



CASE REPORT

Unintentional extrusion of mineral trioxide aggregate: a report of three cases

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Abstract

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Aim Mineral trioxide aggregate (MTA) is the material of choice for apical barrier techniques during root canal treatment of teeth with open apices. However, the precise control of MTA during the placement of an apical plug is challenging. This article describes the outcomes of unintentional extrusion of MTA into the periradicular tissue during apical barrier treatment in three cases.

Summary Three cases of maxillary central incisors in adult patients with open apices were referred for treatment. After conventional access and canal preparation, MTA was placed into the apical portion of the root canals to act as an apical barrier/plug. A large increment of MTA was extruded in all cases. In Case 1, after a 4-year follow-up, the extruded MTA had resorbed and the periradicular lesion had healed. In Cases 2 and 3, after follow-up, the patients remained symptomatic and were scheduled for periradicular surgery. In Case 2, soft unset particles of MTA were present in the lesion and were curetted. In Case 3, the extruded MTA had set hard but was sandwiched between the oral mucosa and bone; its removal relieved the pain experienced on buccal palpation.

Key learning points

- Extruded MTA may not harden and may be associated with ongoing periapical irritation;
- Extruded set MTA when encapsulated in the mucosa and not surrounded by bony matrix may act as a mechanical irritant on palpation;
- Mineral trioxide aggregate should be confined to the root canal system;
- Teeth where MTA has been extruded beyond the foramen should be followed-up to monitor the outcome.

Keywords: apexification, apical plug, healing, mineral trioxide aggregate, overfilling.

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Introduction

When a pulp has become necrotic in an immature tooth, long-term apexification treatment with calcium hydroxide (CH) has been prescribed historically to establish apical closure by the induction of an apical hard tissue barrier (Frank 1966). However, although the technique may be successful (Sheehy & Roberts 1997), it invariably takes a long time to complete and the root dentine becomes more brittle, which increases the risk of future cervical root fracture (Andreasen *et al.* 2002).

An alternative technique for roots with immature or 'open' apices involves the placement of an apical barrier or plug using an appropriate material. The recommended material for this 'apical barrier' technique is mineral trioxide aggregate (MTA) (Shabahang *et al.* 1999, Torabinejad & Chivian 1999), because it is biocompatible (Asgary *et al.* 2006), can harden in the presence of moisture (Camilleri 2007) and has good sealing ability (Tselnik *et al.* 2004). Indeed, using MTA as an apical barrier in immature human teeth with necrotic pulps has been reported to result in good clinical and radiographic outcomes (Pace *et al.* 2007, Simon *et al.* 2007, Holden *et al.* 2008, Witherspoon *et al.* 2008).

The formulation of the original MTA material is known to have several shortcomings, including poor handling characteristics, long setting time, the potential to discolour teeth (Chng *et al.* 2005, Belobrov & Parashos 2011) and high cost. A recent study revealed that it also contains heavy metals, including chromium, lead and arsenic, the acid soluble levels of the latter in set MTA being higher than the standard for dental materials (Schembri *et al.* 2010). Studies have also revealed that the favourable physical properties of MTA decrease substantially following blood and serum contamination during setting (Nekoofar *et al.* 2010a,b). In addition, variations of pH because of inflammatory changes in periradicular lesions (Nekoofar *et al.* 2009a,b) have the potential to affect adversely the physical and chemical features and hydration properties of MTA (Lee *et al.* 2004, Namazikhah *et al.* 2008, Saghiri *et al.* 2008, Shokouhinejad *et al.* 2010).

This article describes the outcomes of unintentional extrusion of MTA into the periradicular tissues during apical barrier treatment in three separate cases.

Case reports

Case 1

An 18-year-old man was referred complaining of repeated swelling and pain in the anterior maxilla. The patient reported a history of impact trauma to the maxillary anterior teeth 9 years previously with avulsion and replantation of maxillary left central incisor. He reported repeated swelling and pain in the region over the last few months.

Clinical examination revealed that maxillary left central incisor was tender to percussion and palpation and had an open access cavity. A localized, erythematous swelling was present on the buccal and palatal mucosa surrounding the tooth. The periodontal status of all maxillary incisors was normal (probing depth < 3 mm), and none were mobile. Radiographs revealed that maxillary left central incisor had an open apex and a large radiolucent periradicular lesion (Fig. 1a). A diagnosis of pulpal necrosis with symptomatic apical abscess for maxillary left central incisor was made. The medical history of the patient was noncontributory.

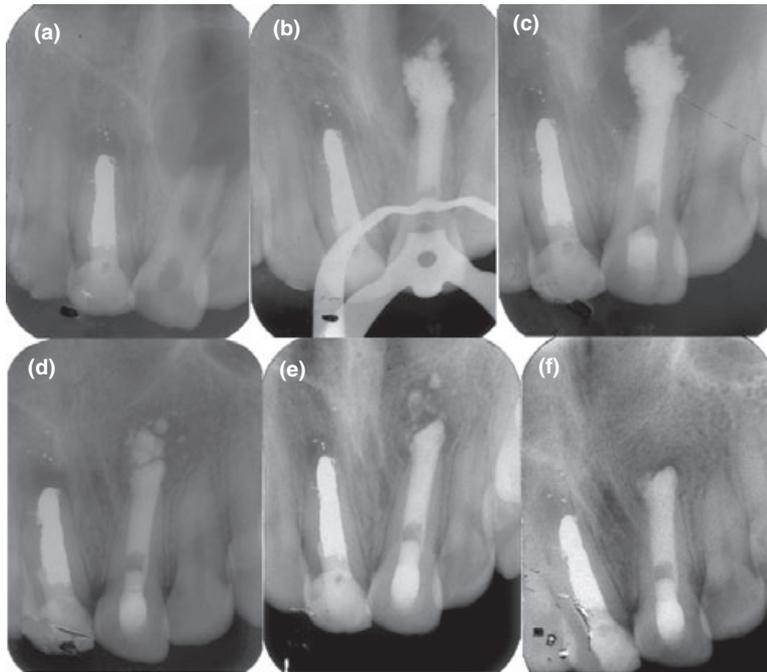


Figure 1 (a) Preoperative periapical radiograph of Case 1, a maxillary left central incisor with a history of impact trauma in an 18-year-old man. Note the immaturity of the root and the extensive periradicular lesion. The patient reported repeated swellings and pain over several months. (b) The intra-operative radiograph after mineral trioxide aggregate (MTA) plug insertion. Note the extruded MTA. (c) Immediately after treatment. (d) One-year follow-up. Note the partial osseous healing of the lesion. (e) Two-year follow-up. Note the gradual resorption of extruded MTA. (f) Four-year follow-up. The patient was asymptomatic. Note the complete resorption of the extruded MTA.

After complete explanation of the treatment procedure, risks and benefits, informed consent was obtained from the patient. Following rubber dam isolation and local anaesthesia using 2% lidocaine and 1/80 000 epinephrine (Daroupakhsh, Tehran, Iran), the outlines of the access cavity was modified with a diamond coated size 10 fissure bur (Diatech, Heerbrugg, Switzerland) in a high-speed handpiece. The root canal space was then gently filed using a size 50-K file (Dentsply Maillefer, Ballaigues, Switzerland) for approximately 20 min and irrigated passively with 20 mL of 5.25% NaOCl. As there was continuous exudate from the root canal, radiopaque CH powder (Ariadent, Tehran, Iran) was mixed with tap water to a creamy consistency and placed inside the canal space using a gentle counterclockwise motion of a size 50-K file to the radiographically estimated working length; the tooth was then temporarily restored with Coltosol (Asia Chemi Teb Co., Tehran, Iran). Considering the wide apical foramen, there was a probability of extrusion of the CH paste. Therefore, the extension of CH dressing was assessed radiographically and the absence of overfilling was confirmed.

Three weeks later, there was no tenderness to percussion or palpation, no soft tissue swelling or erythema and no canal exudate. The temporary restoration was removed under rubber dam isolation and local anaesthesia, and the CH dressing flushed out using alternating irrigation with 5.25% NaOCl and 17% EDTA (Ariadent) together with gentle filing with a size 50-K file. Then, the root canal was dried with paper points (Ariadent); absence of exudate was confirmed with dry paper points placed to the working length. One gram of MTA powder (ProRoot tooth colored MTA,

Dentsply Tulsa Dental, Tulsa, OK, USA) and 0.33 g of distilled water were mixed, and the MTA slurry was introduced into the canal using an amalgam carrier and gently adapted to the apical portion of the canal using size 80 paper points (Ariadent). The procedure was continued until the canal was filled with MTA. Before removing the rubber dam, a radiograph was taken to evaluate the quality of MTA filling (Fig. 1b). The radiograph revealed that a considerable amount of the MTA had been extruded into the periradicular lesion. The remainder of the canal space was filled with distilled water, a wet cotton pellet was placed in the pulp chamber, and the tooth was temporarily restored (Fig. 1c). The patient was informed about the extrusion of the material and the potential risks and consequences. A week later, the patient was completely asymptomatic and reported no problems following treatment. The temporary restoration was removed, and MTA was checked with an endodontic explorer to confirm the setting of MTA. Then, the patient was referred for the permanent restoration of the tooth.

One, two and 4 years following treatment, the patient was recalled to evaluate the treatment outcomes. At all follow-up appointments, the tooth was functional with normal mobility and without tenderness to percussion and palpation or recurrence of the swelling. Radiographic examination over time revealed the periradicular lesion had partially healed after 1 year (Fig. 1d), and the extruded MTA had disappeared and been gradually replaced by newly formed hard tissue after 4 years (Fig. 1e,f).

Case 2

A 15-year-old man presented with occasional pain and swelling. The patient reported a history of impact trauma to the anterior maxilla 5 years previously. A general dentist had initiated apexification treatment with CH, but after 28 months, the patient was referred because of the unfavourable outcome. Clinical examinations revealed that the maxillary right central incisor was tender to palpation and percussion and had a localized buccal swelling; the temporary restoration was loose. The tooth had normal periodontal probing depths (<3 mm) and normal mobility. Radiographs revealed that the maxillary right central incisor had an open apex with a periradicular lesion (Fig. 2a). Considering the patient's signs and symptoms and the previously inadequate root canal treatment,

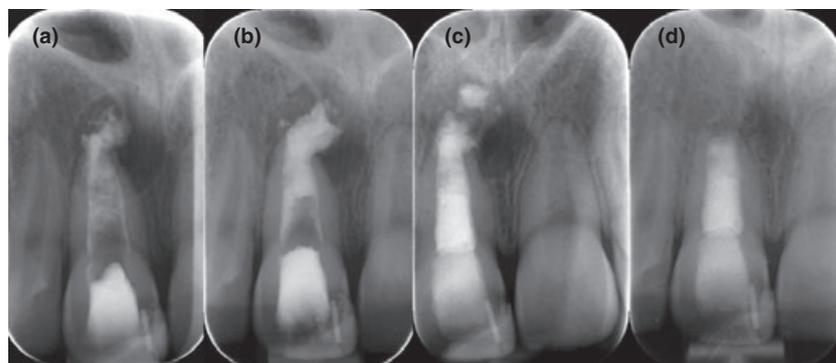


Figure 2 (a) preoperative periapical radiograph of Case 2. The maxillary right central incisor was immature with a periradicular lesion. (b) Immediately after placement of the mineral trioxide aggregate (MTA) plug. A notable proportion of MTA was extruded. (c) Twenty-seven months after treatment. Osseous healing was not complete, and the patient was symptomatic. The patient was scheduled for periradicular surgery. (d) One year after surgery. The patient was asymptomatic. Note the complete osseous healing of the lesion.

the diagnosis was symptomatic apical periodontitis. The patient's medical history was noncontributory. The patient was scheduled for root canal treatment using the MTA plug technique.

The treatment procedure, risks and benefits were explained to the patient, and informed consent was obtained. At the first visit, under rubber dam isolation and local anaesthesia using a cartridge of 1.8 mL Lignospan Special (Septodont, Saint-Maur des Fossés, France) containing lidocaine hydrochloride 2% and epinephrine 1/80 000, the access cavity was extended with a size 08 diamond fissure bur (Diatech) in a high-speed handpiece with copious water spray. The root canal space was then cleaned using copious irrigation with 1% NaOCl along with gentle filing with size 100-K files (Dentsply Maillefer). The canal was then dried with paper points. MTA powder (ProRoot tooth coloured MTA, Dentsply Tulsa Dental) and distilled water were mixed with a 3 : 1 powder to water ratio using gentle spatulation and then introduced incrementally into the canal using the MAP system (Produits Dentaires S.A., Vevey, Switzerland). The material was gently adapted to the apical portion of the canal using pre-fitted no. 4 Machtou heat pluggers (Dentsply Maillefer) until a 5-mm plug was created. A radiograph was taken to check the quality of the MTA plug. The root canal space was filled with a size 80 paper point soaked in distilled water, then a wet cotton pellet was placed in the pulp chamber and the tooth was restored temporarily with Kalzinol (Dentsply De Trey, Konstanz, Switzerland).

The patient was recalled after 4 weeks. After applying rubber dam and removing the temporary restoration, the hardness of the MTA was checked using the tip of an endodontic explorer. The MTA had not set, and therefore, the entire MTA plug was removed using gentle filing and irrigation with normal saline; the process of MTA placement was repeated. A radiograph taken to check the quality of MTA plug revealed that a portion of MTA had been extruded into the periradicular lesion (Fig. 2b). The patient was informed about the extrusion of the material and potential risks and consequences. After 4 weeks, the patient remained asymptomatic and the temporary restoration was removed and the MTA filling checked to ensure its hardness. The remainder of the root canal space was then filled with injectable warm gutta-percha (Obtura-Spartan, Fenton, MO, USA) and AH Plus® sealer (Dentsply Maillefer); the patient was then referred for a coronal restoration.

The patient was recalled 8, 10 and 27 months after treatment. Although the tooth was not tender to percussion and there was no recurrence of swelling, the soft tissue overlying the alveolar bone around the apical part of the tooth remained tender to palpation. Radiographically, the lesion did not heal (Fig. 2c). Based on the continuation of clinical symptoms and absence of bone formation, the patient was scheduled for periradicular surgery. The tooth was anaesthetized using an infiltration of a cartridge of 1.8 mL of Lignospan Special (Septodont) containing lidocaine hydrochloride 2% and epinephrine 1/80 000, and a triangular full muco-periosteal flap was raised, exposing a large cystic lesion full of pus that had perforated the buccal bone. Unset particles of MTA were clearly visible inside the exudate. After performing curettage and a 1-mm apical root resection, the MTA inside the canal was found to be hard. Marginal adaptation of the set MTA was checked using an operating microscope with 25 times magnification (Carl Zeiss Surgical GmbH, Oberkochen, Germany). As the set MTA inside the canal had good marginal adaptation, no root-end preparation or root-end filling was undertaken. The mucoperiosteal flap was then repositioned and sutured.

The patient was recalled 12 months after surgery. The tooth was not tender to percussion or palpation, and there was no recurrence of swelling. Complete osseous healing of the lesion could be seen in the radiograph (Fig. 2d).

Case 3

A 50-year-old healthy woman was referred with a chief complaint of pain on percussion in the maxillary left central incisor. She had a history of periradicular surgery on the maxillary central and lateral incisors (Fig. 3a). On clinical examination, the maxillary left central incisor was sensitive to percussion and palpation. The diagnosis of symptomatic apical periodontitis because of inadequate previous treatment was established. Nonsurgical retreatment was scheduled.

After local anaesthesia using a cartridge of 1.8 mL of Lignospan Special (Septodont) and rubber dam isolation, an access cavity was prepared using a size 10 diamond fissure bur (Diatech) in a high-speed handpiece. The gutta-percha in the coronal portion of the canal was removed using sizes D1 to D3 ProTaper Universal Retreatment files (Dentsply Maillefer), and the remainder was removed using sizes 35 and 40 H-files (Dentsply Maillefer) and chloroform (Merck, Darmstadt, Germany). After removing the gutta-percha, a large apical opening was observed compatible with the history of periradicular surgery and root-end resection without root-end filling. The root canal space was then cleaned using copious irrigation with 1% NaOCl and gentle filling using successively larger K files from size 40 to 60. After drying the canal with paper points, 1 g MTA powder and 0.33 g water were mixed and introduced and adapted to the apical portion of the canal using pre-fitted no. 4 Machtou heat pluggers (Dentsply Maillefer) until the plug was 5 mm in length. Then, the root canal space was filled with a pledget of cotton wool soaked in saline, and the tooth was restored temporarily with Kalzinol (Dentsply De Trey).

A periapical radiograph was taken to assess the quality and length of the MTA plug where it was obvious that some MTA had been extruded (Fig. 3b). The patient was informed about the extruded material and potential consequences. One week later, whilst the patient was asymptomatic, the temporary restoration was removed and the MTA plug checked for hardness; the remainder of the canal space was used for the permanent coronal restoration (Fig. 3c).

At the 1-year recall, the patient complained of tenderness to palpation of the soft tissue overlying the alveolar bone around the apical part of the maxillary left central incisor. The tooth was not tender to percussion, and a radiograph revealed bone formation (Fig. 3d). A nonmovable hard prominence over the root apex was observed, which was exquisitely sensitive to palpation (Fig. 4–a–c). The prominence was palpable in the buccal mucosa and was thought to be extruded MTA. The patient was scheduled for exploratory surgery. After infiltration local anaesthesia using a cartridge of 1.8 mL of

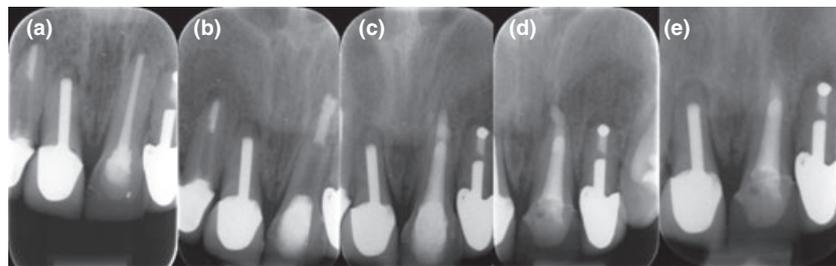


Figure 3 (a) preoperative periapical radiograph of Case 3. A 50-year-old woman with chief complaint of pain on palpation and percussion on the left maxillary central incisor. (b) Immediately after mineral trioxide aggregate (MTA) apical plug insertion. (c) After coronal restoration. (d) One year after treatment. The patient returned with pain on palpation of the buccal mucosa. (e) Six months after surgery, the patient was asymptomatic with complete soft tissue and osseous healing.

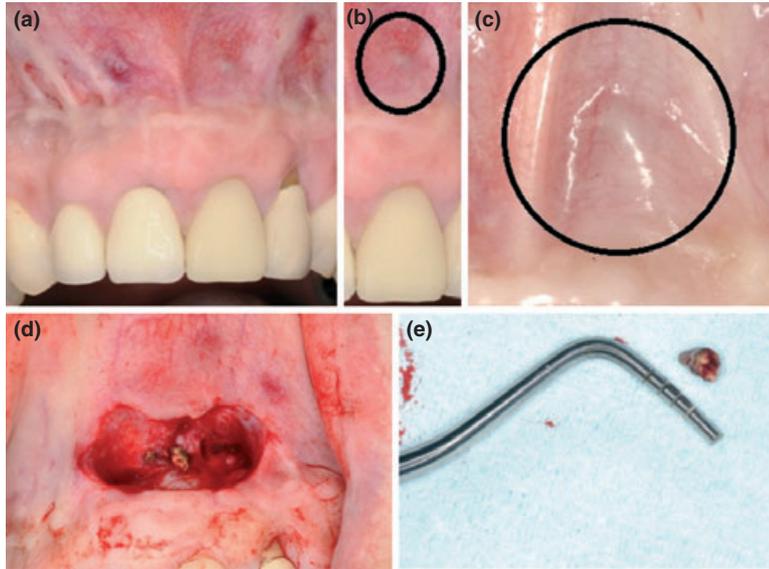


Figure 4 (a) Clinical view of case 3 one year after retreatment. The patient complained of tenderness to palpation on the soft tissue overlying the alveolar bone around the apical part of the maxillary left central incisor. (b,c) Note the prominent area over the root apex that was sensitive to palpation. (d) After elevation of a semilunar flap, the extruded and hard mineral trioxide aggregate (MTA) fragment was found immediately beneath the mucosa. (e) The removed MTA remnant.

Lignospan Special (Septodont) containing lidocaine hydrochloride 2% and epinephrine 1/80 000, a small semilunar flap was raised over the root apex. The extruded and hard MTA fragment was found immediately beneath the mucosa (Fig. 4d). The MTA remnant was removed using an excavator (Fig. 4e). The marginal adaptation of the remainder of MTA in the root-end was evaluated by using an operating microscope (Carl Zeiss Surgical GmbH) with 25 times magnification and no need for further root-end preparation or filling was thought necessary.

The patient was monitored postoperatively, and the tooth remained functional, pain free and without tenderness to percussion or palpation. The soft tissue healed well, and complete osseous healing was observed radiographically (Fig. 3e).

Discussion

One of the main advantages of MTA is its low cytotoxicity (Camilleri *et al.* 2004), which explains why it has been suggested for use in many endodontic treatment modalities (Torabinejad & Chivian 1999). It has been demonstrated that human osteoblasts and alveolar bone cells were able to attach and proliferate on MTA surfaces suggesting the use of the material adjacent to bone (Zhu *et al.* 2000, Al-Rabeah *et al.* 2006). MTA is an osteoconductive biomaterial and up-regulates the expression of bone markers including type 1 collagen (Chen *et al.* 2009), osteocalcin (Tani-Ishii *et al.* 2007), bone sialoprotein (Hakki *et al.* 2009), osteopontin (Nakayama *et al.* 2005) and bone alkaline phosphatase (Chen *et al.* 2009), the latter being an important biochemical marker for bone formation. In addition, MTA is a bioactive material, which induces hydroxyapatite crystal formation on its surface when in contact with tissue fluids (Gandolfi *et al.* 2010). This phenomenon is responsible for its biocompatibility, hard-tissue induction potential (Sarkar *et al.* 2005) and sealing ability (Parirokh *et al.* 2009), features that make MTA an appropriate material for use as an apical plug in teeth with necrotic pulps and open apices.

Mineral trioxide aggregate is composed primarily of tricalcium and dicalcium silicate, which on hydration produces calcium silicate hydrate gel (C-S-H) and CH (Camilleri 2007). Bismuth oxide (Bi_2O_3), the radio-opacifier within MTA powder, is present both as unreacted filler particles and also as part of the structure of C-S-H following the hydration of the material (Camilleri 2007, 2008). The total radiographic disappearance of extruded MTA in Case 1 is representative of complete absorption of hydrated MTA including both unreacted and hydrated bismuth oxide. Total replacement of extruded MTA by newly formed hard tissue and radiographic healing of the periradicular lesion in Case 1 supports the biocompatibility and bone conductivity of MTA. Similar to the outcome of Case 1, a case report study with 12 months follow-up demonstrated that complete bone healing can occur after extrusion of an MTA apical plug into a periradicular lesion (Tahan *et al.* 2010). The authors concluded that extrusion of MTA had no detrimental effect on osseous healing of the periradicular lesion. However, they did not demonstrate any changes in the amount of extruded MTA during the follow-up period, which might be due to the limited follow-up period of 1 year.

In contrast, other studies have revealed that some constituents of MTA material, including bismuth oxide and aluminate, are not biocompatible (Camilleri *et al.* 2004) and that the biocompatibility of MTA material decreases over time because of the decrease in CH release (Camilleri *et al.* 2004). Moreover, despite the upregulation of osteopontin mRNA expression and low cytotoxicity, MTA material may suppress the differentiation process of osteoblast-like cells (Nakayama *et al.* 2005). Also, MTA material releases heavy metal ions including arsenic, lead and chromium in water and tissue fluids, a phenomenon that increases in acidic environments (Schembri *et al.* 2010).

The certain physical and chemical properties of MTA material may change following blood (Nekoofar *et al.* 2010a, 2011) and serum (Nekoofar *et al.* 2010b) contamination as well as in the presence of an acidic pH (Namazikhah *et al.* 2008). In fact, studies have revealed that the sealing ability (Saghiri *et al.* 2008), push-out bond strength (Shokouhinejad *et al.* 2010) and surface hardness (Namazikhah *et al.* 2008) of MTA decrease significantly in acidic environments. Moreover, blood and serum contamination during setting decreases the compressive strength and surface hardness of MTA (Nekoofar *et al.* 2010a,b). Therefore, because of the decreased pH of pus and exudate in periradicular lesions (Nekoofar *et al.* 2009a,b), it is assumed that following extrusion of MTA into periradicular lesions, the material may remain unset. As the composition of unset MTA differs from set MTA, the tissue response to extruded unset MTA is unpredictable and unknown. Case 2 demonstrates that the extruded MTA did not set, and due to the continuation of the patient's symptoms, periradicular surgery was an appropriate treatment option. As the MTA in the root canal space had set, it may be concluded that the hydration process of MTA is predominantly affected by its environment. Although foreign body reaction is an aetiological factor for treatment failure, extraradicular infections and true radicular cysts are other factors that might be related to the persistence of the disease in case 2 (Wu *et al.* 2006). In a case series about MTA plugs in immature central incisor teeth with necrotic pulps (Erdem & Sepet 2008), the authors reported unintentional extrusion of MTA into a periradicular lesion in one case, which resulted in the extraction of the tooth after 6 months. The reason for extraction was severe mobility and persistence of the sinus tract. Although there is no information about the quality of extruded MTA (set or unset), the authors concluded that the MTA should not be pushed out of the canal during placement of the plug. The outcome of Cases 2 and 3 is similar to the finding of Erdem & Sepet (2008).

In Case 3, the extruded and set MTA came to lie beneath the oral mucosa. Although studies using rat subcutaneous implantation have revealed that set MTA is biocompatible (Parirokh *et al.* 2011), one recent study reported that tissue necrosis and chronic

inflammation along with multinucleated foreign body giant cell formation occurred adjacent to set MTA (Martínez Lalis *et al.* 2009). In addition, it seemed that because of the absence of the bony matrix around the material, it acted as an irritant and caused continuation of the patient's symptoms and discomfort, particularly pain when pressing on the prominence created by the material. As there is no information on the effect of set MTA on human oral mucosa, this phenomenon should be studied further.

The effects of canal medication with CH pastes on the sealing ability of MTA apical plugs have been studied. Some have revealed that medication with CH pastes does not have a significant effect on the sealing ability of grey MTA when used as an apical plug (Hachmeister *et al.* 2002, Stefopoulos *et al.* 2008). However, other reports have concluded that canal medication with CH decreased the sealing ability of white MTA apical plugs, which might be associated with residues of CH on the canal walls in the apical area (Stefopoulos *et al.* 2008). It has been suggested that remnants of CH on the root canal walls might produce calcium carbonate, which can interfere with the sealing ability of the filling material (Porkaew *et al.* 1999). Using scanning electron microscopic examination, one study has demonstrated that alternating irrigation with NaOCl and EDTA results in complete removal of CH from dentinal walls (Calt & Serper 1999). As the MTA used in case 1 was white MTA, the clinician followed the method introduced by Calt & Serper (1999) to eliminate remnants of CH dressing before MTA plug insertion.

According to the outcome of cases 2 and 3, although MTA is a nontoxic material, it should be limited to the root canal space, which is a practicable technique as firm compaction of MTA slurry is not recommended (Nekoofar *et al.* 2007). To prevent extrusion of MTA during treatment of immature teeth with pulp necrosis, Castellucci (2003) suggested placing dry MTA powder in the apical portion of the canal and adding water with a wet paper point. However, this suggestion may affect the hydration process of MTA by reducing the optimum water to powder ratio that is essential to produce the necessary physical and chemical properties of the resultant set material (Nekoofar *et al.* 2009b). To obtain reliable physical properties of MTA, the use of ultrasonic vibration was also recommended (Lawley *et al.* 2004). An *ex vivo* study by Yeung *et al.* (2006) on the fill density of MTA in simulated canals using hand condensation or indirect ultrasonic activation revealed that indirect ultrasonic activation created denser MTA root fillings. In addition, in an apexification model, Lawley *et al.* (2004) demonstrated that ultrasonically placed MTA plugs were associated with a better seal against bacterial leakage compared with MTA plugs placed with hand condensation. On the other hand, a comparison of hand condensation and ultrasonic condensation on MTA plugs by Aminoshariae *et al.* (2003) revealed that hand condensation resulted in better adaptation and less voids. Therefore, the use of ultrasonication during MTA apical plug placement is controversial.

The use of resorbable barriers such as calcium sulphate (Trope *et al.* 2006), collagen (Petrino *et al.* 2010), freeze-dried demineralized bone or hydroxylapatite (Lemon 1992, Roda & Gettleman 2011) to prevent unintentional extrusion of MTA might be a viable option to overcome the challenges of controlling MTA during placement. A recent case report by Gharechahi & Ghoddsi (2012) demonstrated that resorbable collagen can be successfully used as an extraradicular barrier. They packed pieces of resorbable collagen membrane into the periradicular lesion through the access cavity. They mentioned that the collagen barrier not only prevented the extrusion of the MTA apical plug but also prevented the contact of MTA with tissue fluids and blood during plug insertion. However, an animal study by Shabahang *et al.* (1999) revealed that when MTA was in contact with periapical tissues, it induced a hard tissue barrier, but, when collagen was in contact with periapical tissues, no apical hard tissue barrier was formed. Further

studies are needed to evaluate the effect of resorbable barrier materials on the physical, chemical and biological properties of MTA.

Following extrusion of MTA into the periradicular tissues, osseous healing and resorption of MTA might occur, or it may remain unset and affect the healing process. The physical irritation of the oral mucosa after MTA extrusion is another possibility when the set material becomes sandwiched between the bone and mucosa. The outcome of treatment after extrusion of MTA into the periradicular tissues is unpredictable. More histological studies on tissue reactions to unset MTA, the effects of unset MTA on the healing process and the effects of set MTA on soft periradicular tissues are recommended.

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