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Mineral Trioxide Aggregate- A Boon to Dentistry

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Authors' contributions

This work was carried out in collaboration between all authors. Author NM designed the study. Author SG wrote the protocol and wrote the first draft of the manuscript. Author Shalan Kaul managed the literature searches. Author Bhawna Kaul analyzed the review and author Sharad Kharyal revised the manuscript. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Surgical treatment involves the placement of a material designed to seal the root canal contents from the periradicular tissues and repair root defects. An ideal endodontic repair material ideally would adhere to tooth structure, maintain a sufficient seal, be insoluble in tissue fluids, dimensionally stable, non-resorbable, radiopaque, and exhibit biocompatibility. The diverse application of Mineral Trioxide Aggregate in the practice of paediatric dentistry is evident in its use as an apical barrier in immature non-vital teeth and in the coronal fragment of fractured roots, as a pulpotomy medicament in primary and permanent teeth, a pulp capping agent in young permanent teeth, and as a repair material for perforation and resorptive defects.

Keywords: Portland cement; calcium hydroxide; pulpotomy; pulpectomy; apexification.

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1. INTRODUCTION

Surgical treatment usually involves the placement of a material designed to seal the root canal contents from the periradicular tissues and repair root defects [1]. Understandably, this material should demonstrate the ability to form a seal with dental tissues while also exhibiting biocompatible behaviour with the periodontal tissues. An ideal endodontic repair material ideally would adhere to tooth structure, maintain a sufficient seal, be insoluble in tissue fluids, dimensionally stable, non-resorbable, radiopaque, and exhibit biocompatibility if not bioactivity [2]. This material allows normal healing response due to the formation of new cementum and bone. Calcium and phosphorus are the main ions dectected under the electron probe micro analysis of the MTA powder.

1.1 History

Mineral trioxide aggregate (MTA) was developed in early 1990's as a root end filling material in surgical endodontic treatment by Torabinejad et al. at Loma Linda University (California USA). MTA was first described in the dental scientific literature in 1993. It was given approval for endodontic use by the U.S. Food and Drug Administration in 1998 [3].

First commercially available MTA was pro-root MTA and it was introduced in market in 1998 as GMTA or gray Pro-Root MTA. Up to 2002, only one MTA material consisting of gray colored powder was available, and in that year white mineral trioxide aggregate (WMTA) was introduced as ProRoot MTA (Dentsply Endodontics, Tulsa, OK, USA) to address esthetic concerns [4].

Various biological properties attributable to MTA are its ability to form hard tissue, better sealing ability, biocompatibility and antimicrobial property. The diverse application of MTA in the practice of paediatric dentistry is evident in its use as an apical barrier in immature non-vital teeth and in the coronal fragment of fractured roots, as a pulpotomy medicament in primary and permanent teeth, a pulp capping agent in young permanent teeth, and as a repair material for perforation and resorptive defects.

Because of various advantages of MTA over other comparative materials, it is important for clinicians to have review of its mechanism of action, clinical usage, indications and limitations.

2. CHEMISTRY AND STRUCTURE

MTA materials are a mixture of a refined Portland cement and bismuth oxide, and are reported to contain trace amounts of silicon dioxide (SiO_2), calcium oxide (CaO), magnesium oxide (MgO), potassium sulphate (K_2SO_4), and sodium sulphate (Na_2SO_4). The major component, Portland cement, is a mixture of dicalcium silicate, tricalcium silicate, tricalcium aluminate, gypsum, and tetracalcium aluminoferrite [3,4,5].

The first research paper on the constituents of MTA (Loma Linda University) in 1995 reported the presence of calcium phosphate [6]. However, Asgary et al. [7] using energy dispersive analysis with X-ray could not detect the presence of phosphorus. Camilleri et al. [3] also showed MTA (ProRoot) did not contain phosphorus. The samples were contaminated by prior immersion in phosphate solution. The powder of MTA was composed mainly of tricalcium and dicalcium silicates with bismuth oxide also present for radiopacity [3].

Table 1. Chemical composition of GMTA & WMTA [7]

Chemical	WMTA	GMTA
CaO	44.23	40.45
SiO_2	21.20	17.00
Bi_2O_3	16.13	15.90
Al_2O_3	1.92	4.26
MgO	1.35	3.10
SO_3	0.53	0.51
Cl	0.43	0.43
FeO	0.40	4.39
P_2O_5	0.21	0.18
TiO_2	0.11	0.06
H_2O+CO_2	14.49	13.72

3. VARIOUS FORMULATIONS

3.1 ProRoot gray MTA (GMTA)

MTA was originally developed as GMTA. It is ash grey in colour.

3.2 ProRoot white MTA (WMTA)

White MTA is similar in composition to grey MTA but it contains significantly less amounts of oxides of iron, aluminium, and magnesium than which are responsible for grey color of the material.

3.3 MTA-Angelus

It has a lower content of bismuth oxide than the ProRoot MTAs.

3.4 MTA Bio

MTA Bio is one commercially available product similar in composition to MTA but incorporates an accelerator in order to decrease the setting time of MTA.

3.5 Manipulation of MTA

It should be prepared immediately before use. Powder must be kept in tight containers away from moisture. Powder is mixed with sterile water in a ratio of 3:1 on a glass slab. It has a working time of 4 minutes. Mixture is carried to its intended site with plastic or metal carrier MTA materials were reported to form a porous matrix characterized by internal capillaries and water channels in which increased liquid/powder ratio produced more porosity and increased solubility (Fig. 1). The effect of mixing MTA powder with different liquids and additives has shown that the choice of preparation liquid can have an effect on setting time and compressive strength [8]. Three and five percent calcium chloride solutions, a water-based lubricant, and sodium hypochlorite gels decreased setting time; however final compressive strength was significantly lower than that obtained prepared with sterile water. Preparation with saline and 2% lidocaine anesthetic solution increased setting time; but compressive strength was not significantly affected. MTA product prepared with chlorhexidine gluconate gel did not set [8]. It should also be intuitive that the chosen preparation liquid must also possess water with the necessary diffusion ability to be available for the hydration reaction.

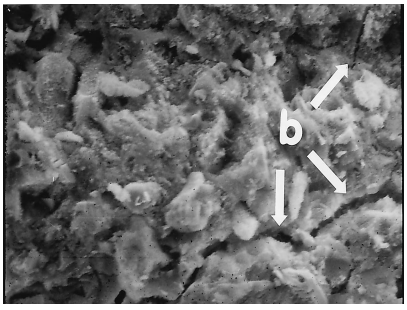

Fig. 1. SEM image of a 0.33 water-to-powder ratio specimen. Capillary channels (b) across the mass of MTA (magnification, ×1800)

3.5.1 Setting / hardening time

The setting time of grey ProRoot MTA was reported by Torabinejad et al. [6] as 2 h and 45 min (± 5 min). Islam et al. [9] reported final setting times of 140 min (2 h and 20 min) for white MTA, and 175 min (2 h and 55 min) for grey MTA. The presence of gypsum is reported to be the reason for the extended setting time of MTA [10]. Extended setting time causes the leakage & material dislodgement during apical surgeries.

3.5.2 Setting reaction

The setting process of MTA has been described as a hydration reaction of tricalcium silicate ($3CaO \cdot SiO2$) and dicalcium silicate ($2CaO \cdot SiO2$), which the latter is said to be responsible for the development of material strength [4]. In the presence of water ($H2O$), CaO hydrogenates to $Ca(OH)2$ and which further reacts with tricalcium aluminate, the following fast reaction occurs:

$$3CaO.Al2O3 + Ca(OH)2 + 12H2O = 4CaO.Al2O3 .13H2O$$

In the hardening process, complex hydration occurs, showing different reaction rates: Dicalcium silicate ($2CaO.SiO2$) hydrates slower than tricalcium silicate ($3CaO.SiO2$) and therefore it is responsible for the later material strength. The trisulfate crystals are formed at the surface of the cement by the reaction of tricalcium aluminate and gypsum:

$$3CaO.Al2O3 + 3CaSO4 + 32H2O = 3CaO.Al2O3.3CaSO4 .32H2O$$

MTA materials have been reported to solidify similar to other mineral cements, in which the anhydrous material dissolves, followed by the crystallization of hydrates in an interlocking mass. The basic framework of the hydrated mass is formed by the interlocking of cubic and needle-like crystals in which the needle-like crystals form in sharply delineated thick bundles that fill the inter-grain space between the cubic crystals [2].

3.5.3 Mechanism of action

The study reported that MTA offered a biologically active substrate for bone & cells stimulating interleukin production [11]. It was reported that osteoblasts have a favorable response to MTA [12]. Another study reported

that MTA has calcium oxide, when mixed with water it forms calcium hydroxide, Reaction between calcium hydroxide & carbon dioxide of the pulp tissue produces calcite crystals which is the initiating step in the formation of hard tissue barrier [13]. In other study it was reported that MTA might be an ideal material because it constantly induced the regeneration of periodontal ligament tissue, apposition of cementum like material, and formation of bone [11]. MTA is rich in calcium oxide which reacts with tissue fluids to form calcium hydroxide which separates into calcium & hydroxyl ions, resulting in increased ph & calcium ion release .Calcium ions may cross the cell membrane by depolarization or activation of membrane bound calcium channels & play a role in the reparative process.

4. PROPERTIES OF MINERAL TRIOXIDE AGGREGATE

4.1 Compressive Strength

Compressive strength is the capacity of a material to withstand axially directed pressure generating compressive stress as a result of compression force. It was reported that mean compressive strength of MTA at the end of 24hr. to be 40mpa and at the end of 21 days to be 70mpa which was comparable to IRM or super EBA, but less than that of amalgam [14].

4.2 Radiopacity

An ideal restorative material should be more radiopaque than its surrounding structures when placed in situ, in order to allow the quality of the restoration or apical seal to be assessed radiopacity of MTA is 6.4 - 7.7 of equivalent thickness of alumunium, which is in the range of zinc oxide eugenol (5.1-9.1) but is less radiopaque than super EBA (9.9 mm Al); IRM (9.3 mm Al); gutta percha (11 mm Al) and amalgam (15.6 mm Al).

4.3 Ph

Usually reported pH of MTA is between 11 or 12, it may slightly decrease over time. The high pH level of MTA materials has led some to theorize that the biologic activity is due to the formation of calcium hydroxide.

4.4 Solubility

The manufacturer recommends the use of 0.33 g of water with 1gm of ProRoot MTA to achieve an optimum mix of the material. Fridland and Rosado demonstrated that both solubility and porosity of the material show a significantly increasing trend that follows the amount of water used when preparing the mix under ISO specifications [15].

4.5 Marginal Adaption and Sealing Ability

An effective root-end filling material should ideally provide a hermetic apical seal, preventing the movement of tissue fluids into the root canal system and the egress of micro-organisms and their by-products from the root canal system [16].

GMTA has been reported to have less microleakage than amalgam [17], zinc-oxide-eugenol (ZOE) preparations, and a conventional glass-ionomer material when used as a root-end restoration following apical resection. Bates et al. [17] reported that MTA was superior to amalgam and comparable with Super EBA in preventing microleakage when used as a root-end filling by the fluid filtration method on extracted human teeth.

4.6 Effect of Compaction / Condensation on MTA

Condensation pressure during the placement of MTA as an apical barrier will be much reduced to prevent the material from being forced into the periodontal ligament or pulp tissue in some of these situations. Nekoofar et al. [18] reported no statistically significant effect of condensation pressure on the compressive strength of white ProRoot MTA, but there was a significant reduction in surface hardness.

4.7 Effect of MTA on the Strength and Hardness of Root Dentine

Studies using sheep and bovine teeth (*in vitro* and *in vivo*) have shown that teeth with an MTA apical barrier and MTA root filling showed higher fracture resistance in comparison to teeth that had calcium hydroxide placed as an intra-canal medicament [19].

4.8 Antibacterial and Antifungal Activity

The healing of tissues damaged by pulp or peri-apical pathology depends on the absence of irritating agents originating from microbial metabolic products, or of chemical origin from the sealing materials. For such healing to occur, the materials placed in contact with healthy pulp

(pulp capping, pulpotomy) and peri-apical tissues (apical barrier, root-end filling) should not damage the tissues and should ideally stimulate the deposition of hard tissue, therefore promoting biological sealing. MTA materials fulfills this requirement adequately [20].

In 2006, Al-Hazaimi et al. [21] assessed the antibacterial effects of the grey and white MTA materials against *Enterococcus faecalis* and *Streptococcus sanguis in vitro*. They reported that lower concentrations of grey MTA were required than the white MTA to exert the same antibacterial effect against each of these microorganisms.

4.9 Reactions with Other Dental Materials

In an effort to offset the extended setting time of MTA, researchers have reported various alternatives to the placement of a moist cotton pellet over the setting MTA material. In an *in vitro* study it was reported that conventional glass ionomer cement can be layered over partially set MTA for a single-visit procedure and that the setting of MTA proceeds unhindered underneath the layer of glass ionomer. It was evaluated that the bond strength of a composite and a compomer to white MTA using different bonding systems. They concluded that the total-etch one-bottle system mediated a stronger bond to white MTA than the self-etch one-step system [22].

4.10 Biocompatibility

The biocompatibility of MTA has been reported widely over the past decade by researchers involved in *ex vivo* cell culture studies and *in vivo* studies in animals and humans.

5. BIOCOMPATIBITY TESTS

5.1 Subcutaneous and Intra-osseous Evaluation

Various studies have reported bacterial and cell culture assays, respectively, to conclude that MTA was not mutagenic or cytotoxic [23]. There have been several studies since then, which have tested samples of MTA as subcutaneous and intra-osseous implants in rats [24], guinea pigs, and rabbits. These studies reported minimal inflammatory responses in the soft tissue and bone, and confirmed MTA to be capable of inducing osteogenesis.

5.2 Animal Studies

The biocompatibility of MTA has also been studied *in vivo* as root end fillings in dogs and monkeys [25,26]. These studies reported satisfactory periapical tissue responses and healing with MTA. Animal studies have also reported MTA as a favorable pulp-capping material following traumatic exposures in monkeys and dogs [13,27]. MTA has been evaluated *in vivo* in rats as a pulpotomy medicament in comparison to formocresol and ferric sulphate, and reported to perform ideally as a pulpotomy agent, causing dentine bridge formation and simultaneously maintaining normal pulpal histology [28].

5.3 Osteoconductive

MTA promotes osteogenesis when implanted intraosseously in test animals. It offers biological active substrate for bone cells and stimulates interleukin production [11]. Studies have shown direct bony apposition on implanted surface.

5.4 Cemento-conductive

Torabinejad & coworker have demonstrated a complete layer of cementum when using MTA as root end filling material in monkeys. MTA is cemento-conductive in tissue cultures with cementoblasts attachment to the material and production of mineralized matrix. Holland et al. [13] showed that tricalcium oxide in MTA reacts with tissue fluids to form calcium hydroxide resulting in hard tissue formation. Cementum deposition is essential to regeneration of periodontal apparatus. Augmentation of new cementum across the root end restoration is essential for ideal healing of peridontium. A layer of cementum also enhances the integrity of apical barrier, making it more resistant to microorganisms in establishing biologic barrier. MTA induces cementoblastic cells to produce hard tissue. Recently cementogenesis in presence of MTA has been evaluated by assessment of-expression of osteocalcin (OCN), cell growth and morphology of cement oblast like cells. Strong expression of ONC gene was seen after application of MTA. SEM studies show that cementoblast could attach and grow on MTA.

5.5 Periradicular Tissue Reactions

When MTA has been used for root-end filling *in vivo*, less periradicular inflammation was

reported compared with amalgam. In addition, the presence of cementum on the surface of MTA was a frequent finding [14]. It induced apical hard tissue formation with significantly greater consistency, but not quantity, in a study of three materials, although the degree of inflammation was not significantly different between the groups. Again, MTA (ProRoot) supported almost complete regeneration of the periradicular periodontium when used as a rootend filling material on noninfected teeth [29]. The most characteristic tissue reaction to MTA was the presence of organizing connective tissue with occasional signs of inflammation after the first postoperative week [25]. Early tissue healing events after MTA root-end filling were characterized by hard tissue formation, activated progressively from the peripheral root walls along the MTA–soft tissue interface [25]. Both fresh and set MTA caused cementum deposition when used after apical surgery. In addition, MTA showed the most favourable periapical tissue response of three materials tested, with formation of cemental coverage over MTA. Use of MTA in combination with calcium hydroxide in one study has shown that the periodontium may regenerate more quickly than either material used on its own in apexification procedures. In vivo studies have shown a favourable tissue response to MTA.

5.6 Pulpal Reactions

MTA used for pulp capping or pulpotomy stimulates reparative dentine formation. MTA-capped pulps showed complete bridge formation with no signs of inflammation [27]. The incidence of dentine bridge formation was higher with MTA than with calcium hydroxide [13]. The dentogenic potential of MTA is because of its ability to proliferate human dental pulp cells which may be due to continuous release of calcium ions which play important role in reparative process of the pulp as well as the antibacterial activity of this material on the infected tissue. Ability of MTA to induce dentinal bridge formation may also be due to its excellent sealing ability.

6. CLINICAL APPLICATIONS

6.1 Direct Pulp Capping

MTA has shown remarkable success when compared to $Ca(OH)_2$ as pulp capping agent. Calcium in hydroxide form is the main chemical released by MTA when mixed with water. This explains the similarity in behaviour when used as pulp capping agent. Better sealing ability favors the use of MTA in comparison to $Ca(OH)_2$. In an animal study, it was found that significantly higher frequency of calcific bridge formation and less inflammation with MTA compared with $Ca(OH)_2$. [14]. Other study compared $Ca(OH)_2$ & MTA as pulp capping agent. He found dentinal bridge in all the samples capped with MTA & no inflammation, in contrast all the samples capped with $Ca(OH)_2$ showed inflammation & bridge formation occurs in very few samples [12].

6.2 Pulpotomy

Formocresol was the material of choice for years to be used for pulpotomy, but it was inherently associated with disadvantages such as toxicity & carcinogenic potential. MTA has shown to form dentinal bridging in shorter periods of time. Barrieshi-Nusair and Qudeimat evaluated the success of grey MTA for partial pulpotomy in 28 cariously exposed young permanent first molars [30]. This was an observational study over a period of 12–26 months with an average of 17.5 months. The authors reported that 79% of the teeth tested positive to sensibility testing with no clinical or radiographic failures. Seven of the teeth which had immature apices at the beginning of treatment showed continued root maturation. A similar findings were also reported by Witherspoon et al. [31] in permanent molars with clinical signs of irreversible pulpal disease.

6.3 Apexification

When a tooth with incomplete root formation suffers pulp necrosis the formation of dentine stops & root development ceases. Consequently the canal remains large with thin & fragile walls & open apex. These features make instrumentation of canal difficult & hinder the formation of an adequate apical stop. So in order to allow condensation of root end filling material it is imperative to create an artificial apical barrier or to induce closure of apical foramen with calcified tissue. Superiority of MTA to use for apexification is related to: Good sealing ability; Biocompatibility; Alkaline Ph; Presence of calcium & phosphate ions in its formulation; Capacity to attract blastic cells & promote favourable environment for cementum formation; Osseous & cementum conductive effect; stimulus to adhesion & cell proliferation; stimulus to expression of alkaline phosphatase by fibroblast. Simon et al. [21] investigated MTA as an apical barrier in non-vital immature permanent incisors reported a decrease in the size of the pre-existing peri-apical lesion in 81% of their cases

[7]. In another study, apical barrier formation in 17 non-vital permanent immature incisors was studied. The one-step placement of an MTA apical barrier was viewed as a promising alternative to traditional, multiple-visit apexification with calcium hydroxide. The advantages of a one step MTA procedure were cited as reduced treatment time; reduced risk of calcium hydroxide induced changes to dentine, and consequently reduced fracture risk, and the early placement of a sealing and possibly reinforcing coronal/intra-radicular restoration [22].

6.4 Retrograde Root-end Filling Material

MTA has significantly less toxicity than amalgam; IRM; super EBA when used as root end filling material.

Table 2. Comparison of Portland cement & MTA

Properties	MTA	Portland cement
Composition	Holland et al. [13] reported both materials have similar chemical formula except for the presence of bismuth oxide in MTA. Gypsum content is less. MTA contains less of toxic heavy metals – mangnese & strontium less chromophores (ferrous ion) less alumunium & potassium [1].	Absence of bismuth oxide. Gypsum content is more. Contains more toxic metals.
Leachable arsenic and lead [9]	Amount of arsenic and lead is below the toxic level.	Arsenic & lead are impurities of lime stone which is used in the manufacturing of Portland cement. Studies have shown that level of arsenic released by both is well below the toxic level.
Biologic properties	Both have similar antimicrobial property; similar biocompatibility; similar tissue reaction when implanted in subcutaneous tissue of rats; and similar effect on pulp when used as pulp capping agent in rats.	Similar antibiotic properties
Particle size	Smaller & equal particles size. Mean particle size is 10µm.Range of particle size is from 0.1 µm to 100 µm [32].	Particles with wide range of sizes.
pH [9]	Less, Initially pH is of 10.2, which raises to 2.5, three hours after mixing. pH is about 9.5 at 168 hours after mixing [32].	Higher
Dimensional change [9]	Slight expansion is associated with superior sealing ability when used as root end filling material. But excessive expansion is undesirable as it may lead to cracks in the root.	Higher value of expansion
Solubility	Less solubility as bismuth oxide present in the MTA is virtually insoluble [9].	High solubility due to presence of high amount of gypsum.
Radioopacity [9]	More radioopaque because of presence bismuth oxide.	It does not meet minimum requirement for radiopacity set out in ISO.
Microhardness [9]	Less amount of potassium is associated with high microhardness of MTA.	Lesser microhardness

Table 3. Comparison of gray & white MTA

Properties	Gray MTA	White MTA
Composition	More amount of magnesium than white MTA	54.9% less Al2O3, 56.5% less MgO, and 90.8% less FeO, which shows that the FeO reduction is most likely the cause for the color change [1]. Reduction of magnesium is also thought to be associated with lighter color of WMTA [4].
Mean particle size	The crystal precipitates on both MTA materials were chemically and structurally similar to hydroxyapatite. But GMTA was found to produce twice as much hydroxyapatite crystals as WMTA, which leads to some speculation that GMTA and WMTA may not possess the same level of bioactivity [34].	Smaller particle size [33]
Tissue reaction evoked by two materials	More of mild to moderate no of macrophages or multinucleated giant cells	No macrophages or multinucleated giant cells.
Radiopacity [9]	6.74 of Al	6.47 of Al
Sealing ability in furcal perforations	According to Ferris & Baumgartner, no significant difference.	No significant difference.
Sealing ability as orthograde root canal filing material	Al-Hezaimi et al. [21] found no difference in leakage	Al-Hezaimi et al. [21] found no difference in leakage
Antifungal activity [21]	No significant difference at higher concentration, but at low conc. GMTA has better antifungal activity than WMTA [35].	No significant difference at higher concentration.

6.5 Repair of Furcal Perforation

Recent developments in the techniques and materials utilized in root perforation repair have dramatically enhanced the prognosis of both surgical and nonsurgical procedures. MTA can be used to repair iatrogenic –lateral perforation, apical perforation during endodontic treatment [36].

6.6 Repair of Root Perforations

Ford TR et al. [35], compared MTA with amalgam for their histologic response to intentional perforation in the furcations of 28 mandibular premolars in seven dogs was investigated. They concluded that mineral trioxide aggregate is a far more suitable material than amalgam for perforation repair, particularly when used immediately after perforation.

6.7 Treatment of Internal Resorption in Primary Tooth

Internal resorption can result from traumatic injury, traumatic occlusion, inflammation, & infection of pulp or idiopathic. Irregularities of root canal in internal resorption poses technical difficulties in cleaning & obturating root canals& interfere with long term success of endodontic treatment. Depending on MTA's better sealing ability, bactericidal effects, biocompatibility& ability to set in the presence of moisture ,it would be ideal to use in the treatment of internal resorption in the coronal third [5].

6.8 Coronal Plug after Complete Obturation

Root canal treatment of the coronal fragment with calcium hydroxide followed by filling with gutta percha is the traditional treatment of choice for non-vital root-fractured teeth. As in the case of open root apices, the use of calcium hydroxide has been promoted to induce hard-tissue barrier formation at the fracture site. The hard tissue barrier is then able to serve as a matrix for the condensation of gutta-percha and sealer. In this situation, MTA has the potential to offer all of the advantages noted for one-step root-end filling [22].

6.9 Obturation of Retained Primary Deciduous Molar

6.9.1 Prophylactic tretment of dens evaginatus

6.9.1.1 Treatment of internal resorption in primary tooth

Internal resorption can result from traumatic injury, traumatic occlusion, inflammation, & infection of pulp or idiopathic. Irregularities of root canal in internal resorption poses technical difficulties in cleaning & obturating root canals & interfere with long term success of endodontic treatment. Depending on MTA's better sealing ability, bactericidal effects, biocompatibility & ability to set in the presence of moisture, it would be ideal to use in the treatment of internal resorption in the coronal third [5] .

6.10 Apical Seal in the Non-vital Coronal Portion of Permanent Teeth Following Root Fracture

Root canal treatment of the coronal fragment with calcium hydroxide followed by filling with gutta percha is the traditional treatment of choice for non-vital root-fractured teeth. As in the case of open root apices, the use of calcium hydroxide has been promoted to induce hard-tissue barrier formation at the fracture site. The hard tissue barrier is then able to serve as a matrix for the condensation of gutta-percha and sealer. In this situation, MTA has the potential to offer all of the advantages noted for one-step root-end filling [22].

6.10.1 Advantages

1. Alkaline
2. Low toxicity
3. Radiopaque
4. Biocompatibility
5. Better sealing ability
6. Negligible solubility
7. Antimicrobial property
8. Promote cementogenesis
9. None or less pulpal inflammation
10. Actively promote hard tissue formation
11. Setting unaffected by blood or moisture

6.10.2 Disadvantages

1. Expensive
2. Nonresorbable
3. Difficult to handle
4. Longer setting time
5. Low compressive strength

A more research is needed and an overview of the material aspect (commercial products) and clinical considerations for MTA materials are discussed by many authors and in various articles [37-43].

7. CONCLUSION

MTA is a promising material for root-end filling, perforation repair, vital pulp therapy, and apical barrier formation for teeth with necrotic pulps and open apexes. This material allows normal healing response due to the formation of new cementum and bone. Calcium and phosphorus are the main ions dectected under the electron probe micro analysis of the MTA powder. When sealing effectiveness and biocompatibility are considered, there is no other dental material on the market similar to MTA. Hydroxyapatite crystals form over MTA when it comes in contact with tissue synthetic fluid. This can act as a nidus for the formation of calcified structures after the use of this material in endodontic treatments. On the basis of available information, it appears that MTA is the material of choice for some clinical applications. More clinical studies are needed to confirm its efficacy compared with other materials. With the recent introduction of a fast setting MTA which also offers excellent handling properties, MTA-based products are likely to remain at the heart of good dental practice for many years to come.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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