Revascularization in Immature Permanent Teeth - A Case Series

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ABSTRACT

Immature permanent teeth with developing, root apices with dental pulp infections resulting from caries or trauma represent a formidable clinical challenge. Biologically based principles of regenerative endodontic procedures in the treatment of immature, necrotic teeth have replaced the traditional 'apexification' procedures. The purpose of this case series was to investigate the outcome of the pulpal revascularization procedure on immature permanent teeth with or without apical periodontitis.

The case series comprised 3 patients (8–11 years of age), consisting of 4 incisors and 1 premolar with incompletely formed apex with or without signs or symptoms of periapical pathology. Induction of blood clot was the technique selected for root closure if the tooth was asymptomatic following the placement of intracanal antibiotic paste for 3 weeks. Apexification was initiated if the tooth remains symptomatic. Out of the five teeth revascularisation was successful, and continued root-end closure was obtained in four teeth. One tooth remained symptomatic and apexification was initiated. One patient failed to follow up for the study.

Revascularisation by induction of apical bleeding is a potential source of stem cells for the continued root maturation and it creates a blood clot that would act as a biologic scaffold for the recruited stem cells.

Keywords: *Immature teeth, pulp revascularization, regenerative endodontics.*

INTRODUCTION

Immature permanent teeth are often susceptible to trauma or caries emanating in pulpal necrosis leaving the tooth with thin root canal walls and blunderbuss apices. Conventional endodontic treatment is complicated to perform in the young permanent tooth due to the lack of an apical constriction and the fragile walls of the root canal dentin which is vulnerable to fracture. Apexification has been proposed as a treatment modality for decades to induce the formation of a calcific barrier against which the obturation material could be repleted. The use of revascularization techniques in regenerative procedures is to induce physiological root closure and thus tissue regeneration, rather than tissue replacement using artificial substitutes.[1]

Pulp revascularization is dependent on the ability of the residual pulp as well as the stem cells of the apical and periodontal area to differentiate. These cells have the ability to generate a highly vascularized and rich living tissue that can colonize the pulp space available. This case series aimed to examine the effect of revascularization procedures on immature teeth with and without apical periodontitis.

CASE REPORTS

This is a case series comprising of 3 patients (8-11 years of age), consisting of 4 incisors and 1 premolar who reported to the Dept of Pediatric and Preventive Dentistry with or without signs or symptoms of periapical pathology. The medical history of all the patients was non-contributory.

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CASE 1

A 10 -year-old girl with decayed mandibular 2nd premolar with acute periapical infection. Intraoral radiograph revealed wide canal and open apex and incompletely formed roots (Figure 1A). Revascularisation was initiated and MTA placed (Figure 1 B). At 12-month follow-up, normal maturation of root with thickening of lateral dentinal walls and root lengthening were observed (Figure 1 C). At 18-month follow-up, further narrowing of root canal was evident in the apical third with thickening of the lateral walls and normal bony architecture at the periradicular region (Figure 1 D).

CASES 2 , 3

An 8-year-old girl reported with two fractured and discoloured maxillary right (Case 2) and left (Case 3) central incisors. Figure 2; A-D - (A) Fractured and discoloured upper central incisors. (B) Intraoral radiograph of tooth showed wide root canal and an open apex; (C) Revascularisation was initiated and MTA placed. (D) At 12-month follow-up, normal maturation of root with thickening of lateral dentinal walls and root lengthening were observed.

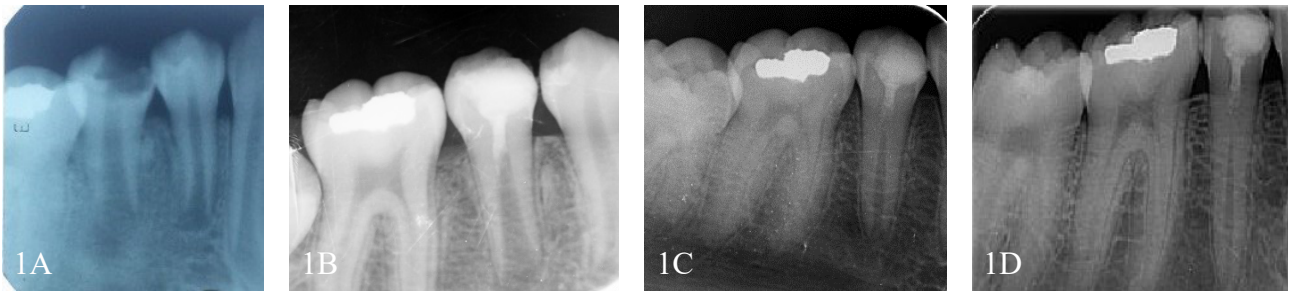

Figure 1. Case 1 (A) IOPA showing 2nd premolar with acute periapical infection with wide canal and open apex and incompletely formed roots (B) Revascularisation and MTA placed. (C) 12-month follow-up, root lengthening was observed. (D) 18-month follow-up, narrowing of root canal in the apical third, thickening of the lateral walls with normal bony architecture at the periradicular region.

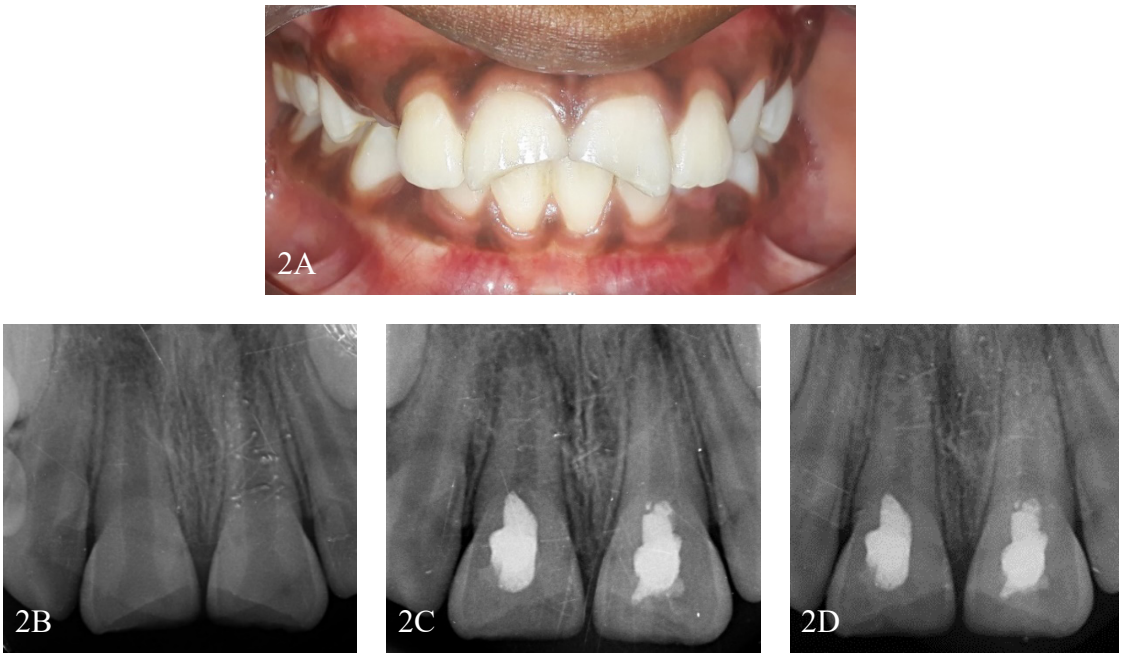

Figure 2. (Case 2, 3) (A) Fractured and discoloured upper central incisors. (B) Intraoral radiograph of tooth showed wide root canal and an open apex; (C) Revascularisation was initiated and MTA placed. (D) 12-month follow-up, normal maturation of root, thickening of lateral dentinal walls and root lengthening were observed.

CASES 4 , 5

An 8-year-old boy presented with fractured maxillary central incisors with a history of swelling concerning 11 (Case 4) and fractured 21 (Case 5, Figure 3A). Emergency access opening was done from elsewhere in both Case 4 and 5. Intraoral radiograph of tooth showed wide root canal and an open apex (Figure 3B); Revascularisation was initiated and MTA placed (Figure 3C). At 12-month follow-up, normal maturation of root with thickening of lateral dentinal walls and root lengthening were observed in 21 alone (Figure 3D). Later apexification was initiated in 11 to achieve root end closure.

On clinical examination, the incisors had an Ellis class III fracture, and mobility and periodontal probing were within physiological limits. Pulp vitality tests were negative on cold and electric pulp testing (EPT), but the patients experienced sensitivity to percussion and palpation. Radiographic examination revealed that the tooth had an incompletely developed apex and peri radicular radiolucency in all the cases. The parents of the study population were informed about the limitations and advantages of revascularization as a treatment modality, and informed consent was obtained from them.

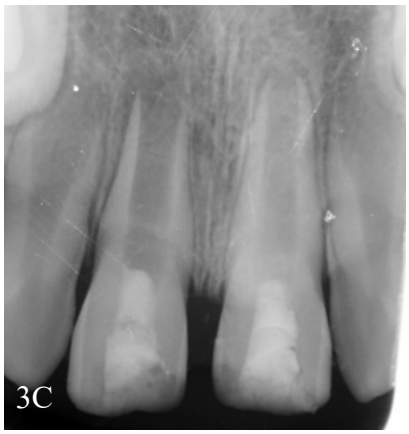

Figure 3. (Case 4, 5) (A) Fractured maxillary central incisors 11, 21. (B)Intraoral radiograph of tooth showed wide root canal and an open apex; (C) Revascularisation was initiated and MTA placed. (D) 12-month follow-up, normal maturation of root with thickening of lateral dentinal walls and root lengthening were observed in 21. Apexification was initiated in 11 to achieve root end closure.

The teeth were anesthetized with 2% lidocaine with 1: 100,000 epinephrine and an access cavity were established under rubber dam isolation. Pus and necrotic tissue were observed within the root canal of Case 4. The root lengths were estimated radiographically using a size 15 K-file (Sybron Endo, Orange, CA, USA) and confirmed with an apex locator (Sybron Endo, Orange, CA, USA). The coronal third of the root canal was widened passively with Gates Glidden drill size #4 (Dentsply Maillefer, Tulsa, OK, USA) to provide adequate space for the canal orifice to accommodate the instrument used to induce blood clot as well as to ensure adequate intracanal disinfection which facilitates the revascularization procedure.[2] Canals were irrigated with 1.5 % Sodium hypochlorite (NaOCl 20ml) using an apical negative pressure irrigation system (EndoVac) that minimizes the possibility of extrusion of irrigants into the periapical space. This was followed by irrigation with saline or ethylenediamine tetra acetic acid (EDTA 20 ml, 5 min), with the needle positioned about 1 mm from the root end so that the cytotoxicity to stem cells within the apical tissues are often minimized. The canals were dried carefully with absorbent points (Dentsply Maillefer).

The antibiotic paste was freshly prepared with powder of 20 mg each of metronidazole, ciprofloxacin, and minocycline mixed with 1 mL of sterile water. The antibiotic paste was introduced into the canal with a lentulo spiral and filled to the level just below the cemento-enamel junction. The access cavity was then sealed with Cavit (ESPE, Seefeld, Germany)

At the 3-week follow-up appointment, the patient was asymptomatic in Case 4, and the tooth showed no tenderness to percussion and palpation. Under local anesthesia with 2% lidocaine, and rubber dam isolation, the temporary restoration was removed. The triple antibiotic paste was removed using 10 mL of 5.25% NaOCl, and the canals were dried with absorbent points (Dentsply Maillefer).

The apical tissue in the tooth was nudged using an ISO 40 K-file/ D11T NiTi (Nickel Titanium) instruments hand spreader (Dentsply Tulsa Dental, TN, USA) to irritate the apical tissue until bleeding occurred apically into the root canal space to create a biological scaffold for the regenerative process. The blood was allowed to clot for 15 minutes to a level 3 mm below the cementoenamel junction. Then 3 mm of ProRoot white MTA (Mineral Trioxide Aggregate Dentsply Tulsa Dental, TN, USA) was placed over the blood clot. A wet cotton pellet was placed against the MTA, and the teeth were restored temporarily with Cavit (3M ESPE). The temporary restoration was removed, and the MTA set was verified one day after, and an approximately 2-mm-thick layer of glass ionomer cement (Fuji; Fuji Corporation, Osaka, Japan) was placed over the set MTA cement. The tooth was then restored with composite resin (Filtek A110; 3M Dental Products, St Paul, MN, USA).

For teeth with persistent infection, (Case 4) or where the canal could not be dried, the triple antibiotics mixture dressing was repeated until no symptoms or exudation were present and then the asymptomatic tooth was treated as described above.

RESULTS

At the 3-month follow-up, the teeth were functional, without sensitivity to percussion and palpation, and normal periodontal findings in all cases other than Case 4. For this study, the criteria of success were - lack of symptoms, radiographic evidence of increased root length, and root canal wall thickness. At the 1-year follow-up examination, the teeth (Case 1,2,3,5) continued to be asymptomatic with a radiographic indication of the continued development of the apex of the tooth with complete resolution of the periapical radiolucency. In Case 4 the tooth remained asymptomatic but there was no radiographic sign of continued development of root apex and hence apexification was initiated. All teeth that received a complete course of revascularization treatment showed complete root development with a closed apex. They gradually regained pulp sensibility and responded positively to the electric pulp tester at a similar reading as the control tooth 12–15 months after the treatment.

DISCUSSION

Endodontic treatment of young permanent teeth most likely causes a challenge to the clinician. Any insult or trauma during the earlier stages of root development can compromise the physiological root closure of the tooth. A major concern with the endodontic treatment of immature permanent teeth with apical pathosis is with the

mechanical cleaning and shaping of their root canal walls. Mechanical filing can fracture the thin dentinal walls and the large volume of necrotic debris contained in the wide root canals is often difficult to completely disinfect.[2]

When an apexification procedure is attempted in a developing tooth the pulp canal space is physically occupied by the filling material and there is no room for the vital tissue to proliferate. Apexification results in the formation of a hard tissue barrier but it would not lead to continued root formation or thickening of the root canal wall which might lead to the risk of an undesirable short and weakened root that is susceptible to fracture.[1]

It was found that the stem cells arising from the dental papilla or apical periodontium could serve as a scaffold for regeneration from the necrotic but uninfected pulp.[3,4] The success of the revascularization procedure is determined by the amount of disinfection of the root canal that can be achieved.[4,5]

Traditional chemomechanical debridement of the conventional root canal treatment leaves behind residual bacteria which are entombed by obturation of the canal space.[5] A well-sealing coronal restoration makes the environment conducive to healing in most cases. Moreover, in regenerative endodontic procedures, the lack of a filling in the canal space while the regenerated tissue is developing may allow the residual bacteria to proliferate and re-establish a biofilm which necessitates a higher level of disinfection than that accepted for traditional root canal therapy.[1] Furthermore, the developing tissue requires sufficient time to establish within the root canal, and, thus, the aseptic environment needs to be maintained for a longer period than in traditional endodontic therapy. Antimicrobial agents with higher levels of substantivity are hence needed.[1]

Disinfection of the root canals in revascularisation generally starts with root canal irrigation. Sodium hypochlorite is the most commonly used root canal irrigant and the free chlorine in it dissolves vital and necrotic tissue by breaking down proteins into amino acids.[2] NaOCl irrigant is also associated with cytotoxicity when injected into periradicular tissues. With EndoVac irrigation system there's less extrusion risk of NaOCl in comparison with needle irrigation.[6] The beneficial effects of EDTA, when used as a final irrigant before recruitment of stem cells from periapical tissues, are higher. These effects are primarily attributed to the EDTA-induced release of growth factors from dentin that is capable of mediating stem cell chemotaxis and differentiation, angiogenesis, and neurogenesis.[7]

17% EDTA solution as a final irrigant has been recommended by The American Association of Endodontics and the European Society of Endodontology.[8,9] The effects of residual EDTA on the microscopic feature of a blood clot in root canal including characteristics and fiber density have shown that a decrease in clot formation was affected by EDTA irrigation for 1 and 5 minutes. Even though the final flushing with Normal saline solution could improve fibrin formation, the amount of growth factor released from root dentin was lower than when EDTA was used alone.[10]

Recent studies have shown that 10% citric acid has distinct advantages over 17% EDTA in terms of TGF-b1 (Transforming growth factor beta 1) release as well as stem cell recruitment, attachment, and survival.[11]Atesci AA et al. has evaluated the amount of growth factors released when 17% EDTA, 10% citric acid, 1% phytic acid (IP6), or 37% phosphoric acid and found that 10% citric acid was superior to others when used as a final irrigant and phosphoric acid appeared to be the most effective agent in terms of growth factor release after 3 days of adipose-derived mesenchymal stem cell (adMSC) seeding.[12]

Studies have shown that local application of a mixture of antibiotics is effective in killing common endodontic pathogens in infected root canals and facilitates root canal disinfection. Sato et al. and Hoshino et al. reported that a mixture of ciprofloxacin, metronidazole and minocycline can eradicate bacteria from the infected dentine of root canals and are hence the most popular intracanal medicaments in pulp regenerative therapy.[13-15]

After adequate disinfection of the root canals, a coronal seal with MTA was used in the present study. To ensure disinfection of the root canals the dentin surface of the root canal is exposed to various irrigant solutions and intracanal medicaments, which may alter the chemical and mechanical properties of MTA during pulp revascularization procedures. The influence of various

intracanal medicaments on the dislocation resistance of MTA to root dentin was evaluated and it was found that the application of Double Antibiotic Paste decreased the dislocation resistance of MTA to root dentin, whereas TAP (Triple Antibiotic Paste) and Calcium Hydroxide did not affect the dislocation resistance after 3 weeks.[15] Studies have shown that dislocation resistance was significantly affected when TAP intracanal medicament was kept for about 4 - 12 weeks. Hence it is important to optimize the type and the treatment time of medicaments kept in root canals used for pulp revascularization to provide maximum antimicrobial effect while creating a favorable environment both for stem cell attachment and MTA adhesion.[16]

Coronal discoloration related to the placement of an MTA barrier has been reported even when the white form of the material is used.[17,18] This can be minimized by occluding the coronal dentinal tubules with a dental adhesive,[19] or largely by the use of other bioceramic materials, such as Biodentine (Septodont, France) and Endosequence (Brasseler, Switzerland) in esthetic zones.[20,21] These materials have improved colour stability and reduced staining potential than MTA, and they are also found to promote proliferation and odontogenic differentiation of mesenchymal stem cells.[22] The improved handling characteristics and reduced risk of tooth discoloration of these materials enable them to be placed above cementoenamel junction which is a desirable advantage, as the cervical hard tissue deposition can potentially increase resistance to fracture and long-term tooth survival.

Preoperative infection has been identified as the single most important factor in the success of endodontic treatment of teeth with a mature apex. The presence of infection delays the complete clinical and radiographic healing by about 15%–20% when compared with cases with vital pulp despite the recent technological advances in the field.[23] Studies have shown that the probability of long-term healing of infection was significantly lower in the tooth with larger periapical lesions and preoperative symptoms or perforations during treatment or in the presence of a sinus tract.[23]

Studies by Austah et al. on the comprehensive characterization of immature teeth treated with regenerative endodontic procedures have shown that recapitulation of the pulp-dentin complex after regenerative endodontic procedures showed vascular, neural, lymphatic, and immune cell markers; all cell types representing an immunocompetent pulp; as well as regeneration of the dentin like tissue.[24]

The major aspect in the regenerative endodontic procedures is in the variation in type and time of root closure in different cases. One of the reasons for this inconsistency in results could be the difference in fundamental principles of tissue engineering required for the regeneration of a pulp-dentine complex. Another possible factor could be the degree of damage to Hertwig's epithelial root sheath (HERS) that has been caused either secondary to dental trauma or during the damage of the periapical area during the stage of induction of bleeding into the root canal.[25]

The apical diameter of immature permanent teeth has been a major concern in regenerative endodontic therapy. As a general rule, it is recommended that immature permanent teeth with necrotic pulp and incomplete root formation are suitable for RET (Regenerative Endodontic Therapy) because of the short root, thin canal walls and wide-open apex as apexification has no potential for root maturation; thickening of the canal walls and/or continued root development.[26] Immature permanent teeth with nearly completed root formation with open apex can be managed with either RET or an apical MTA plug and root canal filling because the canal walls have enough thickness and strength.[26] Studies have shown that apical diameters of 0.5–1.0 mm attained the highest clinical success rate in the immature tooth with pulpal necrosis which may be also related to other factors including patient age, pulp necrosis, etiology, preoperative apical radiolucency, procedure details, follow up period.[27]

Several reports have shown the success of REPs (Regenerative Endodontic Procedures) using blood clots as a scaffold.[26] Even though blood clot has been proved to be a good scaffold it lacks growth factors and it is not always possible to invoke adequate apical bleeding. Recently, autologous platelet concentrates have drawn attention for use in REP as three-dimensional scaffolds. When clinical and radiographic outcomes of Platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) were compared with induced blood clots it was found that PRF had huge potential to accelerate the growth characteristics

in immature necrotic permanent teeth as compared to PRP and blood clot.[28] In another study, it was found that PRP gave results in a short period compared to other groups, but it requires drawing 10-15 ml blood from the patient and needs biochemical processing. On the other hand, despite the delayed results of induced apical bleeding technique compared to PRP, as it requires no drawing of blood from the patient and no biochemical handling of blood makes it less cumbersome.[29]

When Blood Clot, Platelet-rich Plasma, Platelet-rich Fibrin, and Platelet Pellet were used as Scaffolds in Regenerative Endodontic Treatment it was found that PRP, PRF, and Platelet pellet yield similar clinical and radiographic outcomes to bloodclot without the need for prior apical bleeding and with significantly less tendency for root canal obliteration.[30]

CONCLUSIONS

Regenerative endodontic treatment is based on the concept of tissue engineering technology to regenerate the dentine-pulp complex in the canal space of immature permanent teeth damaged by caries or trauma, thus restoring the development of the arrested tooth root. Even though the continued root development (thickening of the canal walls and/or apical closure) after RET is not predictable, it can eliminate the patient's clinical symptom/signs and resolve apical periodontitis, which meets the primary goal of endodontic therapy.

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Conflict of Interest: None

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