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Review Article

Mineral Trioxide Aggregate (MTA): A Comprehensive Review

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ABSTRACT:
MTA is a remarkable biocompatible material, with exciting clinical applications was pioneered by Dr. Mahmoud Torabinejad and co-workers in Loma Linda University. MTA can be used in surgical and non–surgical applications, including direct and indirect pulp capping, Perforation repairs in roots or furcations, apexification, root end fillings and regenerative procedures. The aim of this comprehensive review is to discuss MTA in detail.
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INTRODUCTION
Calcium silicate based materials have gained popularity in recent years because of their better biocompatibility and tissue repairing abilities. A wide range of materials are available of which MTA is known to be the best as an endodontic repair material as well as an ideal pulp capping agent.[1] MTA was developed in Loma Linda University in 1990’s by Torabinejad as a root end filling material. It received acceptance by the US Federal Drug Administration in 1998. Since its approval MTA became commercially available as Pro Root MTA until two commercial forms of MTA have been available namely the Grey and white MTA with similar chemical and physical properties.[2]
Since its first description in the dental literature by Lee & colleagues in 1993, MTA has been used in both surgical and non surgical applications including root end filling, direct pulp capping, pulpotomy, perforation repair, furcation repair, apexification and obturation. This material holds promise because of its sealing capabilities, ability to set up in the presence of blood, biocompatibility and its capability to induce hard tissue formation.[3]

COMPOSITION
MTA is a mixture of three powder ingredients: Portland cement (75%), Bismuth oxide (20%) and Gypsum (5%).[4] MTA consists of 50–75% calcium oxide and 15–25% silicon dioxide. These two components together comprise 70–95% of the cement. When these raw materials are blended they produce tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetracalcium aluminoferrite. On addition of water the cement hydrates to form silicate hydrate gel. MTA is a Type 1 ordinary Portland cement (American Society for Testing Materials), with a fineness in the range of 4500–4600 cm2 g. A radiopacifier (bismuth oxide) is added to the cement for dental radiological diagnosis (Torabinejad & White 1995).[5,6]

TYPES OF MTA

MTA are of two types- grey and white. The white and grey MTA differs mainly in their content of iron, aluminium and magnesium oxides.[7] 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.[8]

MANIPULATION OF MTA

Mineral trioxide aggregate is a water-based dental cement. It is usually supplied in pre-dosed powder and liquid that are blended together to obtain a homogeneous paste. The recommended water/powder ratio is about 3:1 i.e. 3 parts of powder with 1 part of water to obtain putty like consistency.[9] The mixing time of MTA is crucial. If the MTA mixing is prolonged, it results in dryness of the mix. Sluyk et al reported the mixing time of MTA to be kept less than 4 minutes.[10] MTA should be inserted in place immediately after mixing to avoid dehydration. A lentulo spiral can be used for its insertion or alternatively a micro amalgam carrier, guttapercha plugger, Map system, Dovgan applicator, or ultrasound can be used.[4]

PROPERTIES OF MTA

SETTING TIME AND PH

According to Torabinejad and colleagues the setting time of grey MTA is about 2 hours and 45 minutes (+5minutes),[2] whereas Islam et al reported 2 hours and 55 minutes for grey MTA and 2 hours and 20 minutes for white MTA.[11] Extended setting period of MTA is one of its main drawbacks. It has been suggested in literature that MTA material setting time could be prolonged by the formation of a passivating trisulfate species layer, which may serve to prevent further hydration and reaction.[12]

It is suggested by many investigators that the incorporation of accelerators such as sodium phosphate dibasic (Na2HPO4) and calcium chloride (CaCl2) may reduce the setting time. After mixing, the mix should not be left open on the slab as it undergoes dehydration and dries into a sandy mixture. It should be used immediately after it is prepared.[11,13]

COMPRESSIVE STRENGTH

The compressive strength of set MTA is about 70 MPa, which equals IRM and super EBA, but is less than that of amalgam.[14] Owing to the low compressive strength, placement of MTA in functional areas should be avoided. MTA's compressive strength is not significantly affected by condensation pressure. MTA has a prolonged maturation process, with increased compressive strength, push-out strength, and retention strength of the material with time (up to 21 days) in the presence of moisture. The initial compressive strength following 24 hours is 40 MPa, which increases to 67.3 MPa after 21 days.[15]

SOLUBILITY OF MTA

Solubility of a root-end filling materials is an essential property as it may influence other properties such as sealing ability, biocompatibility, and mutual effects with adjacent environment. The ability of a material to seal and get solubilized may influence treatment prognosis. To avoid venomous effects on surrounding tissues by root-end filling materials, these have very low solubility.[16]

The set MTA shows no signs of solubility. But, if more water is used during mixing the MTA it may results into increased solubility. Buding (2008) found that the set MTA when exposed to water it releases calcium hydroxide ($CaOH_2$).[17] $CaOH_2$ might be responsible for its cementogenesis-inducing property. During setting reaction if mix is exposed to acidic environment it does not interfere in the setting.[18]

FLEXURAL STRENGTH

Torabinejad and Chivian recommended placing a wet cotton pellet over GMTA when it is used for perforation repair, pulp capping, or an apical plug.[19] On the basis of limited literature, it appears that placing a moist cotton pellet over MTA for the first 24 hours increases its flexural strength.[15]

MICROHARDNESS

The microhardness of MTA can be influenced by several factors such as the pH value of the environment, the thickness of the material, the condensation pressure, the amount of entrapped air in the mixture, humidity, acid etching of the material, and temperature.[15] Majeed A et al. (2017) found microhardness of MTA better than Biodentine.[20]

RADIOPACITY

The mean radiopacity for MTA has been reported at 7.17 mm of an equivalent thickness of aluminium. This value is higher than that reported for Super EBA or IRM in a separate investigation.[15]

ANTIBACTERIAL EFFICACY

It has been suggested in literature that MTA has an antibacterial properties especially against Enterococcus faecalis and Streptococcus sanguis in vitro. But Torabinejad et al reported that MTA shows no antimicrobial activity against any of the anaerobes but did have some effect on five (S.mitis, S.mutans, S.salivarius, Lactobacillus and S.epidermidis) of the nine facultative bacteria**.**[3]

BIOCOMPATIBILITY

Any material that is identified to be used in humans or animals should be biocompatible without having toxic or injurious effects on biologic tissues and its function. Kettering and Torabinejad studied MTA in detail and found that it is not mutagenic and is much less cytotoxic compared to Super EBA and IRM.[21]

REACTION WITH OTHER DENTAL MATERIALS

MTA does not react or interfere with any other restorative material. Glass Ionomer cements or composite resins, used as permanent filling material do not affect the setting of MTA when placed over it.[22]

Table no 1: Uses of MTA

Clinical Use	Description
Direct pulp capping	Direct pulp capping is a procedure in which the exposed pulp is covered with a biocompatible material. The objectives of the treatment are formation of dentin bridges to wall off outside stimulation and preservation of healthy pulp tissue. MTA has been proposed as a potential medicament for capping of pulps with reversible pulpitis because of its excellent tissue compatibility. It is much superior to the routinely used calcium hydroxide based on the tissue reaction and the amount and type of dentin bridge formed.[23,24]
Pulpotomy	MTA may be used as an alternative pulpotomy agent in immature teeth with pulp exposure to stimulate pulp healing with dentin bridge formation and complete root formation.[25]
Root end filling	Endodontic surgery followed by root-end filling may at times be necessary 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 non toxic, non resorbable, dimensionally stable and radio opaque. MTA forms a good marginal seal and stimulates hard tissue formation (Cementum) can be used as root end filling material.[15]
Perforation repair	Furcation perforations are significant iatrogenic complications of endodontic treatment and could lead to endodontic failure. Perforations may occur during preparation of access cavities, post-space preparation or as a result of the extension of an internal resorption into the periradicular tissues.[19,26] The clinical applications of MTA have proved that it is suitable for solving the problems derived from perforation. The desirable properties of MTA make it a useful material in repairing the root and furcal perforations. MTA offers a biologically active substrate for bone and cells, and osteoblasts also have shown a favourable response to MTA.[27]
Apexification	In recent times, mineral trioxide aggregate (MTA) has gained widespread popularity for the apexification procedure. It produces apical hard tissue formation with significantly greater consistency than calcium hydroxide. MTA, a biocompatible material, can be used to create a physical barrier. It also helps in the formation of bone and periodontium around its interface.[28]
MTA as obturating material	MTA is recommended as an option pulpectomy material for nonvital primary teeth with no permanent successors. Recently, O'Sullivan and Hartwell showed successful treatment of a primary molar that had no successor permanent tooth using MTA as a root canal filling material. However, no long-term results were reported.[29]
Revascularization procedures	MTA can be used for coronal seal in revascularization procedures.[6]

Table no 2: Review of literature	
Author	**Observation**
Holland et al. (1999)	According to Holland et al. (1999) theorized that the tricalcium oxide content of MTA interacts with tissue fluids and form $CaOH_2$, resulting in hard-tissue creation in a similar manner to that of $CaOH_2$.[30]
Hiremath GS et al. (2015)	Evaluated the antimicrobial efficacy of Biodentine, MTA, and MTA Plus and found that MTA and Biodentine showed significant antimicrobial effect against E. faecalis whereas MTA Plus was proved to be a good anti fungal agent against Candida albicans.[31]
Mooney GC et al. (2008)	Observed that the manipulation of MTA was messy when the moisture was excessive in the preparation which further results in soupy material and hence difficult to use.[32]
Hassan FN et al. (2015)	Found that both ProRoot MTA and Biodentine performed equally well when used as furcation repair materials.[33]
Christiansen R et al (2009)	Found that healing of teeth treated with MTA as root end filling material had significantly better healing (96%) than those treated with orthograde GP filling (52%).[34]
Witherspoon DE et al. (2008)[35]	He found that MTA is a good substitute of $Ca(OH)_2$ for vital pulp therapies because it stimulates a higher and greater quality and quantity of reparative dentin and also aids superior long term sealing ability
Soundappan S et al. (2014)	Conducted In-Vitro study to compare the marginal adaptation of Biodentine with MTA and Intermediate Restorative Material (IRM) using scanning electron microscope and concluded that both MTA and IRM were significantly superior to Biodentine in terms of marginal adaptation when used as a root end filling material.[36]
Fallahinejad Ghajari M et al (2008)	Primary molars pulpotomy with MTA have better clinical and radiographic success rates than Formocresol.[37]
Senapathi SN et al. (2021)	The combination of diode laser and MTA yielded better clinical and radiographic success rates over the pulpotomy procedures done with the help of MTA alone in primary teeth

DISCUSSION

Mineral trioxide aggregate (MTA), composed mainly of tricalcic silicate, tricalcic alluminate, bismuth oxide, is a particular endodontic cement. It is made of hydrophilic fine particles that harden in the presence of dampness or blood. It is biocompatible, radiopaque and it is harder to infiltrate, compared to classic materials for root filling such as amalgam, cements, Super-EBA, and IRM. Clinical experience shows how MTA is a material of choice in cases not only of endodontic surgery, apicectomy and retrograde filling but also in the sealing filling of perforations of the pulp chamber and of the root, stripping, internal reabsorptions, readaptations, lacerations, and apical transports. It has been used with success also in direct cappings and in apexifications instead of calcium hydroxide, leading to quicker therapies and more predictable. A very practical advantage of MTA is that it sets in the moist environment omnipresent in dentistry. Unlike many other dental materials, MTA sets in a moist environment. High biocompatibility encourages optimal healing responses. This has been observed histologically with the formation of new cementum in periradicular tissues area and a low inflammatory response with bridge formation in the pulp space. The seal achieved is due to its expansion and contraction properties being very similar to dentin which results in high resistance to marginal leakage and to bacterial migration into the root canal system. A stable barrier to bacterial and fluid leakage is one of the key factors which facilitates clinical success. Despite the high clinical efficacy of this wonder cement, there were always some issues which prevented the clinicians to use it for many cases. The major ones being very long setting time and difficult manipulation.[6,39,40]

CONCLUSION

In recent time the clinical uses of bioceramics have increased exponentially because of their extensive variety of applicability in restorative dentistry and endodontics. The introduction of MTA in dentistry was considered as a major break-through in the history of material science and since then the properties of this material have been improvised in order to attain its maximum benefits. However, there have been a few limitations of this material which have always compelled the researchers worldwide to look for its alternatives.

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