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## REVIEW ARTICLE

# MINERAL TRIOXIDE AGGREGATE

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**ABSTRACT**

Mineral trioxide aggregate (MTA) is a relatively newer material with various beneficial clinical applications. MTA has been recommended primarily as root end filing material but it is also being used in pulp capping, pulpotomy, apical barrier formation in teeth with open apexes, repair of root perforations and root canal fillings. This paper reviews the constituents, properties, anti bacterial activity, clinical applications, drawbacks and mechanism of action of MTA.



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## INTRODUCTION

There has been constant search for dental materials which presents ideal combination of excellent mechanical, physiochemical and biological properties. This search has been unremitting as far as the treatment of periapical injuries is concerned. Loma Linda University in California, USA initially developed Mineral Trioxide Aggregate (MTA) for repair of lateral root perforations. Since then MTA has gained acceptance as material of choice for various dental procedures viz. pulp capping, pulpotomy, root canal fillings, apexification, repair of root perforations (Hernandez *et al*., 2005).

### Availability of MTA

1 gram single use sachet of MTA is available. For the ease of use, premeasured sachet of water is also available for some of the manufacturer. Some of the commercially available MTA are ProRootMTA, White ProRootMTA, MTA Angelus, MTA Angelus Blanco, MTA Bio, light cured MTA, and MTA root canal sealer named CPM sealer and MTA Obtura.

### Constituents

MTA consists of 50-75% (wt) calcium oxide and 15-25% silicon dioxide. These two components together comprise 70-95% of cement. When these raw materials are blended they produce tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetracalcium aluminoferrite. On addition of water, cement hydrates to form silicate hydrate gel. A radio pacifier (bismuth oxide) is added to the cement for dental radiological diagnosis. MTA is currently marketed in 2 forms: gray (GMTA) and white (WMTA). MTA was introduced in gray. Because of the discoloration potential of GMTA, WMTA was developed (Kratchman, 2004). Composition of GMTA is 75% PC, 5% calcium and 20% bismuth oxide. Composition of WMTA is 80% PC, 20% bismuth oxide. WMTA contained significantly less amount of oxides of iron, aluminium and magnesium than GMTA.

### Setting reaction of MTA

When MTA powder is mixed with water, calcium hydroxide and calcium silicate hydrate are formed in the beginning and finally transformed into poorly crystallized and porous solid gel. Calcium hydroxide which is produced by precipitated calcium is the cause for high alkalinity of MTA after hydration. After MTA hydration, calcium hydroxide precipitation is affected by bismuth. In acidic environment (inflammatory tissues) bismuth gets dissolved and releases bismuth oxide. Bismuth oxide does not promote proliferation of cells in cell culture which decreases biocompatibility of MTA.

### Manipulation of MTA

MTA paste is prepared by mixing powder with sterile water in ratio of 3:1 to obtain putty like consistency. Using metal or

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agate spatula mixing is done on glass slab or paper and the mix is taken to desired location using hand instrument (plugger, paper point or messing gun) and moistened cotton pellet is used to condense it lightly (Schwartz, 1999).

**Setting time**

MTA is prepared by mixing its powder with sterile water in the ratio of 3:1(powder to liquid ratio) (Torabinejad *et al*., 1993) WMTA has final setting time of 140 minutes (2hours 20 minutes) and 175 minutes (2 hours 55 minutes) for GMTA (Islam *et al*., 2006). Gypsum present in MTA is one of the reasons for the increased setting time of MTA. However sodium phosphate dibasic and calcium chloride reduces setting time (Islam *et al*., 2006). The presence of sulphur on surface of set cement is three times more than that of powder MTA. This sulphur layer prevents further hydration of cement and increases its setting time. MTA is hydrophilic in nature which requires moisture to set, thus making dryness absolutely contraindicated.

**Setting conditions**

The authors recommend the placement of moistened cotton pellet in the root canal for a period of time before placement of permanent coronal seal. Flexural strength of set cement increases in the presence of moisture (Torabinejad *et al*., 1998).

**Compressive strength**

The compressive strength of MTA is less (40 mpa) after 24 hours when compared to amalgam, Intermediate restorative material (IRM) and Super Ethoxy Benzoic Acid (EBA) but there is no significant difference in the compressive strength of these materials after 3 weeks (Torabinejad *et al*., 1995) MTA consists of dicalcium silicate and tricalcium silicate. As the hydration of dicalcium silicate is slower than that of tricalcium silicate, it takes several days for MTA to reach the maximum strength (Sluyk *et al*., 1998). MTA was reported to have low compressive strength after etching with phosphoric acid. Thats why after MTA placement acid etch composite should be postponed for at least 4 days (Kayahan *et al*., 2009). The factors affecting the compressive strength of MTA include type of MTA, liquid in which material is mixed, the condensation pressure on the material, ph value of mixing liquid and condition of MTA storage (Chgle *et al*., 2007).

**Solubility**

Higher the water/powder ratio, higher the solubility of MTA (Fridland *et al*., 2003) however addition of bismuth oxide to MTA which is insoluble in water is the other cause of solubility of MTA.

**Ph:** Initially the ph of MTA is 10.2 which rise to 12.5 after period of 3 hours. This increase in the ph value is attributed to the release of calcium and formation of calcium hydroxide.[17]

**Radio opacity:** The mean radio opacity of MTA is 17.7 mm (equivalent thickness of aluminium) which is due to the presence of bismuth oxide (Torabinejad *et al*., 1995)

**Displacement:** Hachmeister *et al* investigated that 1mm of thickness of apical barrier offers less displacement than the thickness of 4mm (Hachmeister *et al*., 2002).

**Fracture resistance:** The fracture resistance of MTA is significantly higher than calcium hydroxide when used as an apical barrier in young permanent teeth. Presence of tissue inhibitor metalloprotein -2 (TIMP-2) in MTA inhibits collagen destruction (Hatibovic *et al*., 2008) whereas calcium hydroxide weakens tooth structure by neutralising, denaturing, and dissolving the acidic component of dentine.

**Effect of method of placement on MTA physical properties:** One of the disadvantages of MTA is its handling properties. Carriers used for the placement of MTA includes Teflon sleeves, pluggers, carrier for dispersing MTA and messing gun type syringe.

**Antibacterial and antifungal properties of MTA:** MTA has antibacterial effect on E. faecalis and S.sanguis (facultative bacteria) and has no effect on strict anaerobes (Al-Hezaimi *et al*., 2006). 25mg/ml and 50mg/ml concentration of WMTA has antifungal effect against candida albicans which shows that concentration of MTA is very important factor in inhibiting fungal growth (Al-Hezaimi *et al*., 2006).

**Mutagenicity** Kettering *et al* studied mutagenic effect of MTA with different strains of Salmonella Typhimurium LT2, which is supposed to be sensitive to various classes of mutagens showed that MTA is not mutagenic (Kettering *et al*., 1995).

**Neurotoxicity and neurologic effects**

According to Asraii and Lobner, who studied the neurotoxic effects of MTA, diaket, Super EBA and amalgam on glial and neuronal cells, except MTA all other were toxic (Asraii *et al*., 2003)

**Vascular effects**

A study was done by Tuna YM., *et al* to simulate pulpal vessels and smooth muscle contraction and showed that MTA does induce the contraction of vessels but in dose dependent manner and MTA has no effect on microcirculation (Tuna *et al*., 2007).

**Mechanism of action**

Root canals filled with MTA when placed in phosphated buffer saline for two months releases maximum amount of calcium followed by silica, bismuth, iron, aluminium and magnesium respectively (Tziafas *et al*., 2002).The author discovered the presence of white layer between MTA and root canal wall which is very similar in composition to hydroxyl apatite. This hydroxyl apatite releases calcium and phosphorous respectively, the process which is essential for bone metabolism. This phenomenon increases the sealing ability of MTA and promotes the regeneration and remineralistion of hard tissues. Tziafas *et al* in 2002 reported that collagen matrix is formed when MTA is placed over pulp tissues which cause proliferation, migration and differentiation of odontoblasts cells. After that mineralisation of collagen matrix occurs which produces osteodentin initially and tertiary dentin bridge few months later (Hakki *et al*., 2009). MTA has cementoconductive and cementoinductive activity when used in concentration of less than 20mg/ml as reported by Hakki *et al*.

**Clinical applications of MTA in paediatric dentistry Pulp capping**

Aeinehchi et al in 2004 reported .28 mm thick dentin bridge by two months which increased to .43 mm by six months in MTA in contrast to 0.15 mm thick dentin bridge noted with calcium hydroxide at six months.

**Pulpotomy:** MTA was found to be ideal material for pulpotomy with low toxic effects, increased tissue regenerating properties and good clinical results as compared to calcium hydroxide and formocresol (Eidelman, 2001)

**Root end filling**

MTA was used successfully as a root end filling material in primary molars which had no permanent successor (O'Sullivan *et al*., 2001). According to Sarris *et al*, one step placement of MTA as apical barrier was superior alternative to multiple visit apexification with calcium hydroxide. The advantages cited were; reduced treatment time, reduced risk to fracture and early placement of sealing and possibly reinforcing coronal/intraradicular restoration.

**Perforation**

MTA was first used for repair of furcal perforation by Pittford *et al*. They concluded that cementum was generated under MTA in comparison to amalgam repaired perforation sites.

**Furcal perforation**

MTA when used in the treatment of furcal perforation in primary molars found complete elimination of furcal radiolucency and clinical success after 20 months of placement (Oliveira *et al*., 2008) In permanent molars Pace R etal reported excellent healing after 5 years when MTA was used in furcation or within cervical third of the roots.

**Other clinical applications**

MTA has been used successfully used for treatment of strip and supracrestal perforations, horizontal root fractures, sealing communication between root canal space and external root surfaces, filling root canals of teeth with mature and open apices as well as management of dens invaginatus.

**DRAWBACKS**

The main drawbacks of MTA are as under

1 **Discoloration potential**: Iron and manganese are the elements which are responsible for discoloration of MTA treated teeth (Asgary *et al*., 2005).
2 **Presence of toxic elements**: Insolubility of MTA, stabilising effect of ferric oxide (present in MTA) on arsenic and use of small amount of MTA for clinical application limits the release of arsenic into tissue fluids that may lead to toxicity (Asgary *et al*., 2005).
3 **Root canal filling material**: long setting time, ability to discolour, and difficulty in obturating curved root canals limits its use as root canal filing material (Bogen *et al*., 2009).
4 **High material cost**: The cost of instruments which are used for formation of apical barrier in teeth in which pulps are necrotic and open apices and also the cost of MTA was major concern among paediatric dentist in UK (Srinivasan *et al*., 2006).
5 **Difficult handling characteristics** and difficult to remove after curing.
6 **Long setting time**: Long setting time of MTA is one of the reasons that MTA should not be applied in one visit (Islam *et al*., 2006)
7 **Absence of known solvent**: There is no known solvent to dissolve the set MTA (Boutsioukis *et al*., 2008).

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