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MTA Cement (Mineral Trioxide Aggregate) – A Mini Review

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Abstract

Mineral trioxide aggregate, or MTA, is a new biocompatible material with numerous exciting clinical applications in endodontics. It has been used on an experimental basis by endodontists for several years with anecdotally reported success, some of it quite impressive; MTA's approval in 1998 by the U.S. Food and Drug Administration should lead to more widespread use. The material appears to be an improvement over other materials for endodontic procedures that involve root repair and bone healing.

Applications of MTA is not only confined to pulpal procedures, apexification, repair of perforations, but also in periodontics. The regeneration of new cementum over MTA is a unique phenomena and hence an interest use that can be used in conjunction with bone grafting procedures. To summarize, MTA is a promising material with an expanding foundation of research.

Keywords

Apexification, Apexogenesis, MTA.

Introduction

Oral health is indeed a reflection of a wholesome lifestyle. Man's curiosity for new things and fascination for learning has led to revolution in every field, and dentistry is not been left behind. As therapeutic techniques becomes more sophisticated the management of problems encountered or created during treatment has also become increasingly complicated.

Mahmoud Torabinejad introduced MTA in Loma Linda University.

Mineral trioxide aggregate, or MTA, is a new biocompatible material with numerous exciting clinical applications in endodontics. It has been used on an experimental basis by endodontists for several years with anecdotally reported success, some of it quite impressive; MTA's approval in 1998 by the U.S. Food and Drug Administration should lead to more widespread use. The material appears to be an improvement over other materials for endodontic procedures that involve root repair and bone healing.

Composition

MTA consists of fine hydrophilic particles

- Tricalcium silicate
- Tricalcium aluminate
- Tricalcium oxide
- Silicate oxide

It also contains small amounts of mineral oxides, which modify its chemical and physical properties.

Electron probe micro analysis of the MTA powder showed that calcium and phosphorus are the main ions present.

MTA also contains 5% calcium sulphate dehydrate [6] and tetracalciumalumino ferrite.

Off white coloured formula lacks tetracalciumalumino ferrite and lack of this iron containing compound accounts for off white appearance.

Both the formula contains

70% Portland cements, 20% bismuth oxide and 5% gypsum by weight.

Manipulation

MTA is supplied as a gray powder. Each pack of Pro root TM. MTA powder comes with a pre-measured unit dose of water for convenience in mixing.

Mixing Time

MTA is prepared by mixing 3 parts of powder with one part aqueous solution by weight to obtain a putty consistency which is achieved after 30 seconds of mixing.

Because of its hydrophilic characteristics, moisture in the surrounding tissue, water acts as an activator of a chemical reaction in this material. The moisture also extends the initial setting to a reported 2 hours and 45 minutes, but the compressive strengths has been shown to increase in presence of moisture upto 21 days.

The working time should be limited because the material begins to dehydrate and results in a dry sandy mixture on the mixing slab if left for a longer period of time [5]

Storage

The manufacturer recommends storing of MTA powder by keeping it in containers with tight lids and away from moisture. He further recommends that it be mixed with water into a thick, grainy paste. Some clinicians however report success in mixing MTA with anaesthetic, saline or other sterile liquids, but their effects on MTA's physical chemical and biological properties are unknown[5].

Once mixed it may be carried with a small amalgam carrier or messing gun or placed with a small hand instrument or with a MRF plastic instrument into the site of application.

MCBRC plugger followed by a wet cotton pellet can be used to condense the material gently [7]

If excess of moisture is present in the preparation or resorptive defect, the MTA becomes soupy and difficult to condense. Moisture can be drawn out of the MTA after placement with a dry paper point or cotton pellet. MTA is often pressed into the desired location and not really condensed. In preparing the site to receive MTA, the clinician should follow several guideline. All irrigation should be performed before the MTA is placed. Any irrigation after placement will cause significant wash out of the material. The preparation of the resorptive defect need not be perfectly dry, but most of the fluid should be removed. If MTA is placed from inside the tooth, a moist cotton pellet or paper point should be placed against it because the presence of moisture is essential for the material to set [8,9]

When comparing the use of a wet and dry cotton pellet in the pulp chamber, the results did not show a significant difference. A possible explanation is that the amount of moisture in the matrix is adequate to keep the hydrophilic particles moist.

Mechanism of Action

The regeneration of the new cementum over MTA is a unique phenomenon that has not been reported to occur when other root end filling have been investigated. The deposition of cementum hard tissue with MTA was also seen in root end fillings [10], dental pulps [11] and apical tissue after root canal filling [12]. Torabinejad et al believed that the deposition of cementum against MTA may be due to a number of factors such as sealing ability, biocompatibility or alkaline pH on setting [13].

Koh et al studied the cytomorphology of osteoblasts in presence of MTA and examined the cytokine production. Scanning electron microscopy revealed healthy cells in contact with MTA after 1 and 3 days, and also the presence of raised levels of interleukins. The authors concluded that it is possible that MTA offers a biologically active substrate for bone cells and stimulates interleukins production. Calcium hydroxide in contact with pulp tissue or culture medium produces deposition of calcite crystals. Also observed was rich extra cellular network of fibronectin in close contact with these crystals. Different materials have been used to repair root perforation, but only MTA fulfilled the criteria of an ideal repair material that include (sealability, biocompatibility, and the ability to induce osteogenesis and cementogenesis[14.]

MTA is superior to amalgam, IRM, and super-EBA in preventing leakage of methylene blue, fusobacterium nucleatum, and endotoxin [8,9,15]. It is biocompatible and induces osteogenesis and cementogenesis[10].

Success was reported in furcal repair of human teeth which was repaired with MTA. And also observed was that this material allowed bone healing and elimination of clinical symptoms [17,18]

The deposition of hard tissue was observed with MTA in root end fillings [10,19,20] dental pulps [11,21,22] and apical tissue after root canal filling. [12,23] (Torabinejad et al. believes that the deposition of cementum against MTA may be due to a number of factors, such as sealing ability, biocompatibility or alkaline pH on setting). Koh et al studied the cytomorphology of osteoblasts in the presence of MTA and examined cytokine production. Scanning electron microscopy revealed healthy cells in contact with MTA at 1 and 3 days, and also the presence of raised levels of interleukins [14.]

Holland et al in 2001[14] observed that calcium hydroxide in contact with pulp tissue or culture medium produces deposition of calcite crystals he also observed a rich extracellar network of fibronectin in close contact with these crystals, and concluded that their findings strongly supported the role of calcite and fibronectin as an initiating step in the formation of a hard tissue barrier. The same crystals observed with calcium hydroxide were reported for MTA. The question is how this same phenomenon occurs with MTA if it does not have calcium hydroxide in its composition. According to Torabinejad et al in 1997 [10], 1996 [12] and sluyk in 1998 after the reaction with water, (MTA has two specific phases composed of calcium oxide and calcium phosphate. So, MTA does not have calcium hydroxide, but it has calcium oxide that could react with tissue fluids to form calcium hydroxide. Later this last product can form calcite crystals.

MTA when used as a root end filling material showed an overall good result. Inflammation was observed around one root end filled with MTA but the reason was unclear. A thick layer of cementum was observed over five out of the six MTA root end fillings.(Two possibilities exist for the source of the new cementum ; either it is derived from the remaining periodontal ligament and has grown in from the sides, or it is derived from the in growing connective tissue from bone). Previous work indicates that the blood clot in the bony cavity organizes within 2 weeks. Therefore, the progenitor cells could well be derived from bone rather than from the periodontal ligament. Further the presence of blast cells on the surface of the cementum suggests a bone origin for this mode of attachment. Layer of cementum over the MTA showed irregularities in some sections, although no defects or soft tissue inclusions were noted. The formation of cementum against MTA may be due to a number of factors such as sealing ability, biocompatibility, or alkaline pH on setting. Recent in vitro work has demonstrated the ability of MTA to stimulate cytokine release from bone cells indicating that it actively promotes hard tissue formation rather than being inert or being irritant like existing root end filing materials.

Many clinical and experimental studies have shown that mature dental pulp cells posses the ability to differentiate into a specific cell lineage forming tubular dentine in the absence of normal developmental conditions i.e., dental epithelium and basement membrane (Baume 1980). This phenomenon takes place stereotypically as an intrinsic defensive mechanism in the repair of pulp environment [27].

The superficial zone of extra cellular matrix, which is stereotypically formed at the wound surface of the repairing connective tissues, is physiologically followed in exposed dental pulp by hard tissue deposition. During the natural wound healing process in dental pulp, odontoblast like cell differentiation and reparative dentine formation occurred in association with osteodentine or fibrodentine hard tissue formation (Baume 1980, Ruch 1985) . This primitive type of pulp biomatrix seems to control the differentiation of pulpal cells into odontoblast like cells and initiation of reparative dentine formation..Odontoblast like cells and initiation of reparative dentine formation, substituting the dental epithelium and basement membrane to provide the necessary molecular influences.

The mechanism controlling initiation of reparative dentinogenesis has been repeatedly confirmed after pulp caping with calcium hydroxide based materials. Initially the cells under the wound surface proliferate, migrate and elaborate new collagen along the superficial necrotic zone and the new collagen layer attracts mineral salts, becoming calcified matrices (Fibrodentine). Then a layer of odontoblast like cells is formed in association with the fibrodentine and reparative dentine is secreted. Many data from capping experiments suggest that initiation of reparative dentine formation might not be attributed to any specific dentinogenic effect of calcium hydroxide, although its effect in controlling infection and stimulating the wound healing process might not be excluded. The present experiments demonstrated that pulp capping with MTA induces cytological and functional changes in pulpal cells, resulting in formation of fibrodentine and reparative dentine at the surface of mechanically exposed dental pulp [4]

Physical, Chemical, Biological and Histologicalproperties

1. **pH:** The pH of MTA after manipulation was measured with a pH meter (Psye. Cambridge, U.K.) using a temperature - compensated electrode and was recorded to be 10.2 initially and it rose to 12.5 after 3 hours, and thereafter, it remained constant [5]
2. **Radiopacity:** The radiopacity of MTA was determined according to the method described by the international organization for standardization (ISO 6876). The mean radiopacity for MTA was 7 –17 mm of equivalent thickness of aluminium, because it is more radiopaque than conventional gutta – purcha and dentin, it should be easily distinguishable on radiographs when used as a root filing material [5.]
3. **Setting time:** To determine and compare the setting time and compressive strength of MTA with other commonly used root end filling materials like amalgam, super – EBA, IRM were mixed according to manufacturer's direction and evaluated. The setting times of test materials were determined according to the method recommended by ISO Hydration, and the material was set to a hard structure in less than 3 hours [5]. Advantages of its longer setting time are that, the quicker a material sets the more it shrinks. This explains why MTA in previous experiments had significantly less dye and bacterial leakage than other materials tested as root filling materials [24,25,26]
4. **Compressive strength:** It is an important factor to be considered when a filling material is placed in a cavity that bears occlusal pressure. In 24 hours MTA had the lowest compressive strength (40 Mpa) among the materials (Amalgam, Super EBA & IRM) tested, but it increased after 21 days to 67 MPa. The increase in compressive strength of MTA required the presence of moisture. Long term studies might provide further information on compressive strength of MTA in presence of moisture. However the compressive strength value obtained for MTA is similar to those obtained for super EBA, IRM & Zinc Phosphate [5].
5. **Solubility:** MTA shows no signs of solubility in water and this is a major factor in assessing the suitability of potential substances to be used as restorative materials in dentistry. However the effect of properties of MTA when mixed in saline or any other anesthetic solution, etc is yet to be assessed. Lack of solubility has been stated as an ideal characteristic for root end filing material [24,27,28.]
6. **Biocompatibility:** Application of MTA as a root end filling material promoters regeneration of dental and osseous tissues, and may induce cementoblasts to produce matrix for cementum formation over MTA. The presence of cementum (a unique phenomenon) over MTA in canals obturated with gutta-percha either with or without a root canal sealer indicates the superior sealing ability of MTA and its biocompatibility with periradicular tissues [11,29,30.]
7. **Sealing ability:** MTA has enhanced sealing ability which could be due to the setting expansion when it is used in moist oral environment. It has also been

found that MTA has some antibacterial effect on some oral bacteria that may aid in its superior sealing ability [15,31].

MTA has an antibacterial effect on some of the facultative bacteria and no effect on any of the strict anaerobic bacteria. The antibacterial effect of MTA against these organisms could be because of its alkaline pH or release of diffusible substances into the growth medium [15,31.]

MTA is an effective pulp capping material able to stimulate hard tissue bridge formation during the early wound healing process. The stereotypic pulp defence mechanism by which primitive matrix (fibro dentine) trigger expression of the odontoblastic potential of pulpal cells seems to be related to the dentinogenic activity of MTA. Pulp capping with MTA induces cytological and functional changes in pulpal cells resulting in formation of fibrodentine and reparative dentine at the surface of mechanically exposed dental pulps [11,21,32.]

8. Invitro study of human osteoblasts revealed that MTA stimulated the release of cytokines and the production of interleukin [17]
9. MTA is said to be non – mutagenic [18.]

Clinical Applicationsof MTA

A. Pulpal procedures

MTA a new material currently being used in pulp therapy has been demonstrated to provide an enhanced seal over the vital pulp and is non – resorbable. The favourable tissue responses to MTA as a pulp – capping material mirror those observed in the cuspids of beagle dogs. The formation of dentin adjacent to MTA could be due to its sealing ability, biocompatibility, alkalinity or other properties associated with this material. Recent in vitro investigation has demonstrated sealing ability of MTA to stimulate cytokine release from bone indicating that it actively promotes hard tissue formation rather than being inert, as any dental materials [11].

Direct pulp capping: The use of MTA has been successful in teeth with a history of recent onset of mild sensitivity to chewing or temperature. The most important step here is case selection.

Procedure: The tooth should be anesthetized and isolated with a rubber dam. The caries should be removed under magnification using a caries detector with slow speed round burs and spoon excavators. Once caries has been entirely removed, irrigate with 5.25% sodium hypochlorite for 5-10 minutes to achieve hemostasis and ensure complete debridement. Rinse out the sodium hypochlorite and ensure that the chamber is debris free. Once MTA has been placed, no further irrigation can be accomplished, since the unset MTA can be easily washed out. Then place 1-1.5 mm thick layer of freshly mixed MTA directly over the exposed pulp. Place a wet, thinned, flattened cotton pellet over the MTA. The cotton pellet provides the moisture MTA requires for a proper set. But to its hygroscopic nature, Cavit absorbs water and can be inflammatory to vital pulp and therefore, should not be used as a temporary material in vital teeth; instead use light cured photocore, IRM, or other suitable material. The patient should return one week later for final restoration. At this time, the temporary and cotton pellet should be removed and vitality reassessed. Test for adequate setting of MTA using a spoon to carve around the edges of the material and remove residual cotton fibers, which frequently adhere to the set MTA. The instrument should be kept as far as possible from any previous exposure sites. The MTA should be the same hardness and consistency of a set concrete. Once proper setting of MTA has been ascertained, the tooth can be restored with bonded composite or another restoration of the clinician's choice. The final restoration should be bonded or placed directly over the set MTA. The patient should be checked at six months via radiographs and cold test to monitor vitality [26.]

B. Apexification

A major problem in performing endodontics in immature teeth with necrotic pulp and wide open apices is obtaining an optimal seal of the therapy through an induced hard tissue barrier at the tooth apex. This process is known as apexification. The aim of the procedure is to limit bacterial infection and create an environment conductive to the production of mineralized tissue in the apical region for this purpose. Mineral Trioxide Aggregate (MTA), has been proposed as a potential material to create an apical plug at the end of the root - canal system, thus preventing the extrusion of filling materials. Three clinical cases have been treated with the use of an apical plug of MTA for apexification. All three cases were central incisors that had suffered premature interruption of root development as a consequence of trauma.

Procedure: According to the treatment protocol, the root canals were rinsed with 5% sodium hypochlorite, and then calcium hydroxide paste was placed in the canals for 1 week. Consequently, the apical portion of the canal (4 mm) was filled with MTA. The remaining portion of the root canals was then closed with thermoplastic gutta – percha. At 6 – month and 1 – year follow – up period the clinical and radiographic appearance of the teeth showed resolution of the periapical lesions. MTA appears to be a valid option for apexification with its advantage being the speed at which the treatment can be completed. The most important problem in the classic apexification technique with calcium hydroxide is the duration of the therapy, which is from 3 to 21 months. The duration depends on factors such as size of the apical opening, the traumatic displacement of the teeth and the repositioning methods used. Calcium hydroxide creates an environment conductive to the formation of an apical barrier formed by osteo – cementum tissue at the end of the root canal in teeth with open apices [5,6.] During apexification procedure the root canal is susceptible to re-infection because it is covered by a temporary seal. In addition, the canal is susceptible to fracture during treatment. A permanent treatment is preferable to limit re-infection that could cause apical periodontitis and inhibit canal closure.

With the MTA apical plug technique, a one – step obturation after short canal disinfection with calcium hydroxide could be performed. The MTA mixture creates an artificial, stop to the filling material. In agreement with other studies, MTA appeared to show sealing ability, good marginal adaptation, a high degree of biocompatibility and a reasonable setting time (about 4 hours). From a practical point of view, MTA can be used in the presence of moisture in the root canal. This property is important in teeth with necrotic pulps and inflamed periapical lesions because one of the problems found in these cases is the presence of exudates at the apex of the root [2,6.]

C. Root perforations

Root perforations can occur during root canal therapy or post space preparation and also as a result of the extension of an internal resorption into the periradicular tissues. Perforation repair after an accidental procedure or as a consequence of an internal resorption can be achieved intracoronally and / or by an external surgical approach. Perforations are procedural accidents which can adversely affect endodontic therapy [1,6.]

Extrusion of the filling material is a potential problem in repairing root perforations. This usually occurs during condensation of filling material into the perforation site. Extrusion of filling material can cause traumatic injury to the surrounding periodontal ligament, resulting in inflammation and decay in repair. Hemorrhage control is another factor which can affect sealing ability of the repair material. Presently, available restorative materials are recommended for use in dry fields only [33].

In endodontics materials such as Cavit, Zinc oxide – eugenol, calcium hydroxide, amalgam, gutta – percha, tricalcium phosphate, and hydroxyapatite have been used to repair root perforations. However, none of these are ideal for the special conditions requirements for root repair. To be a superior root repair material, a substance should have the following qualities.

- Resistance to marginal leakage
- Allows normal healing response
- Ease of clinical manipulation
- Non – resorbable
- Non toxic
- Radiopaque

Pro root MTA is compositionally formulated to have the physical properties, setting requirements and characteristics necessary for a clinically effective root repair material [13].

Advantages

1. The advantage of using a material to form an immediate apical barrier over the conventional apexification treatment is that endodontic treatment can be achieved in a single appointment [3].
2. (MTA can be used as a one step obturation material in an open apex) [32]
3. 70% of the failures in study of perforation repair were associated with extrusion of repair material. But MTA does not have to be compacted as firmly as amalgam to adapt adequately to the tooth surface [20].
4. The setting ability of MTA is uninhibited by blood or water. This is an important request of a material which has to be used normally in presence of blood & water and also in teeth with necrotic pulps and inflamed periapical lesions because one of problems in these cases is presence of exudates at the root apex [17].
5. The slow setting time of MTA is an advantage in that it reduces the amount of setting shrinkage which may help explain MTA's low micro leakage [17]
6. A major problem in performing endodontics in immature teeth with necrotic pulp and wide open apices is obtaining an adequate seal of the root canal system. MTA has been proposed as a potential material to create an apical plug at the end of the root – canal system, thus preventing the extrusion of filling materials [1].
7. MTA has an antibacterial effect on few of the facultative bacteria, when comparatively none other test materials had all of antibacterial effects desired [14].
8. MTA has low solubility and a radioopacity slightly more than that of dentin [29]

Disadvantages

1. The use of MTA in cases where the material comes in direct contact with the oral cavity for an extended period of time is unpredictable. This is due to the fact that MTA dissolves in an acidic pH [6]
2. MTA powder has to be mixed with sterile water and cannot be mixed with anesthetic / sterile liquid. This is because the effects other liquids may have on MTA's physical, chemical and biological properties are unknown [14].

3. Excess moisture has to be removed from the preparation / resorptive defect site, because MTA becomes soupy and difficult to condense. All irrigation should be performed before the MTA is place because any irrigation after placement will cause significant washout of the material [14.]
4. It has low compressive strength, and so can not be placed in functional areas [14.]

Summary and Conclusion

MTA is a new biocompatible material with numerous exciting clinical applications. It has been used on an experimental basis by dentists for several years with anecdotally reported success, some of it quite impressive.

A versatile material with principal compounds like tricalcium silicate tricalcium aluminates, tricalcium oxide. In addition small amounts of other mineral oxides responsible for its physical and chemical properties are present.

pH of MTA is 10.2 initially, which rose to 12.5 hours after mixing. MTA is more radiopaque than super EBA and IRM.

An ideal root repair material which has qualities like resistance to marginal leakage, allows normal healing response, ease of clinical manipulation non-resorbable. And finally the most important quality, especially of interest in our field –it is non toxic. Because of all these superior qualities and a high ph similar to calcium hydroxide it is not surprising that induction of hard tissue formation often occurs after the use of this substance. So no longer are immature permanent teeth with carious lesion or traumatic pulp exposure destined for endodontic therapy.

Applications of MTA is not only confined to pulpal procedures, apexification, repair of perforations, but also in periodontics. The regeneration of new cementum over MTA is a unique phenomena and hence an interest use that can be used in conjunction with bone grafting procedures.

To summarize, MTA is a promising material with an expanding foundation of research.

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