



Mineral trioxide aggregate (MTA) - A review

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Abstract

Mineral trioxide aggregate (MTA), is a unique endodontic cement that was initially introduced as a material for root perforation repair by Mahmoud Torabinejad at Loma Linda University in 1993. MTA has been extensively studied and is currently used for perforation repairs, apexifications, regenerative procedures, pulp capping, root end filling materials. This article will review the composition, manipulation, properties, mechanism of action and various clinical applications of MTA in the field of endodontics and pediatric dentistry.

Keywords: mineral trioxide aggregate, MTA, apexification

Introduction

Over the years, various types of dental materials have been developed to serve different purposes and to be applied to multiple scenarios in the field of dentistry. Mineral trioxide aggregate (MTA), is a unique endodontic cement that was initially introduced as a material for root perforation repair by Mahmoud Torabinejad at Loma Linda University in 1993 and was given approval for endodontic use by the U.S. Food and Drug Administration in 1998^[1].

Mineral Trioxide Aggregate (MTA) was originally formulated to provide the physical properties, setting requirements and characteristics necessary for an ideal repair and medicament material. Studies on MTA reveal that it not only exhibits good sealing ability, excellent long term prognosis, relative ease of manipulation and good biocompatibility but favours tissue regeneration as well^[2,3]. MTA material can be used as apical and furcation restorative materials as well as medicaments for apexogenesis and apexification treatments^[4]. In present article, we review the current dental literature on MTA, discussing composition, physical, chemical and biological properties and clinical characteristics of MTA.

Composition of MTA

MTA consists of tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide and bismuth oxide. Its composition is said to be similar to Portland cement except for the absence of bismuth oxide in Portland cement. Bismuth oxide is added (17-18 wt %) to improve the properties and the

radiopacity. The MTA particles are smaller and uniform in size whereas the particle size of Portland cement varies in size^[5]. MTA are of two types- grey and white. The white and grey MTA differs mainly in their content of iron, aluminium and magnesium oxides.⁵ Asgary S *et al.* (2005) claim that these oxides are present in less quantity in white MTA while others claim total absence of these oxides in white MTA. White MTA contains smaller particles with a narrower range of size distribution than grey MTA^[6].

Table 1: Commercially available MTA

Trade name	Manufacturer company
Pro Root MTA	Dentsply Tulsa Dental, Johnson City, USA
White Pro Root MTA	Dentsply Tulsa Dental, Johnson City, USA
MTA-Angelus (Grey)	MTA-Angelus (Grey)
Ortho MTA	Bio MTA, Seoul, Korea
Retro MTA	Bio MTA, Seoul, Korea
MTA Puls	Prevest Denpro Limited
E-MTA	Kids-e-dental
MM MTA	Mico Megha, Besancon, France
Endo Seal	Maruchi, Wonju, Korea
MTA Fillapex	Angelus, Londrina, Brazil

Manipulation of Mineral Trioxide Aggregate (MTA)

Sluyk *et al.* (1998)^[7], Torbinejad *et al.* (1999)^[8] advocated that the powder water ratio for MTA should be 3:1 to obtain putty like consistency. Manipulation can be done on paper pad or on a glass

slab using a plastic or metal spatula. After manipulation mix is placed in the desired location and covered with moistened cotton pellet to prevent dehydration of the MTA and also improves the flexural strength of the set cement. MTA has a pH of 10.2 immediately after mixing and increases to 12.5% after 3 hours almost similar to calcium hydroxide. The mixing time of MTA is crucial. Prolonged mixing can result in dehydration of the mix.⁴ Sluyk *et al.* (1998) suggested that mixing time should be less than 4 minutes. MTA takes long time to set compared to other material^[7]. According to torabinejad *et al.* (1999)^[8] is 2 hours and 45 mins for grey MTA. Islam *et al* claimed it to be 2 hours and 55 mins for grey MTA and 2 hours and 20 minutes for white MTA. Incorporation of accelerators such as sodium phosphate dibasic and calcium chloride may reduce the setting time. Presence of moisture during setting improves the flexural strength of the set cement. Therefore, it is advised to place a wet cotton pellet over the MTA in the first visit followed by replacement by a permanent restoration at the second visit. The long setting time is one of the drawbacks of MTA because of it should not be applied

in 1 visit. Inter-appointment moist cotton palate is required till the final setting of MTA. MTA may be placed into the desired location using a hand instrument or ultrasonic condensation. Pluggers, paper point or messing gun can be used for hand condensation. Ultrasonic condensation is done by first placing a hand instrument such as condenser in direct contact with MTA then an ultrasonic instrument is placed touching the shaft of the hand instrument and activated for several seconds^[4].

Mechanism of Action of MTA^[9]

Once MTA is placed in direct contact with human tissues, it appears that the material;

1. Release of calcium ions for cell proliferation
2. Provide antibacterial environment due to alkaline Ph
3. Modulated of Cytokine production
4. Migration and differentiation of hard tissue producing cells
5. Biological seal by formation of HA (or carbonated apatite) on the MTA surface.

Table 2: Chemical, Physical, and Mechanical Properties of MTA

Property	Feature
Compressive strength	Torabinejad M <i>et al.</i> (1995) studied physical properties of MTA and found that compressive strength at 24 hours 40.0 MPa and at 21 days 67.3 MPa; and in comparison between GMTA and WMTA result showed that compressive strength of Gray MTA > White MTA. ²
Flexural strength	Increase by two sided hydration of MTA ¹⁰
Push-out strength	Increase by moisture ¹⁰
Radio-opacity	Ding SJ (2008) ¹¹ and Shah PMN (1996) ¹² found that MTA has comparable radio opaque as Zinc Oxide Eugenol and it is less radio opaque than Super EBA, IRM, gutta-percha or amalgam..
Marginal adaptation and sealing ability	Bates <i>et al.</i> (1996) ¹³ found that MTA is superior to the other traditional root-end filling materials. Valois <i>et al.</i> (2004) ¹⁴ found that about 4-mm thickness of MTA is sufficient to ensure a good sealing.
Biocompatibility	MTA is not mutagenic and less cytotoxic. ²
Solubility	Low or no solubility. ²
Reaction with other dental materials	MTA does not react or interfere with any other restorative material ¹⁰
Tissue regeneration	Torabinejad <i>et al.</i> (1995) concluded that MTA is potential to activate the cementoblasts and eventually cementum production. ²

Clinical application of MTA

MTA has been used in a wide variety of clinical applications in the pulp therapy of both primary and permanent teeth. (Table no 3)

Clinical application of MTA in primary teeth

Pulp Capping

MTA has been proposed as a potential medicament for capping of pulps with reversible pulpitis because of its excellent tissue compatibility. Since there is no pulpal necrosis, pulp tissue heals faster with MTA. Aeinehchi *et al.* (2003) reported a 0.28 mm thick dentin bridge by 2 months which increased to 0.43 mm by 6 months. The dentin bridge formed with calcium hydroxide was only 0.15 mm by 6 months^[15].

Pulpotomy

The AAPD recommended the use of MTA for pulpotomies of primary teeth with normal pulps or reversible pulpitis when caries removal results in pulp exposure or after a traumatic pulp exposure^[16]. Clinical trials have revealed that MTA's performance is equal or superior to formocresol (FC), ferric sulfate and might be considered as one of the favoured pulpotomy

materials. The introduction of MTA for pulpotomy overcame the drawbacks of FC such as its potential toxicity, caustic nature, tissue irritation and inflammation upon contact with soft tissue. Farsi *et al.* (2005) found that pulpotomized primary molars treated with MTA had significantly more success than those treated with FC^[17].

Miscellaneous applications

MTA was also reported to be used as a root canal filling of retained primary teeth and furcation perforation repair and resorption repair of primary teeth^[18].

Clinical application of MTA in permanent teeth Root-End Filling of Immature Permanent Teeth

Endodontic surgery followed by root-end filling may at times be necessary for certain teeth where conventional 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 such as amalgam, GIC etc. that provides complete apical seal, is nontoxic, non resorbable, dimensionally stable and radio opaque. 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, although routinely used as a root-end filling material, proved to be much inferior when tested with MTA. MTA treated teeth exhibited significantly less inflammation, more cementum formation and regeneration of periapical tissues [19].

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 haemorrhage. Repairing such a communication requires a material that should be biocompatible, should withstand moisture without dissolving and should have good sealing ability. Lee SJ *et al.* (1993) found that MTA had significantly less leakage and less tendency for overfilling or under filling, when compared with amalgam and IRM [1, 3].

Apexification

The treatment of a necrotic pulp in an immature root has always presented a challenge to clinicians due to the lack of an apical stop. This has classically been addressed with long term calcium hydroxide treatment which may require several years of treatment time, involve multiple visits and increase the fracture potential of the root involved. MTA has become an excellent predictable alternative to address these issues by creating a biocompatible apical plug in a single visit [20].

Fracture repair

Following root fracture of permanent teeth, the coronal non-vital portion of the fractured tooth can be sealed with MTA. Many case reports demonstrated the use of MTA mainly for horizontal root fractures repair without any problems or symptoms [10].

Resorption repair

Several case reports have described successful treatment of external root resorption using MTA as the material to fill the resorbed area of the tooth surface with surgical, nonsurgical methods, or by a combination of these approaches [21].

Table 3: Clinical application of MTA

Primary teeth	Permanent teeth
Pulp capping	Pulp capping
Pulpotomy	Partial pulpotomy
Root canal filling	Perforation repair - Apical, lateral, furcation
Furcation perforation repair	Resorption repair - External and internal
Resorption repair	Repair of fracture - Horizontal and Vertical
	Root end filling
	Apical barrier for tooth with necrotic pulps and open apex
	Coronal barrier for regenerative endodontics[
	Root canal sealer

Advantage of MTA [4, 5, 10]

1. Biocompatible
2. Reduced number of treatment appointments
3. Less demanding on both clinical and patient time
4. Less stressful for the patient in terms of overall treatment duration
5. Reduced risk of root fracture
6. Reduced risk of re-infection due to loss of temporary filling.

Disadvantage of MTA [10, 22]

1. High Cost
2. Discoloration potential,
3. Difficulties in handling the material
4. Prolonged setting time
5. Difficulty to remove after setting, and it does not have a solvent

Conclusion

Scientific literature has demonstrated the efficiency of traditional MTA when used in a range of endodontic and pediatric dental procedures. MTA materials have been shown to have a biocompatible nature and have excellent potential in endodontic and regenerative use. MTA materials provide better microleakage protection than traditional endodontic repair materials using dye, fluid filtration, and bacterial penetration leakage models. In both animal and human studies, MTA materials have been shown to have excellent potential as pulp capping and pulpotomy medicaments. MTA material can be used as apical and furcation restorative materials as well as medicaments for apexogenesis and apexification treatments. MTA required to be further explored by clinicians so that its advantageous properties can be practiced.

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