). Physical and chemical properties of a new root-end filling material. *J Endod*,21, 349-353.

Torabinejad, M., Hong, C.U., Lee, S.J., Monsef, M., Pitt Ford, T.R. (1995). Investigation of mineral trioxide aggregate for root-end-filling in dogs. *J Endod,* 21, 603-608.

Torabinejad, M., Hong, C.U., Pitt Ford, T.R., Kettering, J.D. (1995). Antibacterial effects of some root end filling materials *J Endod*, 21, 403-406.

Torabinejad, M., Smith, P.W., Kettering, J.D., Pitt Ford, T.R. (1995). Comparative investigation of marginal adaptation of Mineral Trioxide aggregate and other commonly used root-end filling materials. *J Endod*, 21, 295-299.

Torabinejad: white tooth filling and material use. US Patent No 5 1995 May; 769:638.

Tziafas, D., Pantelidou, O., Alvanou, A., Belibasakis, G., Papadimitriou, S. (2002). The dentinogenic effect of mineral trioxide aggregate (MTA) in short term capping experiments. *IntEndod J*, 35, 245-254.

Varghese, L., Hegde, M., Shetty, A., Shetty, Ch. (2014). Mineral Trioxide Aggregate: A Review. *Research & Reviews: Journal of Dental Sciences*, 2, 19-22.