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Regenerative Endodontic Treatment of a Traumatized Immature Necrotic Permanent Incisor: A Case Report

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The current case report documents the clinical approach adopted for a traumatized immature necrotic permanent upper left central incisor after a bike accident. The treatment involved regenerative endodontic procedures (REPs) using "High Plasticity Mineral Trioxide Aggregate" (MTA Repair HP) as a cervical barrier over blood clot. The preservation included three years of follow-up appointments of clinical evaluations and periapical digital radiographs. Cone beam computer tomography (CBCT) was taken at six and thirty-six months for the evaluation of root development.

Keywords: Regenerative Endodontics, Dental Trauma; Immature Teeth; Pulp necrosis; Mineral Trioxide Aggregate (MTA)

Introduction

The first case report on regenerative endodontics published was completed in 2001. Iwaya *et al.* presented their first case of a necrotic dens evaginatus premolar treated through a new endodontic approach called "Revascularization"[1]. The new method might have contributed to a change of treatment paradigm; *i.e.* when thorough disinfection is achieved, the periapical tissues and the root finishes heals and finishes its course of development, thus, there is no necessity to obturate the root canal space with gutta percha and sealer and/or other materials. In 2019, a sciento- and bibliometric study showed that a total of 1820 authors from 53 countries contributed to the development of regenerative endodontics [2].

Bioactive endodontic cements (BECs) [*e.g.* Mineral Trioxide Aggregate (MTA) (Angelus, Londrina, Brazil) and MTA Repair HP (Angelus, Londrina, Brazil)] play an important role in regenerative endodontic procedures (REPs); as BECs provoke the natural remineralization process at biomaterial-tooth interface. The encouragement occurs with the liberation of calcium (Ca^{++}) ions when BECs are in contact with living tissues; resulting in the formation of a biomimetic layer of hydroxyapatite recognized natural by the adjacent organs/tissues. Additional advantages lie on their great biocompatibility and antibacterial properties due to high pH and tight coronal seal. However, it has been demonstrated that MTA has drawbacks; including discoloration of the tooth (due to its radiopacifier; *i.e.* bismuth oxide), long setting period, apical displacement of the material and difficult application. Consequently, "MTA Repair HP" has been developed to overcome the difficulties of MTA; with calcium tungstate ($CaWO_4$) as the radiopacifier; since it does not alter tooth color. Furthermore, MTA Repair HP has a setting time of 12 minutes, and with its added high plasticity (HP) component, it has revealed to enhance consistency [3].

Although REP is quite simple, the literature shows a great variety in its outcomes over the formation of apical region [4]. In addition, the achievement of proper disinfection has proved to be difficult in some cases [5]. The main challenge in REP is to prepare an appropriate environment to permit root development without being affected by tissue necrosis.

The present case report shows the result of a REP using MTA Repair HP as a cervical barrier after three years of constant follow-ups with cone beam computer tomography CBCT.

Case Presentation

A six-year-old female patient was referred to the Endodontics Department in August 2015, two hours after a bike accident. The accident resulted in lip dilaceration of 1 cm and subluxation/crown fracture of a small enamel portion of the upper right central incisor (URCI). However, no confirmed injury to the upper left central incisor (ULCI) was reported.

Immediate treatment

At the emergency facility, the lip was initially sutured. Then, the dentin of URCI, with no pulp communication, was protected by glass ionomer cement, and the patient was referred to the "Integrated Clinic of Dental Traumatology, the Pontific Catholic University of Paraná" (CITDA/PUCPR). In the first treatment appointment, the digital periapical radiograph x-ray exams were performed, showing incomplete root formation of both central incisors and no alveolar fracture (Table 1). The medication prescribed was paracetamol 200mg/ml (10mg/kg/dose every 6 hours for 3 days) in case of pain.

Clinical protocol

After 7 months, vitality tests were performed in both teeth. ULCI had a negative response while URCI showed a positive response. After one year of the accident, ULCI still tested negative for vitality.

Mediate treatment

Fourteen months after the immediate treatment, the ULCI was accessed for the first phase of revascularization procedure. The patient and his/her? legal guardian(s) were informed about the purpose and scope of the study, and were given all information on the treatment as well as the benefits/risks before an informed consent was signed by his/her? legal guardian(s) and the patient. Treatment procedures followed clinical guidelines proposed by the "American Association of Endodontics" [6] and performed by a sole experienced Endodontist.

Table 1. Clinical and CBCT parameters observed at baseline and 36 months

Clinical Assessment	Cbct Assessment
Pain on Percussion	Periapical lesion and area
Pain on Palpation	Root dentine thickness
Spontaneous pain	Root length increase
Sinus tract or Fistula	Apical closure
Swelling	Type of root shape
Pulp sensibility (cold)	

The first appointment consisted of local anesthesia using Prilocaine hydrochloride 3% with felipressin 0.54 micrograms/mL (DFL, Rio de Janeiro, Brazil). The tooth was isolated with rubber dam and a conventional cavity was prepared with high speed diamond round burs (KG Sorensen, Barueri, SP, Brazil). The working length was radiographically determined and set at 2 mm from the apex. The canal was gently flushed with 20 mL of 1.5% sodium hypochlorite (Danafarma Pharmacy, Curitiba, PR, Brazil) for five minutes, followed by irrigation with 20 mL of 17% EDTA (Biodinâmica, Ibiporã, PR, Brazil) for five minutes. The canal was dried with paper points and calcium hydroxide paste (Ultracal XS - Ultradent, South Jordan, UT) was applied as the intracanal medicament 2 mm shorter than the root apex. Teeth were double sealed with Coltosol® (Coltene-Whaledent, Langenau, Germany) and resin-based dental composite restorative material (Z250 Filtek; 3M ESPE, Sumaré, SP, Brazil).

After 30 days, the second appointment was conducted by the same operator with clinical signs and symptoms of a successful treatment; *i.e.* the absence of pain, swelling, sinus and fistula. The patient received local anesthesia with 3% Mepivacaine without vasoconstrictor (DFL, Rio de Janeiro, Brazil) and the tooth was isolated with rubber dam. Irrigation was gently applied using 20 mL of 17% EDTA (Biodinâmica, Ibiporã, PR, Brazil) for 5 minutes to remove the calcium hydroxide paste, and then, the canal was dried with paper points #80. The periapical tissue (2 mm beyond the apical foramen) was lacerated with a pre-curved K file #35 (Dentsply Maillefer, Ballaigues, Switzerland) using a rotation movement in an attempt to induce bleeding into the canal to the extent of CEJ.

The blood clot filled the canal space after ten minutes, and a cervical barrier of 3mm to 4 mm of MTA Repair HP (Angelus, Londrina, Brazil) was applied over the clot using an amalgam carrier. The material was lightly packed with a dry cotton pellet, a periapical radiograph was taken to confirm coronal seal, and the access opening was restored with glass ionomer cement and resin-based dental composite restorative material. A postoperative radiograph was taken at the end of second appointment using a standardised paralleling technique with large 3 cm x 4 cm phosphorus storage plates (PSPs).

Follow-ups

Digital periapical radiographs and CBCT were used for quantitative and qualitative evaluations. Patient was followed at 6-, 12-, 18-, 36-month intervals via digital periapical radiographs (PR) whereas CBCT was obtained only at 6 and 36 months. Time intervals of CBCT aim to avoid unnecessary exposure of the

Figure 1. A) Clinical exams at 12 months; *B*) 18 months and *C*) 4 years and 4 months showing no edema, no sinus tract and color stability

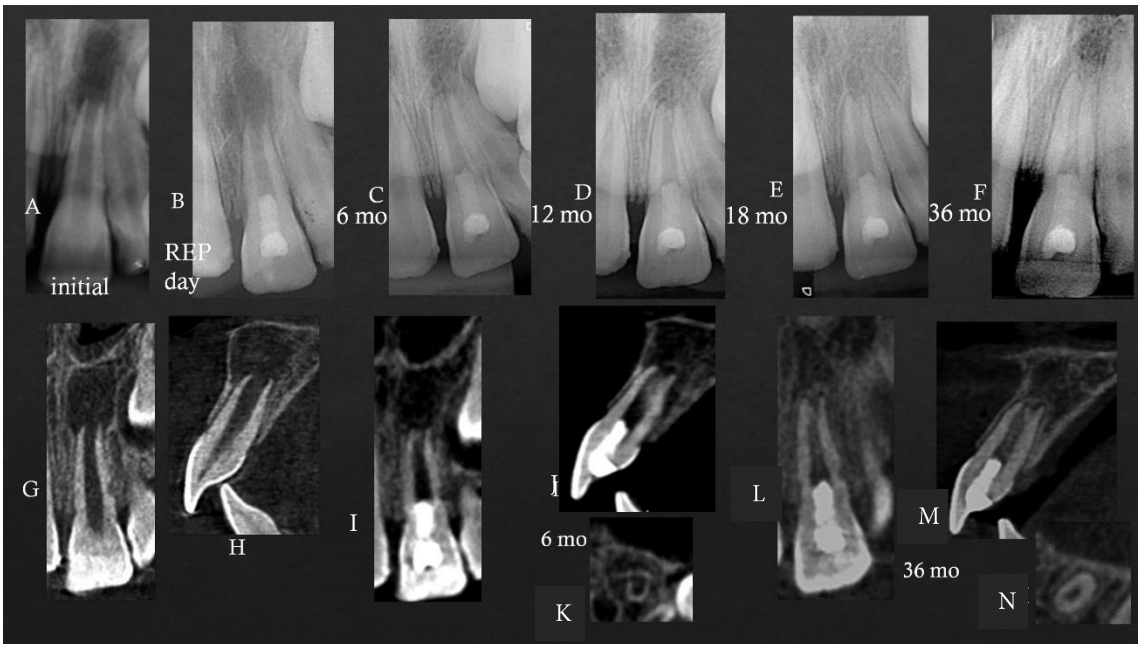

Figure 2. Digital periapical radiographs; A) initial; B) REP day; C) 6 months; D) 12 months; E) 18 months; F) 36 months, G, I, L) CBCT cuts. coronal planes at initial, 6 and 36 months; H, J, M) Sagittal planes at initial, 6 and 36 months; K, N) axial planes at 6 and 36 months. Representing the evolution on periapical bone healing and root development in width and length

patient. The sensibility, *i.e.* cold, test was performed using Endo-Ice (Coltène/Whaledent Inc, Cuyahoga Falls, OH). Clinical photos were taken at 12 and 18 months, and 4 years and 4 months for the evaluation of discolouration (Figure 1). The patient was contacted at every six months but during the Coronavirus pandemie the recalls where suspended and initiated again when the services where reestablished.

Pre-operative and follow-up PR images were transferred to an imaging software (Image J version 1.48: National Institutes of Health, Bethesda, MD, USA) with Turbo Reg plug-in for the alignment of recall and baseline radiography (Biomedical Imaging Group, Swiss Federal Institute of Technology, Lausanne, Switzerland). The calibration process permitted the measurement of quantitative changes based on millimeter scale.

The root length was calculated by measuring a straight line from CEJ to the radiographic apex of the tooth. Moreover, the development of root in width was measured by the subtraction of external root area from the root canal area. The dimensional changes of root length and the root wall thickness between pre-operative and follow-up radiographs were reported in millimeters.

Cone beam computer tomography images were obtained with the Scanora 3D (Soredex) using 50 mm x 50 mm field of view under the exposure condition of 90.0 kV (X-ray tube voltage) and 5.0 mA (X-ray tube electric current) with the exposure time of 17.5 sec. Data sets were exported using DICOM file format with a voxel size of 0.15 mm x 0.1 mm. while the data was viewed using Scanora 3D software (OnDemand). Recorded periapical lesions (PAI) and area, root development in width (area) and length (millimeters) through the three plans (coronal, sagittal and axial), and the root shape observed showed the thickening of canal walls as well as continued root maturation (Figure 2) [4].

Discussion

REP's progress over the past 20 years has been remarkable [2]. A great number of studies in the search of an ideal protocol for root development and new formation of dental pulp tissue are still in progress [7-9]. The assessment of outcomes is a way to control treatment success; especially when there is a different approach to heal periapical lesions focused on disinfection and self-healing rather than the conventional treatment; *i.e.* cleaning, shaping and filling the root canal system with gutta percha and sealer. REP aims to allow nature to complete its course once infection is controlled.

This case report is in agreement with a large portion of literature that shows positive results for endodontic regeneration treatment when compared to conventional therapy for immature teeth; e.g. apexification or apical plug [10-13]. There are very interesting considerations that are carried out by REP; such as enhancement of root strength with thicker and longer walls when compared to the roots resulted from the other two forms of treatment [11]. Moreover, The REP may be applied to the posterior teeth with high degrees of success [14] as well as dens invaginatus [15].

The clinical success of this case report was initially evaluated via the absence of the clinical aspects of pain to percussion, palpation, edema, sinus tract and fistula. The radiographic aspects considered were periapical bone healing and root development in width and length at 6 and 36 months from initial REP; a favorable outcome confirmed by literature [4, 16, 17]. The importance of CBCT to evaluate REP outcome lies on one of the biggest challenges; *i.e.* the level of image accuracy, since patients are young and the structures, e.g. bone architecture and root, are in constant development. Moreover, the three-dimensional view permits the analyses of root formation in different plans as the root apex may appear closed in the coronal plan while it is wide open in the sagittal view.

The first goal of endodontic treatment in general is disinfection. In the presented case report, the root canal system was disinfected using a low concentration of sodium hypochlorite (1.5%) in order to protect the apical stem cells responsible for root formation. Next, 17% EDTA was used to activate the bioactive molecules present in radicular dentin, capable of root growth [18, 19]. In the third step, the use an intracanal medication was applied. In the case reported, calcium hydroxide [20], *(b)* no crown discoloration, and *(c)* lack of antibiotics adverse effects when compared to tri-/bi-antibiotic pastes [21, 22]. Furthermore, the tooth may suffer root fracture due to the dide sffects caused by minocycline in the triple antibiotic paste [23].

After a period of 4 weeks of disinfection procedures, the root was assessed and the medication was removed via extra flushing with 17% EDTA to stimulate the bioactive molecules present in the root dentin. The periapical region was lacerated to fill the root canal space with blood rich in apical stem cells, encountering bioactive molecules. The process of clot formation developed a scaffold; over which the new tissue was formed. Although the literature suggests other types of scaffolds, e.g. platelet-rich plasma and platelet-rich fibrin, the blood clot scaffold was chosen owing to its simpler use in children [24]. The blood clot scaffold formed up to the cervical region; over which a layer of BEC was applied aiming three goals: *(i)* stimulation of hard tissue formation [25-27], *(ii)* prevention of reinfection for due to antimicrobial features, and *(iii)* strong marginal seal [28]. In the current case, all the aforementioned goals were achieved; which were in line with the literature [28-30]. MTA Repair HP was the BEC chosen, since its radiopacifier (*i.e.* calcium tungstate) is different from MTA's bismuth oxide which is capable of altering tooth color.

The responses to REP in root shape followed class I definition as reported by Chen *et al* [4]; in which increased thickening of canal walls and continued root maturation can be observed. This is the outcome expected in all successful cases of REP although it is not predictable [31]. Some studies point that the size of apical foramen at the moment of injury, the type of trauma and the protocol of disinfection [31] are variables to be considered when the root forms differently from the original its shape; *e.g.* in cases of no significant continuation of root development with the root apex becoming blunt and closed, continued root development with the apical foramen remaining open, severe calcification (obliteration) of the canal space, and a hard tissue barrier formed in the canal between the coronal barrier and the root apex [4].

Conclusion

The REP used in the case reported herein is in accordance to the AAE REP protocol. The use of the bioceramic MTA Repair HP over the scaffold of blood clot resulted in periapical bone healing and root development in width and length.

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Conflict of Interest: 'None declared'.

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