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The use of mineral trioxide aggregate to achieve root end closure: three case reports

CASE REPORT

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Abstract – The use of mineral trioxide aggregate (MTA) to achieve root end closure has many advantages over the traditional calcium hydroxide ($Ca(OH)_2$) technique including the reduced number of visits and the reduced mechanical damage to dentine. Limited studies have reported the outcome of using MTA as an apexification material and a one-stage obturation technique in non-vital immature teeth. This article illustrates three successful clinical cases where MTA was used as an apexification material. In case study one: Type 1 Dens Invaginatus tooth with incomplete root formation, case study two: an immature tooth that suffered pulp necrosis following an enamel and dentine fracture trauma and case study three: a non-vital tooth following an apical root fracture.

The management of dental trauma to permanent incisors in young children can be challenging. As a result of accidental damage to immature permanent teeth, these teeth may become non-vital, which leads to arrested root development. The management of these teeth will require root canal treatment that is complicated by an open apex. Therefore, the root canal treatment of these teeth is facilitated by a root end closure technique to form a barrier at the apex, against which a root filling can be condensed (1). The United Kingdom survey of Child Dental Health in 2003 reported that the prevalence of accidental damage to permanent incisors in children was 5% at age 8 years and increasing to 11% at 12 years (2). Around 6% of these teeth are expected to become non-vital and require root canal treatment with root end closure as reported in the British Society of Paediatric Dentistry Guidelines.

Apexification is defined as the technique used to induce a calcific barrier in an immature root with an open apex or the continued apical development of an incomplete root in teeth with necrotic pulp (3). Traditionally, the most commonly used material for apexification is calcium hydroxide Ca $(OH)_2$. Calcium hydroxide stimulates the formation of mineralized and fibrous tissue by the granulation tissue cells in the apical part of the root canal as well as acting as a root canal disinfectant (4, 5). The efficiency of $Ca(OH)_2$ to achieve hard tissue apical barrier even in the presence of an apical lesion has been demonstrated by many authors (3, 6, 7). This treatment technique involves multiple visits for replacement of the $Ca(OH)_2$ at recommended 3 month intervals (1, 3). The relatively long treatment time on average ranges from 5 to 20 months for calcific barrier formation (8–11). This can create a social-economic burden on the children and parents (12). A study by Mackie et al. (13) demonstrated that 86% of the non-vital immature permanent incisors treated with apical closure using $Ca(OH)_2$ and root filling had a survival rate of 5 years. Other disadvantages associated with the use of $Ca(OH)_2$ may include failure of formation of an apical barrier, overfilling of $Ca(OH)_2$ that has a high pH of 12.7 and may induce a high necrotic zone in the periapical bone (3). In addition, dressing with $Ca(OH)_2$ for extended periods has been reported to be associated with a higher risk of root fracture (14, 15). Finally, the lack of an appropriate coronal restoration during the frequent replacement of the intracanal dressing may further compromise the prognosis of the tooth (16).

Recently mineral trioxide aggregate (MTA) has been proposed as a promising alternative to $Ca(OH)_2$ in the treatment of non-vital permanent teeth with open apices (17–20). MTA is a biomaterial that has been investigated for endodontic applications since the early 1990s and was described in the dental literature in 1993. It was given approval for Endodontic use in 1998 (21, 22). MTA has a diverse clinical application including formation of an apical barrier in the coronal fragment of fractured roots, a pulpotomy medicament in primary and permanent teeth, pulp capping agent in young permanent teeth and a repair material for perforation and resorptive defects (22, 23). There are numerous studies on the use of MTA for endodontic procedures such as root end filling, compared with only a few published articles for its use in immature teeth with open apices, the majority being case reports.

MTA consists of a mineral powder whose mineral compounds are tricalcium silicate, tricalcium aluminate, tricalcium oxide and other mineral oxides. There are two marketed forms of MTA, grey (GMTA) and white (WMTA), the former with a potential for discolouration. The powder is mixed with sterile water in a 3:1 powder/liquid ratio. This forms a colloidal gel and solidifies to form a hard structure in approximately 3–4 h. The high pH of MTA (pH = 12.5) is known to activate alkaline phosphatase and antibacterial activities (24). Several studies have shown that MTA has antibacterial and antifungal properties. In a study by Al-Hezaimi et al., they assessed the different concentrations of GMTA and WMTA against *E. Faecalis* and *S. sanguis*, the two most prevalent microorganisms present in root canal failures. A lower concentration of GMTA compared with WMTA was required to exhibit the same anti-bacterial effect against each of these organisms (25). Both GMTA and WMTA were also effective against *C. albicans*. However, GMTA in concentrations <25 mg ml^{-1} was significantly more effective than WMTA (26).

MTA has been proven to have a superior sealing ability to amalgam, zinc oxide eugenol and intermediate restorative material (IRM) in microleakage studies (27). Biocompatibility and low cytotoxicity of MTA has been demonstrated in the literature compared with other root end fillings (28). In a histological study of perforation repair using MTA, cementum was shown to grow over the MTA with minimal inflammation even with over extrusion of the material (29). The histological pulpal response comparing MTA to $Ca(OH)_2$ as a pulpotomy dressing was investigated, and it was reported that MTA induced a more homogenous and continuous dentine bridge, with less pulpal inflammation than calcium hydroxide (30).

The main advantage of MTA in root end closure is reduction in treatment time, with minimal delay before placing a permanent restoration and minimizing coronal leakage. Another advantage would include avoiding changes in the mechanical properties of dentine caused by prolonged use of highly alkaline $Ca(OH)_2$. MTA stimulates a higher quality and greater amount of reparative dentin (31). The risk of root fracture may be avoided by placing an apical plug of MTA in the last 5 mm of the canal, followed by obturation of the root canal system. The coronal restoration is immediately placed on the tooth thereafter. These key elements enable the long-term conservation of the treated tooth (18, 32).

The use of MTA in apexification has been investigated in many studies. Studies *in vitro* and in animal studies have shown a high degree of biocompatibility. Felippe et al. (19) conducted an experiment on dogs and concluded that all the treated teeth with MTA had the formation of an apical barrier. Panzarini et al., compared the healing of reimplanted monkey teeth filled with either Ca $(OH)_2$ or MTA. Both sets of results showed similar histological regeneration of the periodontal ligament (33). More recent studies supporting the use of MTA in human teeth has evolved (17, 34, 35). One report showed a clinical success rate of 94% using MTA in a one visit apexification technique on 17 non-vital immature permanent incisors in children (36). In a prospective clinical study, investigation of the effectiveness of apexification with MTA on 57 immature permanent incisors was followed up from 6 to 36 months. The results showed a decrease in pre-existing periapical lesion in 81% of cases (37).

A retrospective study by Mente et al. (38) assessed healing of teeth with open apical foramina treated with MTA apical plugs. The study showed a healing outcome of 84%. Teeth with a preoperative periapical radiolucency had a healing rate of 78%. The following three case reports describe the use of MTA to achieve apical barrier seal in different clinical scenarios presenting to the Paediatric Clinic. All of these presented with chronic sinuses and periapical radiolucencies associated with the affected teeth.

Case one

A 14-year-old boy was referred to the Dental Hospital by his general dental practitioner (GDP) with recurrent labial sinuses associated with the upper right and left permanent lateral incisors (12, 22). The patient was otherwise medically fit and well. On clinical and radiographic examination, 22 was tender to percussion and 12 was asymptomatic. Both of these teeth had type I dens invaginatus (39) with an incomplete root development (Fig. 1a). Access on the upper right lateral incisor (12) was obtained with a high-speed bur under the operating microscope after administration of local anaesthesia and dental dam placement. The pulp chamber and the root canal were located, shaped with Gates Glidden bur (X-Gates) in a crown down technique. The canal was irrigated with 2% Chlorhexidine gluconate. The working length was established using an electronic apex locator (RayPex 5; DENTSPLY, Munich, Germany) and confirmed with periapical radiograph and a size 60 K file. The tooth was dressed with non-setting $Ca(OH)_2$ using a disposable micro-needle to the full working length. The access cavity was sealed with a cotton pellet and Cavit (3M ESPE, Seefeld, Germany) as the temporary filling.

At the following visit, the upper right lateral incisor (12) was asymptomatic and the sinus had resolved. Access of 12 was again established under dental dam and local anaesthesia. The root canal was very wide, and the apex was divergent. A decision was then made to perform root end closure using MTA (Pro root MTA; DENTSPLY, Johnson city, TN, USA). After the canal had been irrigated with 2% Chlorhexidine gluconate and dried with paper points and micro-suction, an MTA apical plug of 5 mm was placed in increments using an MTA carrier and the appropriate sized endodontic plugger (Machtou pluggers; DENTSPLY, Maillefer, Baillagues, Switzerland). This was carried out under direct vision obtained with the operating microscope. The MTA was condensed against the periodontal ligament; a collagen matrix was not used.

Radiographic examination of the apical plug was then carried out. After cleaning the canal walls with wet paper

(a)
(b)
(c)

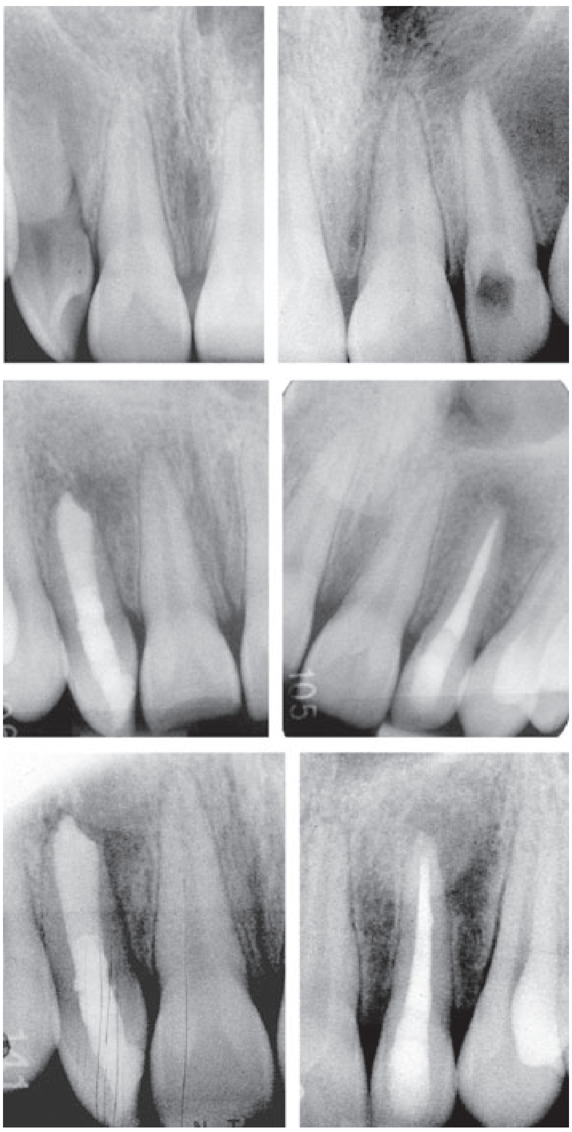

Fig. 1. (a) Periapical radiographs of two non-vital upper permanent lateral incisors, both with type I dens invaginatus and incomplete root development. (b) At 6 months follow up – periapical radiographs of mineral trioxide aggregate used as an apical barrier and obturation with gutta percha. (c) At 18 months follow up – periapical radiographs shows apical healing with bony infiltration.

points, the coronal part of the canal was backfilled with thermoplastic gutta-percha using the Extruder (Elements Obturation Unit, SybronEndo) after applying Tubliseal Extended Working Time sealer (SybronEndo). An intraoral periapical radiograph using a parallel technique was used to confirm the quality of the obturation. The root canal filling was of acceptable quality. The access cavity was then restored with a reinforced glass ionomer lining (Fuji II LC, GC, UK) followed by Adper Prompt L-Pop self-etching adhesive (3M ESPE) and a hybrid composite filling (Spectrum; DENTSPLY, Konstanz, Germany). The above-mentioned treatment was repeated on the 22. The 12 and 22 remained asymptomatic at the 3 month and 6 month reviews. Periapical radiographs at 6 and 18 months revealed signs of bony infill (Fig. 1b,c).

Case two

A 9-year-old girl was referred to the Dental Hospital following trauma to the upper left central permanent incisor (21) 7 months previously. On initial presentation to the GDP, there was a large enamel—dentine incisal edge fracture. There was no pulpal exposure at the time and a composite restoration was placed by the GDP. Several months following the treatment, the patient developed pain and tenderness to the 21. Clinical and radiographic examination showed healthy gingival tissues and good oral hygiene. There was no obvious sinus or mobility associated with the 21. A periapical radiograph revealed an open apex on the 21 with periapical pathology (Fig. 2a).

At the first visit, an access cavity was prepared on the tooth 21 with a high-speed bur under an operating microscope after dental dam placement. The same clinical technique as in case one was followed to obturate 21 (Fig. 2b). The 21 remained asymptomatic at the 3, 6 and 12 months reviews. Periapical radiograph at 12 months revealed signs of bony infill (Fig. 2c).

Case three

A 16-year-old girl was referred by her GDP to the Dental Hospital with apical root fractures to the upper right and upper left permanent central incisors (11 and 21). The patient previously had trauma to her anterior teeth when she was 13 years old. These teeth were initially mobile and were splinted following the incident. The patient was reviewed regularly by her GDP who had noticed a labial sinus above the 11. The patient was otherwise medically fit and well.

Clinical and radiographic examination revealed mild gingival inflammation with plaque present interproximally. The 11 was slightly tender to percussion and a visible sinus was present on the labial gingivae above this tooth. The 11 showed a fracture to the apical third of the root with displacement. The 21 showed an apical third root fracture with no displacement (Fig. 3a). Sensibility testing was used with the electric pulp tester (EPT). The 11 was negative to EPT, whilst the 21 was positive to EPT.

At the first visit, access on the 11 was obtained with high-speed burs under an operating microscope after administration of local anaesthesia and dental dam placement. The root canal was located to the level of the fractured apex. The working length was established with a periapical radiograph and a size 35 K file. The tooth was dressed with non-setting $Ca(OH)_2$ using a disposable micro-needle to the fractured apex. The access cavity was sealed with a cotton pellet and Cavit (3M ESPE) as the temporary filling.

At the following visit, the same clinical technique as in case one was followed to obturate 11. MTA was condensed up to the fractured apex. An intraoral periapical radiograph using a parallel technique was used to confirm the quality of the obturation. The root

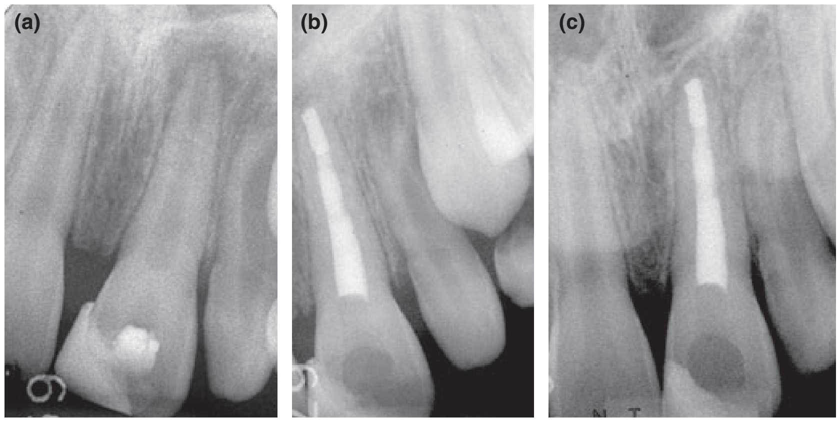

Fig. 2. (a) Periapical radiograph of dentine enamel fracture in a non-vital immature left maxillary incisor in a 9 year old. (b) Post operative radiograph with mineral trioxide aggregate as an apical barrier and obturation with gutta percha. (c) 12 months review.

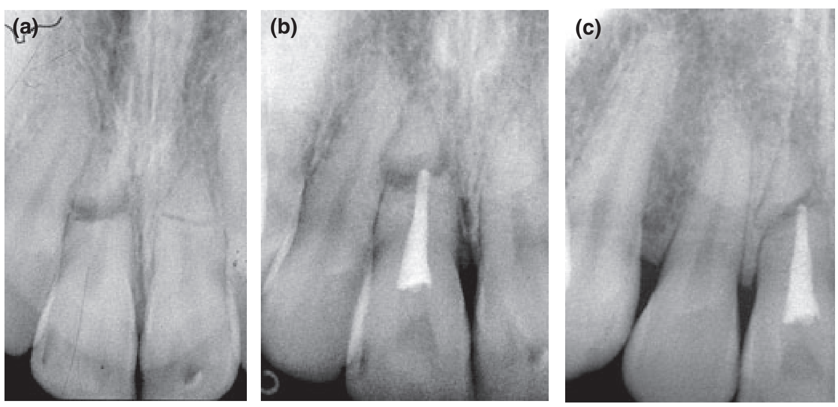

Fig. 3. (a) Periapical radiograph showing coronal root fragment of the maxillary central incisors in a 16 year old. (b) Periapical radiograph of mineral trioxide aggregate used as an apical seal in a coronal fragment. (c) At 6 months follow up.

canal was adequately obturated up to the fractured apex (Fig. 3b). The access cavity was then restored with a reinforced glass ionomer lining (Fuji II LC, GC) followed by Adper Prompt L-Pop self-etching adhesive (3M ESPE) and a hybrid composite filling (Spectrum; DENTSPLY). The 11 remained asymptomatic at the 3, 6 and 12 month reviews. Periapical radiographs at 6 months revealed signs of bony infill (Fig. 3c).

Discussion

$Ca(OH)_2$ has been conventionally used as a successful material for apexification. However, this requires a long treatment time with regular changes of $Ca(OH)_2$, and poor coronal seal increases the susceptibility to infection. Prolonged use of alkaline $Ca(OH)_2$ can also change the mechanical properties of dentine. MTA is an alternative to the conventional $Ca(OH)_2$ with reduction in treatment time. There is minimal delay before a permanent restoration is placed minimizing coronal leakage. The cases mentioned earlier demonstrated that MTA provides an effective seal in the apical portion of the root and a material to obturate canals. MTA can also be used to create an apical barrier at the coronal portion of the fractured root. At 12-month follow up, the radiographs in all three cases showed resolvement of the periapical area. MTA has shown to be clinically and radiographically successful as a material used to induce apical and coronal root closure in necrotic immature permanent teeth. The teeth were obturated with either gutta-percha or MTA following an apical MTA plug and restored with a permanent restoration. This technique limits re-infection of the canal but also reduces a further appointment for obturation. This one visit approach is useful particularly when multiple treatment visits require time taken off school and work. In conclusion, this report confirms that MTA provides a viable alternative to achieve root end closure in immature teeth or root fracture, even in cases with a wide open apex as demonstrated in case one. However, at present, there are no reported randomized controlled trials in the literature and no long-term follow ups completed, to evaluate the long-term success of MTA as an apical barrier in non-vital immature teeth.

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