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Sealing Ability of MTA Used in Perforation Repair of Permanent Teeth; Literature Review

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Abstract: There were several materials used to seal different types of perforation defects. MTA is one of these restorative materials that is considered the most effective, biocompatible, non-toxic, and non-irritant; promote bone healing and cementum regeneration. The objective of this article was to review and summarize the sealing ability of MTA compared with the other materials used for sealing different types of root perforations of permanent teeth. A literature search was conducted using Medline, accessed via the National Library of Medicine Pub Med from 2005 to 2015 searching for articles related to sealing ability of MTA. This study found that factors affecting prognosis are the size, site of the perforation and time elapsed as well as the repair material. MTA is an important filling material to be used for sealing different types of perforations when perforated sites sealed immediately with MTA.

Keywords: Micro leakage, MTA, Perforation, Sealing ability.

1. INTRODUCTION

Perforations of the pulp chamber floor or the root can occur accidentally during root canal treatment or restorative procedures [1]. Such perforations resulted in the formation of granulation tissue as a chronic inflammatory reaction of the periodontium that either led to irreversible loss of attachment or tooth [2]. The treatment of these perforations is either surgically or nonsurgically depends on the case [3]. A good prognosis obtained when the problem is correctly diagnosed and treated with a suitable material of sealing ability and biocompatibility while it will be questionable when the perforation is at the level of radicular furcation [1]. Prognosis of perforation depends on the time of contamination, location and size of the lesion [4].

Many materials used for managing perforations such as: glass ionomer and resin modified glass ionomer, zinc oxide-eugenol, amalgam, calcium hydroxide and composite resin [1 - 4]. The material of choice for treating radicular perforations should be nontoxic, non-absorbable, radiopaque, bacteriostatic, bactericidal and provide a seal against micro leakage [5].

In 1998 the U.S. Food and Drug Administration approved MTA (Mineral trioxide aggregate)[6]. This material showed good results in treating cases of lateral radicular and furcal perforation, root-end surgery, direct pulp coverage, apexification and radicular resorption [7]. This is because of its characteristics as biocompatibility, low induction of inflammation, solubility, creating a seal between the pulp chamber and periodontal tissues and repair capacity [8]. It is the only material which allows the overgrowth of cementum, bone formation and facilitates the regeneration of the periodontal ligament [9 - 12].

Composition and Physical Properties of MTA

MTA is a fine hydrophilic powder [13]. It is available in two types grey and white MTA. These two types are similar but have slight differences in chemical composition [14], the presence of the trace minerals gives the dark grey

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appearance of grey MTA[15]. Clinical studies found that these two forms of MTA can respond differently as the white preparation resulting in less tooth discoloration in anterior teeth [10]. Also White MTA has less levels of tetra calcium aluminoferrite than the grey preparation which is responsible for discoloration [16].

MTA sets in the presence of fluids such as the blood. A colloidal mixture results by mixing sterile water and powder preparation forms which set to form hardened cement. Initial setting obtained approximately three to four hours [17]. MTA slowly releases calcium hydroxide at least 3 months after initial mixing and placement [18]. Heithersay suggested that calcium hydroxide released by MTA can activate the pyrophosphatase enzyme that interacts with precapillary sphincters to reduce local blood flow and induce hard tissue formation [19, 20].

Initial pH of MTA is 10.2 that increase during setting reaction to a pH of 12.5 due to the calcium hydroxide release from the setting material [13]. The therapeutic mechanism of MTA is due to the high pH of the setting material [21].

Micro Leakage Properties of MTA

The successful endodontic treatment is highly dependent on minimizing micro-leakage in root canal [2]. Many researches evaluated the sealing ability of MTA in perforation repair and root end filling and this was obtained through an *In vitro* dye, fluid filtration or an *In vitro* bacterial penetration method [22].

The sealing ability of dental materials can be evaluated by Dye penetration techniques [23, 24]. These techniques were used due to their ease of use without sophisticated materials. Also they were commonly used because of the many disadvantages of dye leakage methods such as: (a) Molecular size of dye particles is smaller than bacteria. (b) Most studies measure penetration in one plane rather than total leakage. (c) Studies showed static interaction rather than the dynamic interaction with periradicular tissues. Dye-extraction has the most reliable results as it measures all of the dye taken up in the root [24].

Therefore the aim of this paper divided into two parts:

Part I: reviewing and summarizing the current literatures that evaluate the sealing ability of MTA as a perforation repair material of permanent teeth.

Part II: comparing the sealing ability of MTA with the other materials used in perforation repair.

MATERIALS AND METHODS

With the help of currently available literature, this paper attempted to point out the sealing ability of MTA comparing it with the other materials used to seal different types of root and crown perforations. The electronic database PubMed was searched for scientific articles on sealing ability of MTA and other materials that were used in repair of crown and root perforations. The search was carried out in papers between 2005 to 2015 to represent the latest developments in the last 10 years. The search words MTA, root perforations, sealing ability and micro-leakage were used. The search was done for papers discussing sealing of crown and root perforations using MTA and other materials. Total 58 papers were selected out of 70 papers. The selection was done on the basis of papers that discuss and compare sealing ability of MTA with other materials used to repair crown and root perforations. The rejected papers discussed other aspects as well which are not related to the scope of the review. The results of selected studies are presented in tables 1 and 2. The papers were listed in the tables with ascending arrangement according to the year of publication.

DISCUSSION

Part I of this review is discussing the sealing ability of MTA when used in repair of different types of root and crown perforations (Table 1) [25 - 42].

Table 1. Studies that investigating Sealing ability of MTA used to repair different types perforations of permanent teeth.

First author + year	Description of study	Type of Perforation/Case	Methods of assessment	Results
Menezes <i>et al.</i> , (2005) [30]	Case report Presents repair of a supracrestal root perforation using MTA.	32 years old patient with accidental supracrestal root perforation and radiolucent periapical area.	-Clinical examination -Radiological examination.	After Fifteen months radiographs showed adequate sealing of supracrestal perforation and reparation of the radiolucent periapical area.

(Table 1) *contd....*

First author + year	Description of study	Type of Perforation/Case	Methods of assessment	Results
Silveira <i>et al.</i> , (2008) [34].	Case report Use MTA to repair furcal perforation of different causes.	- 27 years old patient with pulpal necrosis with acute periradicular periodontitis and carious furcation perforation. - 30 years old patient with accidental furcal perforation.	-Clinical examination. -Radiologic examination.	In the 1st case: Three months after treatment there was radiographic evidence of bone formation adjacent to MTA. In the 2nd case the final radiograph obtained at the time of treatment showed evidence of perforation seal and at 6-months follow up, bone formation was evident. MTA was suitable material for furcation perforation repair either accidental or due to caries.
Amaral <i>et al.</i> , (2009) [35]	Case report Use MTA as a filling material in internal root resorption.	2 Cases 40 years old patient with an extensive destruction in the middle third of the root due to trauma at 22 year before. 52 years old patient with asymptomatic large internal resorption communicating with periodontal ligament.	-Clinical examination. -Radiologic examination.	MTA used to treat internal root resorption was successful with 2 years follow up showed lack of pain, fistula, normal space on the periodontal ligament, no mobility, favorable periapical tissue response, with new formation of cemental coverage over MTA.
Mehta <i>et al.</i> , (2011) [36]	Case report Use non-surgical approach to treat root perforation and resorption.	13y Male patient with lateral root perforation, widening of the periodontal ligament space and periapical abscess followed by external root resorption .	-Clinical examination - Radiologic examination. -Non-surgical endodontic approach.	On follow up after 12 months, MTA placed to restore the osseous defect using MAP system showed no evident radicular lesion. MTA provided an effective seal of root perforations and external resorption.
Saha <i>et al.</i> , (2011) [25]	Case report repair furcal perforation with MTA.	45y Male patient with perforation in the furcation area 18y Girl patient with perforation on the floor of the pulp chamber.	Clinical examination. Radiologic examination. Microscopic examination.	After 6 months follow up teeth were asymptomatic. MTA is a suitable material for closing the communication between the pulp chamber and the underlying periodontal tissues.
Silva <i>et al.</i> , (2012) [26]	Case report Repair of iatrogenic perforation with MTA under operating microscope.	43y old female patient with coronary perforation during endodontic retreatment.	-Clinical examination. -Radiologic examination. -Microscopic examination.	Retreatment done under operating microscope with MTA was suitable material for Perforation repair and the one year follow up with the absence of periradicular radiolucent lesions, pain, and swelling along with functional tooth stability showed good prognosis.
Nunes <i>et al.</i> , (2012) [40]	Case report use MTA to treat a perforating internal root resorption.	32y old female patient traumatized Maxillary lateral incisor with internal radiolucent area in the middle third of the root.	Clinical examination. Surgical microscope. Radiologic examination. Computerized tomography.	In follow up after 11y and 8months, no symptoms, no sinus tract, periodontal bone repair with normal ossification of internal bone septa adjacent to the tooth root. MTA was most commonly used because of its sealing ability, biocompatibility and potential induction of osteogenesis and cementogenesis.
Upadhyay <i>et al.</i> , (2012) [39]	Case report Repair of perforated internal resorption using MTA.	36y female with radiolucent lesion in the internal root canal dentine walls of maxillary incisor.	Clinical examination. radiologic examination.	The results were satisfactory at 2-year follow-up. MTA resulted in rapid resolution of symptoms and signs and successful repair of perforating internal resorption.
Vijetha <i>et al.</i> , (2012) [32]	Case report Manage the external cervical resorption using mineral trioxide aggregate.	45y Male patient external cervical inflammatory resorption with periapical lesion underwent orthodontic treatment.	Clinical examination. Radiologic examination. Root canal therapy.	The 1 year follow up showed patient's tooth was asymptomatic and there was no evidence of progression of the resorptive process.
Froughreyhani <i>et al.</i> , (2013) [29]	Case report Introduced repair of strip root perforation using MTA.	25y female patient with stripping perforation of the mesiolingual canal of mandibular 1st molar. With pain on percussion.	- Clinical examination. - Canal instrumentation. - Radiologic examination.	On 15 month recall no signs or symptoms, and complete resolution of furcal and periapical radiolucency. Successful repair of strip root perforation using root MTA.

(Table 1) contd....

First author + year	Description of study	Type of Perforation/Case	Methods of assessment	Results
Sinkar <i>et al.</i> , (2015) [42]	An ultraviolet spectrophotometric analysis. Comparison of sealing ability of ProRoot MTA, RetroMTA, and Biodentine as furcation repair materials.	35 extracted intact human mandibular molars with non-fused well developed roots with furcation perforations.	Dye extraction method.	MTA has numerous clinical problems such as difficult handling characteristics, prolonged setting time, and prospective discoloration.

Perforation is defined as "the mechanical or pathological communication between the root canal system and the external tooth surface"[25]. Owing to factors affecting perforation repair Saha *et al.*, 2011 [25] and Silva *et al.*, 2012 [26] reported that the successful perforation repair is affected by the etiology, perforation location, size and time elapsed before repair.

Perforations are successfully treated when they immediately sealed to prevent infection [27]. Time passed, size of the perforation [27, 28] and the material used for repair all are important factors affecting better prognosis of perforation healing [27]. Froughreyhani *et al.*, 2013[29] found a successful use of Root (MTA) in repair of strip root perforation as the time elapsed between perforation and repair was short. Menezes *et al.*, 2005[30] described a successful immediate sealing of an iatrogenic supra crystal perforation case with hemorrhage inside canal with pro-Root MTA.

Also location of the perforation is an important factor affecting perforation prognosis (better prognosis with the more apically located perforations while the lesser prognosis with coronal perforations) [31]. Vijetha *et al.*, (2012) [32] reported that the successful treatment depends on the location and severity of perforation lesion when treated ECR (external cervical resorption) with MTA under a full-thickness periosteal flap to allow access to the ECR.

Perforations of the crown or root result in an inflammatory process that breaks down the periodontium, extending to the gingival sulcus, forming a deep and unmanageable periodontal defect, so that coronal perforations have lesser prognosis compared to those are apically located [33]. Silveira *et al.*, 2008 [34] illustrated a successful use of MTA with complete osseous healing on long term follow up in treating two cases of perforations with different causes (one is accidentally during access cavity and the other is caries-related). Both had periradicular periodontitis and bone loss at area adjacent to perforation site secondary to the perforation. Saha *et al.*, 2011[25] also reported a successful use of MTA in treatment of two cases with untreated infected furcation perforation that led to an abscess formation, large inflammation and subsequent proliferation of the crevicular epithelium. Amaral *et al.*, 2009 [35] showed two cases with large internal root resorption due to dental trauma communicating with periodontal ligament repaired with MTA as a filling material and there were stop of resorption progress and complete healing.

Mehta *et al.*, 2011 [36] observed widening of the periodontal ligament space and periapical abscess followed by external root resorption associated with a lateral root perforation that were successfully treated with MTA which provided better seal of root perforations and resorption. Silveira *et al.*, 2008 [34] also reported chronic periodontium inflammation and granulation tissue formation that led to the loss of attachment due to furcation perforation.

Ideal material used for perforation sealing should promote regeneration of peri-radicular tissues, as it should have antimicrobial activity; prevent leakage of microorganisms and their byproducts [37]. It should also be dimensionally stable, radiopaque, insensitive to moisture, adhesive to dentine, non-toxic, nonirritant, non-carcinogenic, biocompatible [38] and promote osteogenesis and cementogenesis [25]. Saha *et al.*, 2011[25] reported that (MTA) is the best material for furcal perforation repair when used it in the treatment of two cases with furcation perforation. Silva *et al.*, 2012 [26] found that the ideal material for perforation repair, retrograde filling, pulp capping and apexification is (MTA) when used to repair a case with coronal perforation. Upadhyay *et al.*, 2012 [39] found that MTA has many good properties as biocompatibility, good sealing ability, radiopacity and moisture resistance when used in a case of internal resorption with buccal perforation and healing was satisfactory at 2-years follow-up with cease of the symptoms and signs. Nunes *et al.*, 2012 [40] reported successful use of MTA that showed good sealing ability, biocompatibility and potential induction of cementogenesis and osteogenesis in filling a perforating internal root resorption area with the help of surgical microscope during root canal treatment of the apical third. Machado *et al.*, 2013 [41] described the successful use of mineral trioxide aggregate (MTA) in the management of large furcal perforation due to its sealing capacity, biocompatibility, bactericidal effect, radiopacity, and ability to set in the presence of tissue fluids or blood. In contrast to all of the previous studies Sinkar *et al.*, 2015 [42] reported that MTA has numerous clinical problems such as difficult handling characteristics, prolonged setting time, and prospective discoloration.

Part II of this review is comparing the sealing ability of MTA to other materials used in repair of different types of root and crown perforations (Table 2) [43 - 58].

Table 2. Studies compared the sealing ability of MTA to other materials used in perforation repair of permanent teeth.

First author + year	Description of study	Subjects/ teeth	Methods of assessment	Results
Holland <i>et al.</i> , (2001) [52]	<i>In vitro</i> study Assess healing of intentional lateral root perforation repaired with (MTA)	48 root canal of 4 mongrel dogs teeth	-Endodontic treatment -Clinical examination -Radiologic examination	MTA allowed healing and deposition of cementum without inflammation better than Sealapex that exhibited chronic inflammation
Yazdi <i>et al.</i> , (2006)[49]	<i>In vitro</i> study Compare tissue reaction of pulp chamber perforations with MTA, light-cured GIC and amalgam	54 lower premolar teeth of 9 Dogs with perforation in floor of pulp chamber	-Access cavity preparation -Histologic evaluation.	MTA and GI were more suitable materials for perforation repair, as both showed bone regeneration and less inflammation than amalgam.
Broon <i>et al.</i> , (2006)[55]	<i>In vitro</i> study Investigate healing of root perforations treated with Pro RootMTA, MTA-Angelus and portland cement	15 teeth of 4 young adult dogs perforated at cervical third of root	-Endodontic cleaning and shaping -Microscopic evaluation	white Portland cement(WPC) and MTA-Angelus(grey MTA) showed more teeth inflammation than the ProRoot MTA (white MTA)
Morais <i>et al.</i> , (2006)[56]	<i>In vivo</i> study Evaluation of tissue response to MTA and portland cement with iodoform.	18 Wistar albino rats Devided into 3 groups (n = 6).	- Microscopic examination - Histologic processing	There were no significant differences regarding inflammatory responses between MTA and portland cement with iodoform.
Hamad <i>et al.</i> , (2006)[57]	<i>In vitro</i> dye extraction study Compare furcation perforation repair with gray and white MTA	76 human extracted mandibular molars with furcation perforations	- Dye extraction study - Spectrophotometer measurement	No statistically significant difference in leakage was found between gray and white MTA
De-Deus <i>et al.</i> , (2007)[58]	<i>In vitro</i> study Investigate the ability of portland cement, MTA and MTA bio to prevent through fluid movement in repaired furcal perforations	55 human mandibular first molar teeth with furcation perforation	-Fluid filtration evaluation -Measurements of air bubble movement	MTA Bio has superior handling and fast setting than MTA and Portland cement plus the freedom of Arsenic and lead that present in Portland cement. The three materials had the same sealing ability as they could prevent through-and-through fluid movement.
Ghanbari <i>et al.</i> , (2008) [51]	<i>In vitro</i> study To compare between amalgam and MTA in repairing furcal perforations.	28 Molar teeth from 4 cats with furcation perforations	Microscopic evaluation	MTA showed better sealing than amalgam for perforation repair, particularly when used immediately after perforation.
Abdul Hamed <i>et al.</i> , (2011) [50]	<i>In vitro</i> study Repair root canal perforation by different materials	30 fresh extracted lower premolar teeth obtained from orthodontic treatment with root perforations divided into 3 groups(N=10)	Dye leakage measurement Stereomicroscope Magnification	MTA showed the lowest dye leakage and best sealing ability than Glass ionomer followed by Epiphany obturation system that showed the highest dye leakage when used to seal root perforations in extracted human teeth
Bayram <i>et al.</i> , (2015) [54]	<i>In vitro</i> study Determination of the Apical Sealing Abilities of Mineral Trioxide Aggregate, Portland Cement, and Bioaggregate After Irrigation with Different Solutions	130 extracted single canal teeth	computerized fluid filtration method	Bioaggregate (BA) (new bioceramic- based material) showed better perforation repair and biocompatibility than MTA and Portland cement when used as root end filling and perforation repair materials.
Sinkar <i>et al.</i> , (2015) [42]	An ultraviolet spectrophotometric analysis Comparison of sealing ability of ProRoot MTA, RetroMTA, and Biodentine as furcation repair materials:	35 extracted intact human mandibular molars with non-fused well developed roots with furcation perforations.	Dye extraction method	Biodentine has the best sealing ability and least microleakage than RetroMTA and ProRoot MTA

De-Deus *et al.*, (2006) [43] reported that many materials have been used for sealing root perforations as: amalgam, zinc oxide eugenol, IRM, Super EBA, Cavit, zinc polycarboxylate, zinc phosphate, glass ionomer cement, dentine chips, tricalcium phosphate, calcium hydroxide, hydroxyapatite and mineral trioxide aggregate (MTA) [44 - 46].

Although amalgam has been widely used for long time in restorative dentistry and apical retrograde filling techniques, its use is limited in recent years due to the following phenomena of ions release, mercury toxicity, corrosion and electrolysis, marginal leakage, delayed expansion, and tattoo formation [47, 48]. Yazdi *et al.*, 2006 [49] found that MTA and GI were more suitable materials for experimental pulp chamber perforation repair in dogs' teeth than amalgam that showed the highest level of inflammation without bone regeneration. Abdul Hamed *et al.*, 2011[50] reported that MTA showed the lowest dye leakage and best sealing ability than Glass ionomer followed by Epiphany obturation system that showed the highest dye leakage when used to seal root perforations in extracted human teeth.

Ghanbari *et al.*, 2008 [51] found that the immediate use of MTA produced less inflammation and better sealing than amalgam, in repairing the pulp chamber floor perforation of cats' molar teeth. Holland *et al.*, 2001[52] reported that the acceleration of Portland cement made it shows good sealing ability, adequate physical and mechanical properties as a

restorative material.

MTA and Portland cement had similar mechanism of action and components except for bismuth oxide which gives MTA its radiopacity. Both of them contain calcium oxide that forms calcium hydroxide when mixed with water. Calcium hydroxide and the carbon dioxide stimulate pulp tissue to produce calcite crystals. Calcite crystals and fibronectin initiate the formation of a hard tissue barrier [53]. Bayram *et al.*, 2015 [54] reported that Portland cement and MTA had the same tissue reactions.

While in contrast Broon *et al.*, 2006[55] reported that white Portland cement(WPC) and MTA-Angelus(grey MTA) showed more teeth inflammation than the ProRoot MTA (white MTA) when all of them used to evaluate the response of interradicular periodontal tissues of dogs' teeth with root perforations. Morais *et al.*, 2006[56] reported no differences in inflammatory response and biocompatibility between ProRoot MTA(white MTA) and Portland cement that mixed with iodoform for suitable radiopacity when both of them were implanted in rats' tissues used for the experiment. Hamad *et al.*, 2006[57] reported that there were no differences between gray and white MTA when used to seal furcation perforations in extracted human mandibular molars by measuring dye penetration.

De-Deus *et al.*, 2007 [58] found that MTA Bio has superior handling and fast setting than MTA and Portland cement plus it is free of Arsenic and lead materials that present in Portland cement. But the three materials showed the same sealing ability as they could prevent through-and-through fluid movement.

Despite of all studies that supported the use of MTA in sealing root and crown perforations, Sinkar *et al.*, 2015 [42] reported that Biodentine has better sealing ability and least microleakage than RetroMTA and ProRoot MTA when used in furcation repair of mandibular molars using a dye extraction leakage method. Bayram *et al.*, 2015[54] also reported that Bioaggregate (BA) (new bioceramic based material) showed better perforation repair and biocompatibility than MTA and Portland cement when it was used as root end filling and perforation repair material.

CONCLUSION

There are many factors affecting healing and repair of different types of root and crown perforations. Such as size of perforation, time elapsed until repair, location of perforation and type of material to be used in repair. Studies reported that MTA is the best material of choice used in repair of different types of crown and root perforations due to its biocompatibility promoting healing of inflammation, bone and cementum formation while others illustrated its clinical drawbacks such as difficult handling, prolonged sitting time and potential discoloration. MTA showed better sealing and repair of perforations than amalgam, GIC, epiphany obturation system. Some studies reported similar sealing ability of MTA and Portland cement. While others reported better inflammation healing with MTA than Portland cement that contains Arsenic and lead. In contrast to those reported best sealing ability of MTA some authors reported better sealing with BioAggregate (BA), MTA Bio and Biodentine materials. These new materials overcome the drawbacks of MTA showing best sealing ability. More studies required to compare sealing ability of MTA with these new materials.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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