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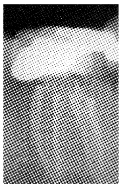

CASE REPORT

Revascularization of an immature tooth with apical periodontitis using a single visit protocol: a case report

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Abstract

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Aim To discuss the clinical and radiological outcome of a revascularization procedure which was completed in a single visit (using sodium hypochlorite 5% as the sole disinfectant) in an immature tooth with a necrotic pulp and apical periodontitis.

Summary A 7-year-old girl was referred in pain following trauma to the maxillary anterior region some 6–7 weeks previously. The maxillary left central incisor tooth was diagnosed with a necrotic pulp and acute apical periodontitis. Under local anaesthesia and rubber dam isolation, an access cavity was prepared. The canal was irrigated with a 5% sodium hypochlorite solution and agitated with an ultrasonic file. A 17% EDTA solution was also used for a final rinse. Bleeding was induced into the canal space from the periapical tissues using a K-file. An MTA layer/barrier was placed directly onto the blood clot, and a further layer of GC Fuji IX cement was placed on top of the MTA to restore the access cavity. The tooth was reevaluated at 6 weeks, 3 months, 6 months, 1 year and 18 months. The tooth has remained symptom free. Radiographic examination shows progressive thickening of the root canal walls, root lengthening and apical closure.

Key learning points

- Disinfection with 5% sodium hypochlorite followed by the induction of a blood clot into the root canal space may be sufficient to promote revascularization in certain circumstances.
- A single visit revascularization procedure is a potential treatment option.

Keywords: apical periodontitis, immature tooth, open apex, revascularization, single visit, sodium hypochlorite 5%.

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Introduction

Trauma and/or carious exposure in immature permanent teeth can lead to pulp necrosis and arrested root development. The consequences of interrupted development include a

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poor crown/root ratio, very thin root walls, an increased risk of root fracture and an open apex (Cotti *et al.* 2008). The conventional root canal treatment protocol for these immature teeth is significantly more difficult to perform because of the open apex (Mackie 1998, Rafter 2005). Traditionally, the open apex was managed by a root end closure technique using calcium hydroxide (apexification). More recently, the placement of mineral trioxide aggregate as an apical barrier has been advocated (Shabahang & Torabinejad 2000, Steinig *et al.* 2003). Whilst both of these techniques have been shown to have good long-term success (Ghose *et al.* 1987, Felippe *et al.* 2006) in the absence of continued root development, they do not help strengthen the root, rendering it prone to fracture.

The ideal treatment of these immature teeth with necrotic pulps and apical periodontitis would be to stimulate the regeneration of the pulp-dentine complex to obtain further root development (Banchs & Trope 2004, Cheuh & Huang 2006, Andreasen & Bakland 2012). Regenerative endodontic procedures are defined as biologically based procedures designed to replace damaged cells and structures with live viable tissues which restore the normal physiologic functions (Garcia-Godoy & Murray 2012). Regeneration can be achieved through the activity of cells from the pulp, periodontium, vascular or immune systems (Garcia-Godoy & Murray 2012) or alternatively through stem cell therapies (most of which are currently under development) (Srisuwan *et al.* 2013). Most of the current therapies involve the use of the host's own pulp or vascular cells and are based on the process of revascularization. There are numerous case reports and series in the literature reporting to use regeneration/revascularization procedures to treat immature permanent teeth with necrotic pulps with or without apical periodontitis (Thibodeau & Trope 2007, Cotti *et al.* 2008, Jung *et al.* 2008, Shah *et al.* 2008, Petrino *et al.* 2010, Cehreli *et al.* 2011, Nosrat *et al.* 2012, Keswani & Pandey 2013, Bezgin *et al.* 2014). These case reports and series have demonstrated radiographical evidence of increased root length and thickening of the root walls with apical closure.

The revascularization treatment protocol varies considerably (Iwaya *et al.* 2001, Cheuh & Huang 2006, Cotti *et al.* 2008, Huang 2008), but most follow that recently recommended by Garcia-Godoy & Murray (2012). The protocol has the following common features: (i) minimal or no instrumentation, (ii) irrigation with sodium hypochlorite in various concentrations, (iii) intracanal medication most commonly in the form of a triple antibiotic paste (metronidazole, ciprofloxacin and minocycline) although calcium hydroxide has been used (Cheuh & Huang 2006, Chen *et al.* 2011), (iv) two or more appointments, (v) overinstrumentation to induce bleeding into the canal space and (vi) placement of an MTA barrier on the clot before sealing the access cavity.

Questions have been raised about the need to use the triple antibiotic paste in the disinfection process in these revascularization cases (Garcia-Godoy & Murray 2012). Although the triple antibiotic paste was used in most studies, some teeth were treated without any antibiotic mix with a successful outcome (Bose *et al.* 2009, Chen *et al.* 2011).

This purpose of this case report is to report and discuss the clinical and radiological outcomes of using 5% sodium hypochlorite as the sole disinfectant in the revascularization of a necrotic immature tooth with apical periodontitis in a single visit protocol.

Case report

A 7-year-old girl was referred complaining of pain from the maxillary left central incisor (21). The pain was constant in nature and had been present for several days. There was a history of trauma to the maxillary anterior region some 6–7 weeks previously. The patient was asymptomatic immediately following the trauma and did not seek any treatment at the time. There was no relevant medical history. Clinical examination revealed an oblique crown fracture of the maxillary left central incisor involving enamel, dentine and a small pulp exposure (Figs 1 and 2). The tooth was acutely tender to percussion and palpation. Sensibility tests were negative. Specifically, there was no response to 1,1,1, 2-tetraflouroethane (Endo-ice, Hygenic Corp., Akron, OH, USA) or the electric pulp test (Analytic Technology, Redmond, WA, USA). Periodontal probing depths ranged from 1 to 2 mm. Radiographic examination revealed probable periapical disease with an incomplete root development and a wide open apex (Figs 3 and 4). The tooth was diagnosed with an acute apical periodontitis associated with a necrotic pulp. The treatment plan was to explore the possibility of carrying out a revascularization procedure in a single visit or to proceed with the conventional placement of an apical barrier with mineral trioxide aggregate cement (MTA) and a conventional root canal treatment. The treatment plan was agreed and appropriate consent obtained.

Local anaesthetic infiltration was given using 2% lidocaine with 1 : 80 000 epinephrine (Lignospan Special, Septodont, Saint-Maur-des-Fosses, France) over tooth 21. Under rubber dam isolation (Hygenic; Coltene/Whaledent AG, Alstatten, Switzerland) (Fig. 5), the pulp chamber was accessed using a diamond fissure bur in an air turbine handpiece with copious irrigation. The pulp chamber and canal system were explored with the aid of a dental microscope (Global Surgical Corp., St Louis, MO, USA), and no vital tissue was identified (Fig. 6). The canal was gently irrigated with a solution of sodium hypochlorite 5% to flush out gross debris using a 3-mL Leur Lock syringe with a 30-G irrigating needle tip (PacDent, Walnut, CA, USA). The canal length was measured using a size 15K-file (Dentsply Maillefer) and a Root ZX apex locator (J Morita MFG Corp., Kyoto, Japan). Once the working length was established, an irrigating needle tip was placed to length and the root canal system was irrigated over a 20-min period with a 5% solution of sodium hypochlorite. At all times, the irrigating syringe was in constant motion up and down the canal, and care was taken to ensure that irrigant was

Figure 1 Pre-op 27 September 2012.

Figure 2 Pre-op intra-oral (mirrored view) 27 September 2012.

Figure 3 Periapical radiograph showing 21 with open apex and probable periapical disease.

Figure 4 Periapical radiograph showing open apex and probable periapical disease.

not forced out through the open apex. A total volume of approximately 30 mL was used. From time to time, the irrigant was agitated using a Suprasson ultrasonic handpiece (Acteon- Satelec, Merignac, France) and Irrisafe files size 25 (Acteon- Satelec) periodically with a power setting of 45/100 for short intervals of 3–5 s. The Irrisafe file was moved up and down the canal system in an attempt to agitate the irrigant better. Once the agitation cycle was complete, the irrigant was replaced. A 17% EDTA solution was used in the final rinse sequence. A total volume of 3 mL (approximately) of EDTA was used. Two 3-mL syringes (one containing NaOCl the other EDTA) were used in the final rinse sequence. A small volume of NaOCl was delivered to the canal. This was

Figure 5 Rubber dam isolation 18 October 2012.

Figure 6 Access cavity.

Figure 7 MTA barrier.

then washed out with EDTA and vice versa until the syringes were emptied. At the end of the irrigation phase, the canal was dried with paper points (Dentsply Maillefer) and a Stropko irrigator (Sybron Endo, Oregon, CA, USA). The canal was deliberately over instrumented to induce periapical trauma and bleeding into the canal. Once the canal filled with blood to the level of the cervical constriction, an MTA plug (MTA; Angelus, Londrina, PR, Brazil) was placed on top of the blood clot. A Lee block (Tap Plastics, San Rafael, CA, USA) was used to prepare a plug of MTA, which was then gathered and carried to the access cavity with a standard Ward's carver. The plug was deposited in the canal orifice, and paper points were used to gently place the MTA on the blood clot (Fig. 7). The MTA was covered with GC Fuji Cement IX (GC Corp., Tokyo, Japan) to seal the access cavity. A radiograph was taken to confirm the positioning of the plug of MTA (Fig. 8).

Figure 8 Periapical radiograph confirming MTA placement immediately postoperatively.

Figure 9 Periapical view 6 weeks post-treatment.

At 6 weeks, the patient returned and was asymptomatic. A periapical radiograph was taken (Fig. 9). The patient was recalled and radiographs were taken at 3 months (Fig. 10), 6 months (Fig. 11), 12 months (Fig. 12) and 18 months (Fig 13). The tooth has remained asymptomatic throughout and shows radiographic evidence of continued root development.

Discussion

There are three key steps to revascularization procedures (i) disinfecting the canal space, (ii) inducing bleeding to form a blood clot in the canal space or placement of

Figure 10 Periapical view 3 months post-treatment showing root elongation and apical closure.

Figure 11 Periapical view 6 months post-treatment showing further root elongation and apical closure.

another suitable matrix into which new tissue can grow and (iii) a bacteria-resistant coronal seal (Ding *et al*. 2009, Jadhav *et al.* 2012, Nosrat *et al*. 2012).

Controlling infection in the canal space is an important initial step in the revascularization process. It is suggested that a higher level of disinfection is required for pulp regeneration (Fouad 2011). In younger teeth, bacterial cells can penetrate further into the dentinal tubules and advance deeper in comparison with older teeth (Peters *et al*. 2001, Kakoli *et al.* 2009). Two *in vitro* studies by Hoshino *et al.* (1996) and Sato *et al.* (1996) showed that the mixture of ciprofloxacin, metronidazole and minocycline was

Figure 12 Periapical view showing root thickening 1 year post-treatment.

Figure 13 Periapical view showing almost complete root maturation at 18 months post-treatment.

effective against endodontic pathogens and was able to disinfect into the dentine tubules. This antibiotic mixture has become known as Hoshino's paste. Both Windley *et al.* (2005) and Cohenca *et al.* (2010) have shown that irrigation with sodium hypochlorite followed by triple antibiotic paste renders 70–78% of the canals culture negative. This protocol has become the basis for disinfection in revascularization cases. Most of the studies used Hoshino's tri antibiotic paste as the intracanal medicament of choice in the disinfection process for the treatment of nonvital immature teeth undergoing revascularization treatment (Iwaya *et al.* 2001, Banchs & Trope 2004, Cotti *et al.* 2008, Ding *et al.* 2009, Petrino *et al.* 2010, Keswani & Pandey 2013, Bezgin *et al.* 2014). Others have used calcium hydroxide (Chen *et al.* 2011) and one study used formocresol (Shah *et al.* 2008). The need to use intracanal medicaments in the disinfection process increases the complexity of the procedure significantly (Shin *et al.* 2009, Nosrat *et al.* 2012). It increases the number of visits, the need for temporization, patient compliance, attendance issues, increasing the treatment time and cost of treatment (Nosrat *et al.* 2012). There are issues regarding possible sensitivity to some of the medicaments used (Ding *et al.* 2013), and staining or possible discoloration of the tooth has been reported (Nosrat *et al.* 2012). It has also been shown that these intracanal medicaments may impact adversely on dentine fracture resistance (Yassen *et al.* 2013).

There are potentially significant advantages to be gained if revascularization can be achieved in a single visit. da Silva *et al.* (2010) demonstrated that sodium hypochlorite delivered using the EndoVac system (a negative apical pressure system) may be considered as an effective means of disinfection in the treatment of immature teeth with apical periodontitis. They suggested that the use of intracanal antibiotics may not be necessary (da Silva *et al.* 2010).

Shin *et al.* (2009) described a case where they carried out a revascularization procedure on a partially necrotic pulp in a mandibular second premolar tooth. The irrigation technique used consisted of initially irrigating the coronal portion of the root with 10 mL of 6% sodium hypochlorite (NaOCL) followed by a sterile saline solution which in turn was followed by 10 mL of 2% chlorhexidine gluconate, which was left in place for 5 min (Shin *et al.* 2009). No instrumentation was performed. The coronal aspect of the canal was dried and MTA placed. Both clinical and radiographic follow-up showed complete periradicular bone healing and root maturation.

Traditionally, teeth with open apices have been identified as being a high risk from irrigant extrusion (Trope 2010). It was common practice to use a lower strength solution of sodium hypochlorite because of the fear of inadvertent extrusion into the periapical tissues (Trope 2010). It could be postulated that teeth with open apices were treated more cautiously as a result. Diogenes *et al.* (2013) showed that only 34% of the published cases on pulp revascularization used full strength sodium hypochlorite (5–6%). It is possible that this reflects operator anxiety when treating immature necrotic teeth.

The perceived importance of irrigation in root canal treatment has grown considerably in recent years (Zehnder 2006, Park *et al.* 2012). Sodium hypochlorite is considered the primary irrigant of choice for all root canal treatments (Zehnder 2006). In the report by Shin *et al.* (2009), both sodium hypochlorite 6% and chlorhexidine 2% were used. In this report, sodium hypochlorite 5% was the sole irrigant used.

A slotted or notched size 30-gauge needle (PacDent, Walnut, CA, USA) was used to deliver the sodium hypochlorite solution in this case. This needle tip has the advantage of irrigating up to 3 mm beyond the needle tip in a tapering canal system (Park *et al.* 2012). In this report, the irrigation needle was kept moving slowly in the canal system at all times with a maximum penetration depth close to that of the estimated working length, whilst the irrigant was being delivered. Although Boutsioukis *et al.* (2014) have shown a significant increase in irrigant extrusion when the needle tip advances apically from 3 to 1 mm from the constriction, it was hoped by keeping the tip moving the potential for extrusion was diminished whilst maximizing the irrigation effect. The rate of delivery or flow rate of the irrigant was not measured, but care was taken to ensure that the irrigant was not delivered forcefully into the canal system.

It is important to control the pressure for the delivery of the irrigant and to prevent the irrigation needle binding in the canal to reduce the potential for irrigant extrusion (Hulsmann & Hahn 2000). In a survey of the diplomats of the American Board of Endodontists, an open apex, wedging the needle tip or excessive syringe pressure was perceived to be a likely cause of an extrusion accident (Kleier *et al.* 2008).This may not be as big a concern in a wide open canal system where there is always a coronal escape-way. Boutsioukis *et al.* (2013a) suggested that a well-established periapical lesion will offer less tissue resistance and so will offer less resistance if the irrigant is forced against it and so other factors such as periapical tissue status may be just as important as the high flow rate. So it could be postulated that the risk of a sodium hypochlorite accident occurring in an immature necrotic tooth may not be any greater than that of a mature tooth and could possibly be less. Therefore, there is no evidence-based reason to adopt a more cautious approach when dealing with an immature tooth with a necrotic pulp.

In addition to using to using a high volume of irrigant (approximately 30 mL) over a 20-min time period (approximately), there are still certain limitations to syringe irrigation. These limitations include the presence of the stagnation plane and difficulty in irrigant penetration, and the shortcomings of laminar flow being able to exert shear stress on the canal walls and biofilm (Park *et al.* 2012). Although the literature is inconclusive when it comes to comparing the irrigation efficiency of ultrasonic, sonic and syringe methods, there are certain merits in using some form of irrigant agitation. Ultrasonic agitation has been shown to improve irrigant flushing and penetration (Teplitsky *et al.* 1987) and was used periodically throughout the irrigation in short-time intervals. A size 25 file was used and was kept free in the canal system to minimize the damping effect with wall contact (Boutsioukis *et al.* 2013b). According to the manufacturer, a power setting of 6–7/20 is recommended for ultrasonic agitation by the Irrisafe file (Acteon-Satelec 2012). In this report, a power setting of 45/100 was actually used, which is slightly higher than that recommended. Increasing the power setting may increase the cleaning efficiency without increasing the risk of irrigant extrusion (Jiang *et al.* 2011).It is likely that the ultrasonic file tip will generate a lateral flow towards the root canal walls rather than an apical flow (Park *et al.* 2012).

The irrigation protocol used in this report was in keeping with current recommendations taking into consideration that there are no studies done on the fluid dynamics in an immature tooth with parallel sided roots and an open apex (Simon & Smith 2014).

In this study, the apical tissues were slightly overinstrumented to induce bleeding. This is not always the case. Some authors have reported failure to induce bleeding (Ding *et al.* 2009, Cehreli *et al.* 2011). An animal study showed that root canals that had blood clot formation inside them after disinfection had a better radiographic outcome compared with those without a blood clot (Thibodeau *et al.* 2007). It is with this in mind that Petrino *et al.* (2010) have recommended using local anaesthetic without vasoconstrictors. However, a lack of bleeding or insufficient bleeding has also been reported after using plain local anaesthetic (Petrino *et al.* 2010, Cehreli *et al.* 2011). In this report, local anaesthetic with vasoconstrictor was used.

The importance of the blood clot cannot be overemphasized (Nosrat *et al.* 2012). The blood clot inside the root canal space provides a protein rich scaffold that contains platelet derived growth factors and mesenchymal stem cells (Thibodeau *et al.* 2007). However, it is technically difficult to place MTA directly on to the clot. Both Petrino *et al.* (2010) and Diogenes *et al.* (2013) suggested the addition of a collagen matrix to the blood clot would assist with optimal MTA placement. One of the benefits of using a different scaffold than the blood clot would be the placement of MTA. The placement of the MTA could be more idealized. To maximize root development, the MTA needs to be placed at the level of the cervical constriction or even a little more coronally (Diogenes *et al.* 2013). A more coronal placement of MTA will potentially achieve hard tissue formation in the critical cervical area of the tooth which is where catastrophic fractures appear to occur. Platelet-rich plasma (Jadhav *et al.* 2012), platelet-rich fibrin (Keswani & Pandey 2013) and concentrated platelet-rich plasma (Bezgin *et al.* 2014) have all been used recently. Whilst all of these scaffolds have potentially improved properties from a wound healing and growth factor perspective, they have not been shown to have a better outcome (Simon & Smith 2014). They also require special equipment to prepare, increased costs, involve drawing blood from children and involve a multivisit protocol.

Most of the case reports/series have shown an increase in root length and dentinal wall thickening with a reduction in the volume of the pulp canal space radiographically (Thibodeau & Trope 2007, Cotti *et al.* 2008, Jung *et al.* 2008, Shah *et al.* 2008, Petrino *et al.* 2010, Cehreli *et al.* 2011, Nosrat *et al.* 2012, Keswani & Pandey 2013, Bezgin *et al.* 2014). Clinically, the teeth were symptom free. This case report showed a similar clinical and radiographic outcome. However, where histological analysis of teeth which had undergone revascularization treatment was possible, the mineralized layer on the walls which was observed appeared to be of periodontal origin rather than pulpal origin. This histological outcome was observed in two case reports one of which had been revascularized by simple blood clot (Shimizu *et al.* 2012) and the other had used a platelet-rich plasma (Martin *et al.* 2013) This suggests that the new tissue was not of dentinogenic origin and highlights the shortcomings of dental radiography for characterizing new mineralized tissue in endodontics (Simon & Smith 2014).

From a clinical perspective, the true origin of this tissue may not matter (Simon & Smith 2014). If the objective is to induce healing of the periapical tissues, stimulate bone regeneration and render the patient free from signs and symptoms, then this current case report can be deemed a clinical success. However, it may not exhibit ‘true’ biological pulpal regeneration but the filling of the root canal space with a vital biological tissue which has further repair and defence capabilities. This represents a step forwards when compared to gutta-percha or MTA (Simon & Smith 2014). Whether this revascularization process improves the root strength remains to be seen.

Conclusion

This case report used 5% sodium hypochlorite as the sole irrigant for disinfection and a single visit protocol to achieve radiographic evidence of root end closure and root lengthening in an immature tooth with a necrotic pulp. The tooth remains symptom free. This is a similar clinical and radiological outcome to the other case reports and case series which report revascularization.

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Disclaimer

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