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MTA: A review of literature with clinical applications

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Abstract: *Mineral trioxide aggregate (MTA) is a calcium silicate-based cement. It has remained a wide-reaching material in endodontics since its introduction in the 1990's. Several studies have illustrated its use in various clinical applications. 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 history, composition, setting reaction, properties, mechanism of action and various clinical applications of MTA in the field of Endodontics with four different case reports.*

Keywords: *Apexification, MTA, Open apex, Perforation.*

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I. Introduction

Bioceramic materials are biocompatible ceramic materials suitable for its use in human body. They were introduced into endodontics in the 1990's, first as retrograde filling materials and then as root repair materials, root canal sealers, and coatings for gutta-percha cones. Their advantages are related to their biological and physic-chemical properties. They are biocompatible, non-toxic, non-shrinking and chemically stable within the biological environment. Another advantage is their ability to create a bond between dentin and the material.[1]

After the introduction of bioceramic materials into clinical endodontics, mineral trioxide aggregate (MTA) has become recognized as the gold-standard material for a variety of clinical situations and perhaps closest to the ideal reparative material, because of their excellent physic-chemical and biological properties.[1]

MTA is derived from a Portland cement parent compound. Although these compounds are similar in some aspects, Portland cement and MTA are the same. MTA undergoes additional purification processing having a smaller mean particle size and contain fewer toxic heavy metals when compared to Portland cement. MTA was developed by Mahmoud Torabinejad at the Loma Linda University, California, USA and was introduced in dental literature in 1993. It received FDA approval in 1998. The goal was to develop a material to help eliminate communication between the interior and exterior of the tooth.[2]

In 1999 Pro Root MTA (Dentsply Tulsa Dental Specialities, Johnson City, TN) was the first commercially available MTA product. Later in 2001, MTA Angelus was introduced and received FDA approval in 2011.[2] MTA is a calcium silicate based material which has an excellent sealing ability and biocompatibility. It has several clinical applications including apical plug in teeth with necrotic pulps and open apices, as root-end filling material, for pulp therapy and perforation repair among others.[3] In this article, the composition, setting reaction, properties, mechanism of action, and the various clinical applications of MTA in the field of Endodontics are reviewed.

II. Composition of MTA

MTA contains 50-75% (wt) of calcium oxide and 15-25% of silicon dioxide in its composition. These two together comprise 70—95% of the cement. When these raw materials are blended they produce tricalcium silicate, tricalcium aluminate, gypsum, tetracalcium aluminoferrite.[4]

Two forms of MTA are available, ProRoot MTA and MTA-Angelus. ProRoot MTA are available in grey and white forms. The difference is in the concentrations of aluminium, magnesium and iron compounds. The white MTA lacks the alumino-ferrite phase that imparts the grey color to grey MTA.[4]

III. Setting Reaction of MTA

Sluyk et al. (1998), Torabinejad et al. (1999), and Schmitt et al. (2001) advocated that the powder water ratio for MTA should be 3:1. Mixing can be done on a paper pad or glass slab with a plastic or metal spatula to achieve a putty like paste consistency. This mix should be covered with a moist cotton pellet to prevent dehydration of the mix. MTA has a pH of 10.2 immediately after mixing. By the end of 3 hours, the pH increases to 12.5 similar to that of calcium hydroxide. Sluyk et al suggested that mixing time should be less than 4 minutes for MTA.[5]

Torabinejad et al found setting time to be 2 hours and 45 minutes for grey MTA.[5] The setting of MTA takes a relatively long 'clinical' time and is variable between studies and different brands. The setting time of grey MTA varies between 2 h 45 min and 2 h and 55 min, and white MTA sets in 2 h 20 min. Angelus MTA has an initial setting time of less than 10 min, and a final setting time of less than 24 min.[6] MTA can be placed into the desired location using ultrasonic condensation, plugger, absorbent points or specially designed carriers.[5]

IV. Properties of MTA

4.1. Compressive strength

Less than 3% weight loss has been reported after immersing the set MTA in water for 24 hr. After 24 hr of setting, MTA has a mean compressive strength value of 40 MPa which is lower than amalgam, Intermediate Restorative Material and Super EBA cement. After 3 weeks, the compressive strength of MTA increases to 67 MPa as MTA continues to mature for up to 1 year. The compressive strength of Angelus MTA was 46.4 MPa and 65.1 MPa after 24 hr and 4 day storage, respectively at 37ºC.[6]

4.2. Sealing ability

Bates *et al* found that MTA is superior to the other traditional root-end filling materials. Valois *et al* found that about 4-mm thickness of MTA is sufficient to ensure a good sealing. According to Shipper *et al* and Torabinejad *et al* MTA has excellent sealing ability which may occur because MTA expands during setting reaction. In a slightly wet condition the sealing ability of MTA is enhanced due to the setting expansion hence is recommended to place a moistened cotton pellet in contact with MTA before placement of the permanent restoration.[5]

4.3. Solubility

The set MTA shows no signs of solubility. However, if more water is added during mixing, the solubility increases. Buding et al in 2008 found that when set MTA was exposed to water, it releases calcium hydroxide which may be responsible for its cementogenesis-inducing property.[5]

4.4. Radio-Opacity

According to Shah Ding and SJ MTA has comparable radiodensity as Zinc Oxide Eugenol and is less radio opaque than Super EBA, IRM, gutta-percha or amalgam. According to Torabinejad the mean radio opacity of MTA is 7.17 mm of equivalent thickness of aluminium, which is adequate to make it easy to visualize radiographically.[5]

4.5. Biological Property

The biocompatibility of MTA is similar to chemically-inert titanium and greater than silver amalgam, Super EBA, and IRM. After setting, MTA produces crystalline calcium hydroxide called Portlandite. Portland cement and MTA are rich in Calcium oxide and in the presence of water, it forms calcium hydroxide. Alkaline pH levels and Calcium ions in the fluid surrounding MTA are conducive to hard-tissue precipitation. The calcium ions released by MTA enhances osteoblastic viability, proliferation, and differentiation, and hydroxide increases the alkalinity of the environment, which is unfavorable for bacterial growth. Calcium silicate-based cements are active biomaterials; that is, they have the ability to induce a favorable response from the host tissues.[6]

V. Mechanism of Action of MTA

MTA when placed in direct contact with human tissues

- Releases calcium ions for cell proliferation
- Create an antibacterial environment by its alkaline pH
- Modulates cytokine production
- Encourages migration and differentiation of hard tissue producing cells
- Forms hydroxyapatite on MTA surface and provides biological seal.[7]

VI. Clinical Applications of MTA

MTA is used for forming an apical plug during apexification, repairing root perforations and the treatment of internal root resorption and used as a root-end filling material and pulp capping material.

VII. Case Reports

7.1. Case 1-Apexification

A 32 year old female patient reported with a chief complaint of mild discoloration of upper front tooth since 10 years. Patient gave a history of trauma to upper tooth at the age of 10. Medical history was non-contributory. Intra oral clinical examination showed discolored 21 which was sensitive to percussion and palpation tests (figure 1). The affected tooth did not respond to both electric and heat tests. Intra oral periapical radiograph revealed blunderbuss canal in 21 (figure 2). To avoid the patient from multiple visits for completion of the treatment, the treatment approach with MTA was opted over the traditional calcium hydroxide approach for apical closure.

Access opening for root canal treatment of 21 was done and refined with a safe end tapered bur (Endo-Z) under rubber dam isolation and working length was determined radiographically as per the standard procedure (figure 3). Root canal preparation was performed using #80 K-file with a circumferential filing motion and an alternate irrigation with 2.5% NaOCl and 0.9% saline was carried out for debridement. Calcium hydroxide was placed in the root canal with paper point and the patient was recalled after 7 days. At the second appointment after removal of the temporary dressing the root canal was found completely dry. It was then debrided with 2.5% NaOCl followed by 17% EDTA and a final rinse with 2% chlorhexidine was done.

The canal was dried with absorbent points and mineral trioxide aggregate was dispensed and mixed according to manufacturer's instructions. The canal was filled up to half its length using an amalgam carrier and subsequent increments was condensed with a hand plugger and back-end of a paper point. The thickness of the MTA plug was 3 to 5 mm of the material and this was confirmed with a radiograph (figure 4). A moist cotton pellet was inserted into the canal to aid in setting and was left undisturbed for 15 min. The access cavity was then sealed with temporary cement Cavit.

In the subsequent third appointment the root canal was back filled using thermoplasticized gutta percha and a radiograph to assess the obturation status was considered (figure 5). The access cavity was sealed with a light-cured composite resin. A follow-up radiograph of 1 year was taken which showed complete healing of the periapical region and closure of the root apex (figure 6).

7.2. Case 2: Indirect pulp capping

A 20 year old female patient reported with a chief complaint of mild to moderate sensitivity on thermal (cold) stimulation and discomfort associated with eating in the left mandibular first molar since 3 months. Clinical there was an amalgam restoration with secondary decay in the mandibular left first molar tooth (figure 7). The tooth responded normally to percussion and palpation. Normal appearance of adjacent gingival tissue was evident. Intra oral periapical radiograph revealed an amalgam restoration with secondary decay, very close to the pulp, absence of radiolucency in the periapical region and no periodontal space widening (figure 8). Pulp sensitivity was confirmed by thermal (cold test) pulp vitality test. There was no exaggerated or lingering pain after removal of the stimulus. A diagnosis of reversible pulpitis of left mandibular first molar was made and the treatment plan was established to preserve the pulp vitality by indirect pulp capping with MTA followed by permanent restoration with light cured composite resin.

Local anesthesia was administered and isolation was done with rubber dam. The amalgam restoration was removed by using no. #4 diamond bur at high speed with sufficient water spray. Infected dentin from the distal cavity wall and the floor was excavated with a spoon excavator followed by low speed round carbide bur leaving the affected dentin to avoid the pulp exposure (figure 9). The cavity was dried with sterile cotton pellets. MTA was mixed and was placed into the cavity by amalgam carrier (figure 10). A moist cotton pellet was placed for about 12 minutes and the cavity was temporized with GIC (figure 11). After 1week follow-up, the patient was asymptomatic and a final restoration with posterior composite was given (figure 12 and 13). The patient was recalled for clinical and radiological evaluation at 1 and 3 months time interval which showed reparative dentin formation at the dentin over the pulp and MTA interface (figure 14 and 15).

7.3. Case 3: Furcal perforation repair

A 38 year old male patient was referred for root canal treatment for lower left mandibular first molar. During the procedure an iatrogenic perforation of the furcal floor occurred. A cotton pellet was placed in the orifice of perforation and working length was determined radiographically (figure 16). The root canals were cleaned and shaped and obturated. After the obturation, the cotton pellet was removed to expose the site of perforation (figure 17). The furcal perforation was irrigated with saline solution and 2% chlorhexidine. MTA was placed into the pulp chamber with the help of an amalgam carrier (figure 18 and 19). It was gently packed with a moist cotton pellet to obtain a good adaptability Afterward, the MTA and the cavity was restored with GIC. The patient was then recalled for a permanent coronal restoration after a week. 1 month follow up radiograph showed adequate sealing of the perforation region and reduction in the size of radiolucency at the furcal area indicationg signs of healing (figure 20).

7.4. Case 4: Root-end filling

An 18 year old female patient came with a chief complaint of pain in the upper front tooth region since 1 year. History revealed trauma 3 years back to the same region. Intra oral examination revealed tenderness to percussion and palpation in 12 region. The affected tooth did not respond to both electric and heat test. Panoramic radiograph showed diffused periapical radiolucency and intra oral periapical radiograph revealed calcified canal (figure 21 and 22). Access opening was attempted but the canal could not be negotiated, hence a surgical approach was planned to treat the symptoms. Periapical surgery was initiated. Full thickness mucoperiosteal flap was raised and the periapical lesion was enucleated (figure 23). Three millimeter apical resection of the root of 12 was done and retrograde preparation was done to receive MTA as root end restorative material (figure 24). Sutures were placed, which was removed after 1 week (figure 25). Radiograph was taknen immediately after surgery (figure 26). The patient was kept under observation. Follow-up was done at 1 and 3 months (figure 27 and 28). Periodic radiographic examination revealed healing of the defect and the patient was asymptomatic.

VIII. Figures

8.1. Case 1: Apexification

Fig 1: Pre operative

Fig 2: Pre operative IOPAR

Fig 3: Working length IOPAR

Fig 4: MTA apical plug

Fig 5: Obturation IOPAR

Fig 6: 1 year follow-up IOPAR

8.2. Case 2: Indirect pulp capping


Fig 7: Pre operative

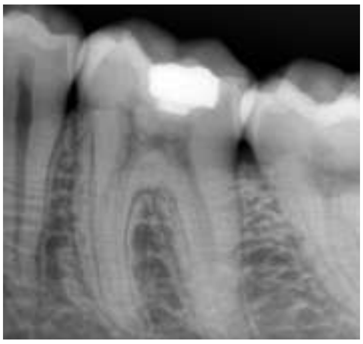
Fig 8: Pre operative IOPAR


Fig 9: Removal of decay


Fig 10: MTA placed in deepest portion

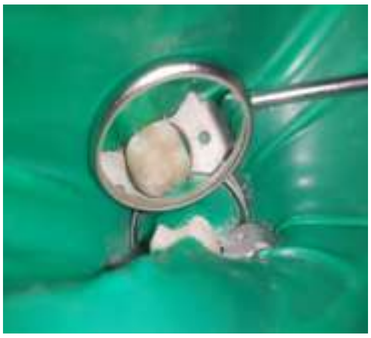
Fig 11: Temporarization with GIC


Fig 12: Composite restoration

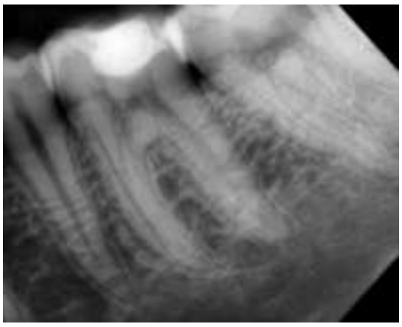
Fig 13: Post operative IOPAR

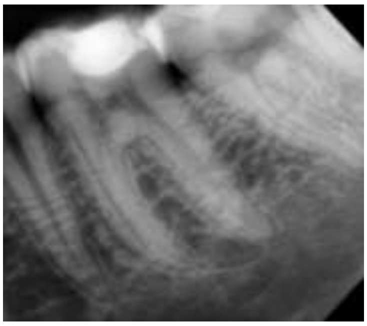
Fig 14: 1 month follow-up IOPAR

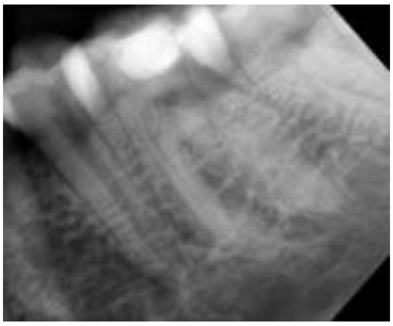
Fig 15: 3 month follow-up IOPAR

8.3. Case 3: Furcal perforation repair

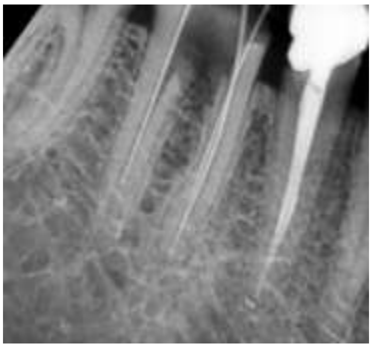
Fig 16: Furcal perforation IOPAR


Fig 17: Furcal perforation clinically


Fig 18: Repair with MTA

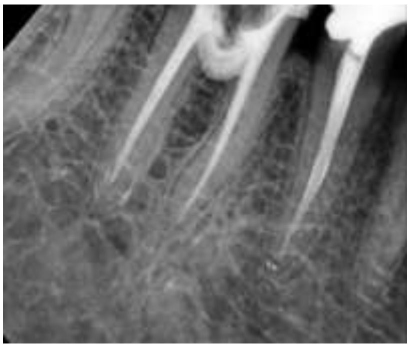

Fig 19: Perforation repair with MTA

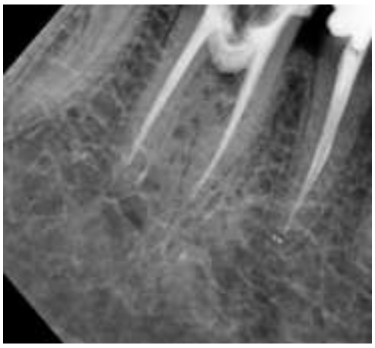

Fig 20: 1 month follow-up IOPAR

8.4. Case 4: Root-end filling

Fig 21: Panoramic image

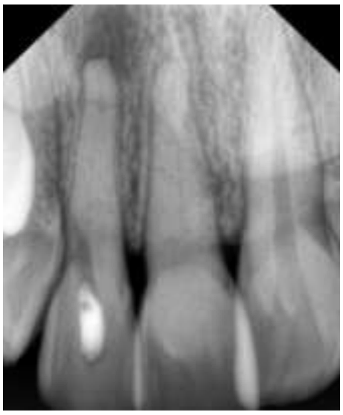

Fig 22: Pre operative IOPAR

Fig 23: Enucleation of lesion

Fig 24: MTA placement

Fig 25: Sutures placed

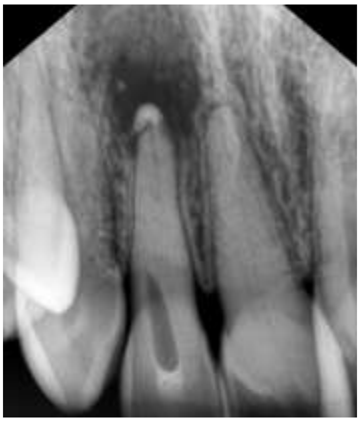

Fig 26: IOAPR after surgery

Fig 27: 1 month follow-up IOPAR

Fig 28: 3 month follow-up IOPAR

IX. Discussion

The treatment of a necrotic pulp in an immature root has always been a challenge to clinicians due to the lack of an apical stop. This has been treated with long term calcium hydroxide therapy involving multiple visits where there is an increase in the fracture potential of the root involved. MTA has become an excellent alternative to these complications by creating a biocompatible apical plug in a single visit.[2] Several investigators have demonstrated the use of dentin apical plugs in nonsurgical root canal therapy of mature teeth. MTA is a material that is best suited as an apical plug. In 1999, Shabahang et al showed consistent barrier formation when MTA was used as an apical plug in an in vivo dog model with open apices.[8] Pace et al reported 17 cases with necrotic pulp and immature apices in a 10-year study with a success rate of 94% (only one failure). They used the "MTA apical plug technique", demonstrating it was suitable for the management of teeth with open apices and periapical lesions. Mente et al., in a long-term cohort study, found that orthograde placement of MTA with apical plug technique is a promising treatment for open apices.[9] A study was done by Al-Kahtani in which he suggested placing a 5 mm thickness of MTA as an apical barrier for apexification. This is because it gives an excellent seal and provides sufficient material to prevent it from being displaced. Thermaplasticized gutta-percha is usually recommended in these cases with thin walls.[7] Hence in the present case, an apical plug of 5 mm thickness of MTA was placed and thermoplasticized gutta percha technique was used for obturating the remaining canal. Follow up after treatment is the most importance factor to study the success of the treatment. In the present case, 1 year of follow-up was done. The radiographic appearance of the teeth showed hard tissue formation at the apex and complete closure of root apex.

A study by Petrou et al demonstrated that non-reabsorbable materials like MTA offer clinical advantages for indirect pulp treatment in deep carious lesions. White MTA demonstrated the ability to induce the formation of a harder dentin and lower the bacteria presence after 6 months. The study suggests a high success rate of 90.3% and leaves more remaining demineralized dentin in deep carious lesion than calcium hydroxide.[9] The time of follow-up is an important factor after indirect pulp capping. A clinical and radiographic investigation reported significantly higher success rates for MTA compared to calcium hydroxide as an indirect pulp capping material three months following treatment.[10]

Pitt Ford et al were the first investigators who used MTA for repair of furcal perforations. They showed that cementum was formed beneath MTA in most treated teeth converse to the teeth whose furcation perforation sites were repaired with amalgam. Various studies done suggests that MTA produces the best histologic results compared with other currently used perforation repair materials.[11]

A root-end filling is performed in endodontics when an extra-radicular surgical approach is needed to address endodontic pathology. Most cases treated surgically cannot be expected to be treated by orthograde conventional root canal methods because of complex canal anatomy. MTA has excellent physical sealing properties and a good biological seal is obtained by the proliferation of cells directly on the cementum while healing. Once the apical 3mm of the root has been resected, the canal system can be opened and cleaned with surgical ultrasonic tips to create the retro-preparation. It is dried and MTA is placed and condensed in that space to create the retro- an additional filling.[2]

X. Conclusion

Scientific research has demonstrated the effectiveness of MTA when used in a range of endodontic procedures. MTA has various exciting clinical applications as it has numerous qualities required for an ideal dental material. In this review article, the properties, sealing ability, setting reaction, biocompatibility and clinical performance of MTA have been discussed. When sealing effectiveness and biocompatibility are considered, there is no other dental material comparable to that MTA. MTA based products are likely to remain the heart of good dental practice for many years to come so that its advantageous properties can be explored.

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