Root fracture healing outcome after a revascularization procedure: an 8-year follow-up case report

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Pulp revascularization is the traditional protocol for treating immature necrotic teeth; however, it is not the usual management practice for traumatized teeth with horizontal root fracture. This is a case report of an 11-year-old patient subjected to trauma that occurred four years prior to treatment. The trauma led to horizontal root fracture in tooth #11, and the immature tooth #21 became necrotic with periapical radiolucency. Both teeth were treated with revascularization procedures. Each tooth was disinfected with triple antibiotic paste and a coronal seal using mineral trioxide aggregate. During the eight-year follow-up using periapical radiograph and cone beam computed tomography, tooth #21 showed periapical repair with apical closure. The fractured rooted tooth #11 was functional and asymptomatic, with evidence of bone growth inside the fracture line. From this case outcome, revascularization can be a successful treatment modality for traumatized teeth that have either root fracture or necrotic open apex.

Keywords: *Immature root, Open apex tooth, Revascularization, Root fracture, Cone beam computed tomography (CBCT)*

INTRODUCTION

Dental trauma to permanent teeth most commonly occurs in young people aged seven to nineteen years of age and often affects the anterior teeth[1]. In this age group, the maxillary anterior teeth possess an immature open apex with thin root dentin. The trauma may cause tooth devitalization with the subsequent root fracture or the cessation of root development. Pulp necrosis is the most common sequela of trauma, with an incidence range of 1–16%[2], and it can lead to complications in the pulp prognosis.

Root fracture is defined as a dental injury that affects the dentin, cementum, pulp and periodontal tissues[3]. Among the different types of dental trauma, the incidence of horizontal root fracture of permanent anterior teeth is 1.2–7%[4]. Due to the thin canal walls of immature teeth, teeth often cannot withstand the trauma, leading to root fracture. When such a fracture occurs, the reaction of the pulp depends on whether the coronal fragment has been displaced. Horizontal root fracture may occur with coronal displacement, while the apical segment remains *in situ*. In such situations, the coronal tooth fragment will have a reduced blood supply, which in turn could lead to pulp necrosis and may influence the fracture healing pattern[5]. Based on radiographic and histological observations, there are four types of healing: calcified tissue healing; healing with only connective tissue interposition; interposition of bone and soft tissues; or no healing, with granulation tissue between the fracture fragments[6–9].

The management of nonvital young traumatized teeth, with or without root fracture, remains a treatment challenge in en-

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dodontics. The traditional orthograde treatment of nonvital open apex is either apexification or revascularization [10], whereas for horizontal root fracture, long-term calcium hydroxide intracanal dressing has been recommended to provide a hard tissue barrier at the apical end of the coronal part of the fracture. However, this procedure takes a very long time and increases the risk of tooth weakening [11].

Regenerative endodontic procedures (REPs) are defined as biologically-based procedures that replace damaged or missing structures (including pulp–dentin complexes and tooth structures) with variable tissues of the same origin in an effort to restore normal physiologic function [12]. The use of revascularization procedures in regenerative endodontics constitutes a new approach for the management of traumatized nonvital immature teeth, even with root fracture [13,14]. The use of regeneration procedures in traumatized teeth with horizontal root fracture has been minimal and has been described in only a few case reports [14,15].

The use of mineral trioxide aggregate (MTA) is recommended as a root repair material [16]. It can achieve a high rate of success [17] because of its superior sealing properties [18], biocompatibility [19], alkaline pH, and bactericidal effects [20]. The use of MTA in intra-alveolar root fractures has been described in just a few case reports but has shown satisfactory healing outcomes [21].

The purpose of the present case report is to describe the outcomes after an 8-year follow-up of traumatized maxillary central incisors that suffered horizontal root fracture and complicated crown fracture after treatment with MTA and regeneration.

CASE REPORT

An 11-year-old Saudi boy was referred from the pediatric clinic of King Abdulaziz University, Faculty of Dentistry for evaluation and endodontic treatment of both maxillary central incisors. The patient had a history of trauma four years prior that had affected these two teeth. Teeth #11 and #21 suffered from complicated crown fracture (Fig. 1A). Tooth #21 showed a carious lesion and exposed pulp. Purulent exudate from the pulp cavity of tooth #21 was visible. Upon clinical examination, teeth #11 and #21 did not respond to sensitivity testing via either cold or electric pulp testing (EPT), although their response to percussion and palpation were within normal limits and similar to those of the adjacent lateral incisors. No mobility of either tooth was observed. Radiographic examination revealed that tooth #21 had an immature apex, whereas tooth #11 had a mature root and evidence of horizontal root fracture (Fig. 1B). Upon the radiographic evaluation, the diameter of the apical foramen of tooth #21 was measured as 2.4 mm, using R4 software (Caresteam Dental LLC, Atlanta, GA, USA). The diagnosis for both maxillary central incisors was necrotic pulp with asymptomatic apical periodontitis for #21 and necrotic pulp with normal apical tissue for #11. Since both affected teeth were immobilized, no splint was needed [22,23]. Revascularization protocol was initiated in tooth #21, as follows [10,24]. Under rubber dam application without local anesthesia administration, as the teeth were necrotic, the caries was removed, and irrigation with normal saline was performed to evacuate the pus until the pulp chamber was clean. The root canal was then dried with a sterile paper point and filled with triple antibiotic paste in a 1:1:1 ratio of metronidazole (Samil Pharm, Seoul, Korea), ciprofloxacin (Sinil Pharm, Seoul, Korea), and minocycline (Aurobindo Pharma Inc., East Windsor, NJ, USA). Finally, the coronal access was temporary sealed using intermediate restorative material (IRM) (Dentsply, Sirona, Charlotte, NC, USA). In the same appointment, tooth #11 was endodontically initiated. During tooth length determination, the file failed to bypass the apical segment through the coronal segment, and granulation tissue was felt under the file. Root canal irrigation was conducted, followed by application of triple antibiotic paste [25]. The coronal access was also temporarily sealed with IRM. After one week, under rubber dam isolation, the temporary filling was removed from both maxillary central incisors, and the triple antibiotic paste was washed out with 20 mL of 2.5% sodium hypochlorite. In tooth #21, bleeding was created by over-instrumentation using a suitably sized K-file size (Dentsply Maillefer, Ballaigues, Switzerland). Controlled bleeding was performed at the level just below the cemento-enamel junction (CEJ). Premixed white mineral trioxide aggregate (MTA, Dentsply Tulsa Dental, Johnson City, TN, USA) was applied at the orifice of tooth #21, followed by the application of a wet cotton pellet and temporary IRM coronal restoration. In tooth #11, bleeding was created through laceration of granulation tissue at the fracture line using a K-type file. After approximately 15 minutes, bleeding occurred, and 3 mm of MTA was applied at the coronal segment of tooth #11, followed by cotton pellet application and an IRM coronal seal. One week later, the cotton pellets were removed and the coronal access for both teeth was finally sealed with light-cured composite resin (Filtek™ Supreme, 3M, St. Paul, MN, USA), without splinting (Fig. 1C–D). The patient was instructed to return after two weeks and after three, six and twelve months for postoperative follow-up [1].

The patient was asymptomatic at all follow-up evaluations. Both treated teeth were functional and responded within normal limits to percussion and palpation when compared with the adjacent lateral incisors. There was no tooth mobility. At the six-month follow-up, radiographic evaluation showed disappearance of the periapical radiolucency related to tooth #21. Evidence of bone trabeculation also appeared at approximately the root apex and extended slightly inside the canal lumen. No radiographic changes were observed around the fracture line of tooth #11 (Fig. 2A). At the 12-month follow-up, the fracture line of tooth #11 appeared to be filled with calcified tissues, without any evidence of radiolucency in the surrounding area (Fig. 2B). Bone trabeculation was apparent around the apex of tooth #21 at the 16-month follow-up (Fig. 2C).

At follow-up times of 20, 24, and 30 months, the treated teeth were functional and asymptomatic. The tooth mobility and the periodontal pockets around both treated teeth were within normal limits. Radiograph examinations revealed progressive decreases in the root canal lumen of the apical root and increases in root length, with complete healing of periapical tissue and intact lamina dura of tooth #21. Tooth #11

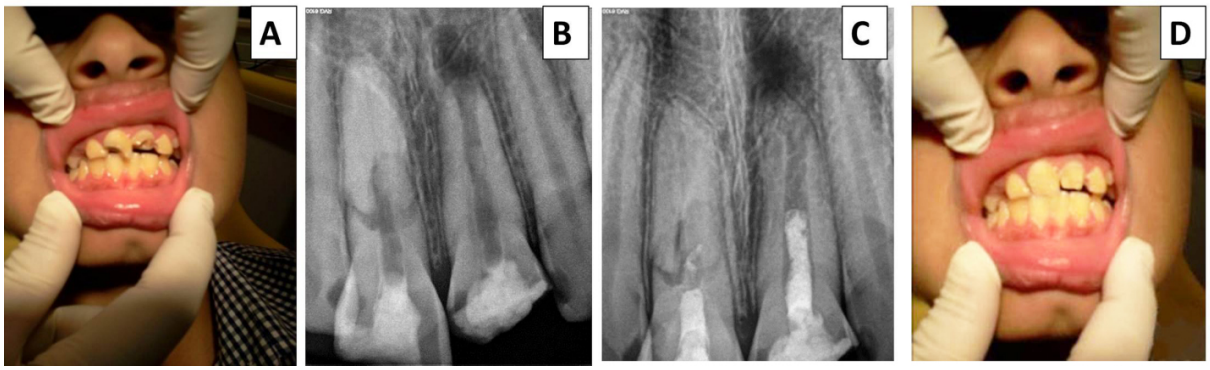

Figure 1: Clinical and radiographic images of traumatized maxillary central incisors, with complicated coronal fracture. (A) Complicated coronal fracture, clinical picture, (B) #11 Preoperative radiograph, #11 horizontal middle root fracture, #21 open apex, (C) Immediate postoperative radiograph with MTA, (D) Postoperative clinical picture.

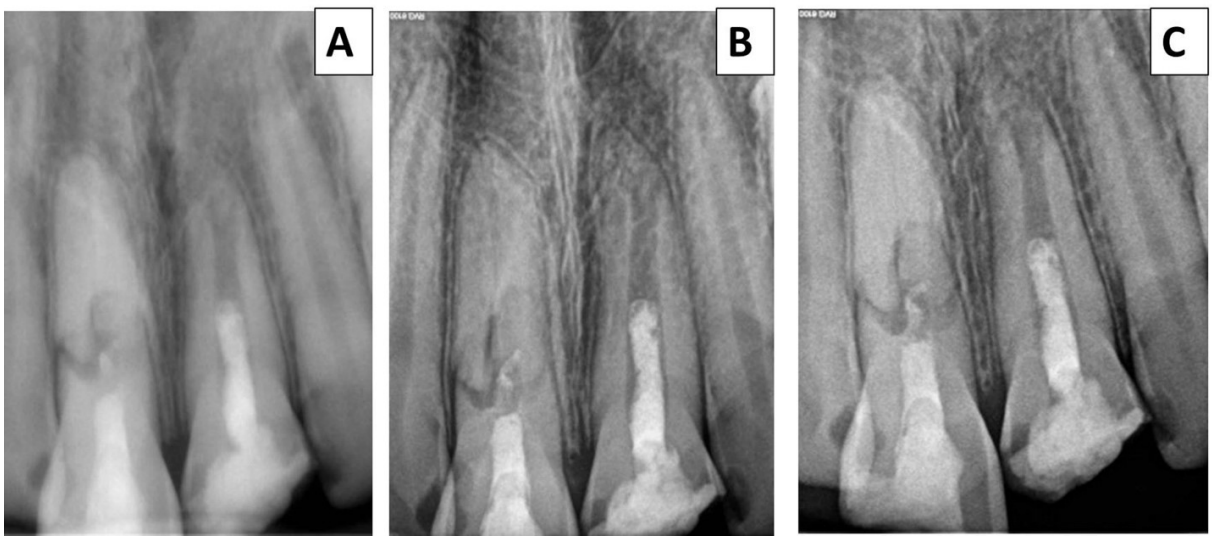

Figure 2: Periapical-radiographs taken at the 6-, 12- and 16-month follow-up times. (A) 6 months follow up. (B) 12 months follow up. (C) 16 months follow up. showing progressive resolution of periapical radiolucency around the apex of tooth #21 and no evidence of bone changes around the fracture line of tooth #11.

showed normal bone around the fracture line and root apex (Fig. 3).

Five years later, the patient failed to present for follow-up. Eight years and three months after completing the treatment, the patient came in with an esthetic concern and wanted to replace the anterior restoration. Both of the treated teeth were still functional and asymptomatic. Because there was sufficient tooth structure, the anterior teeth were restored with a post-free microhybrid composite resin layering technique using Filtek™ Z350 XT (3M ESPE, St. Paul, MN, USA)[26] (Fig. 4A). A periapical radiograph revealed a significant reduction of the pulp lumen of tooth #21, with no periapical changes around the root apex. The tooth appeared to be increased in length as a result of the continuation of root development. There was evidence of fracture line healing of tooth #11 (Fig. 4B). With patient consent, cone beam computed tomography (CBCT, i-CAT®, Imaging Sciences International, Hatfield, PA, USA) was performed at voxel size 0.02 and field of view (FOV) 8 × 8 to evaluate the outcome progress of both treated teeth. The coronal view revealed calcified tissue healing of the fracture line related to tooth #11 and canal obliteration of tooth #21 (Fig. 4C). The axial view revealed complete canal obliteration of tooth #11 below the level of the fracture line (Fig. 4D). The sagittal view showed palato-buccal oblique root fracture related to tooth #11 with horizontal displacement (Fig. 4E) and apical closure with narrowing of the canal lumen for tooth #21 (Fig. 4F).

DISCUSSION

Revascularization is a classic protocol for treating conditions of immature teeth that are associated with apical periodontitis[13]. The survival rate of teeth treated with revascu-

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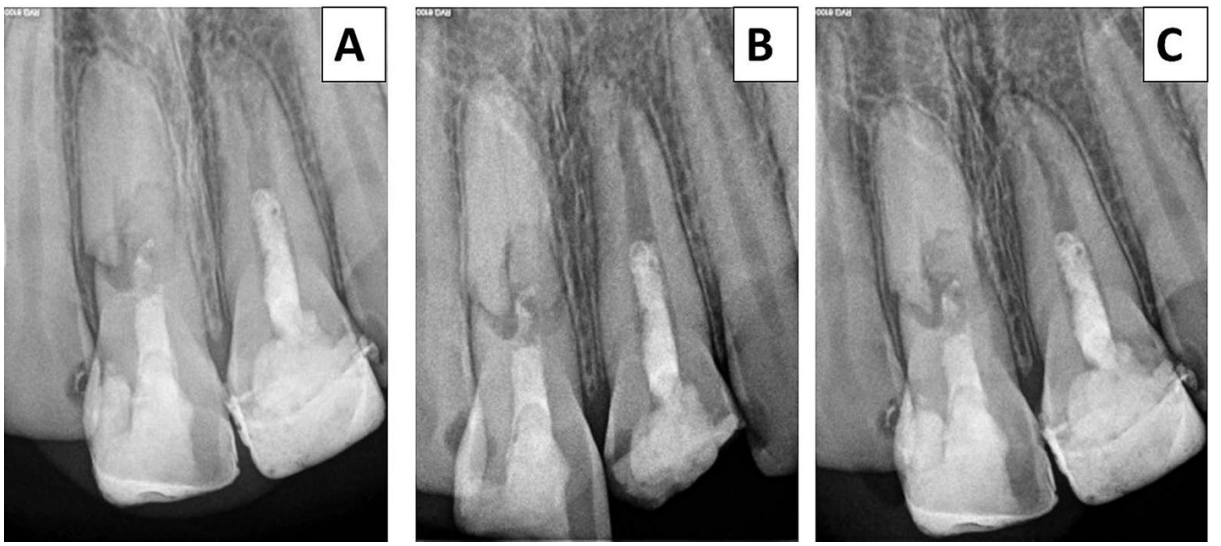

Figure 3: 20th, 24th, and 30th month follow-up times. (A) 20th months follow up. (B) 24th months follow up. (C) 30th months follow up: showing progressive decreases in the root canal of apical root and increases in root length, with complete healing of the periapical tissue of tooth #21. Tooth #11 showed normal bone trabeculation.

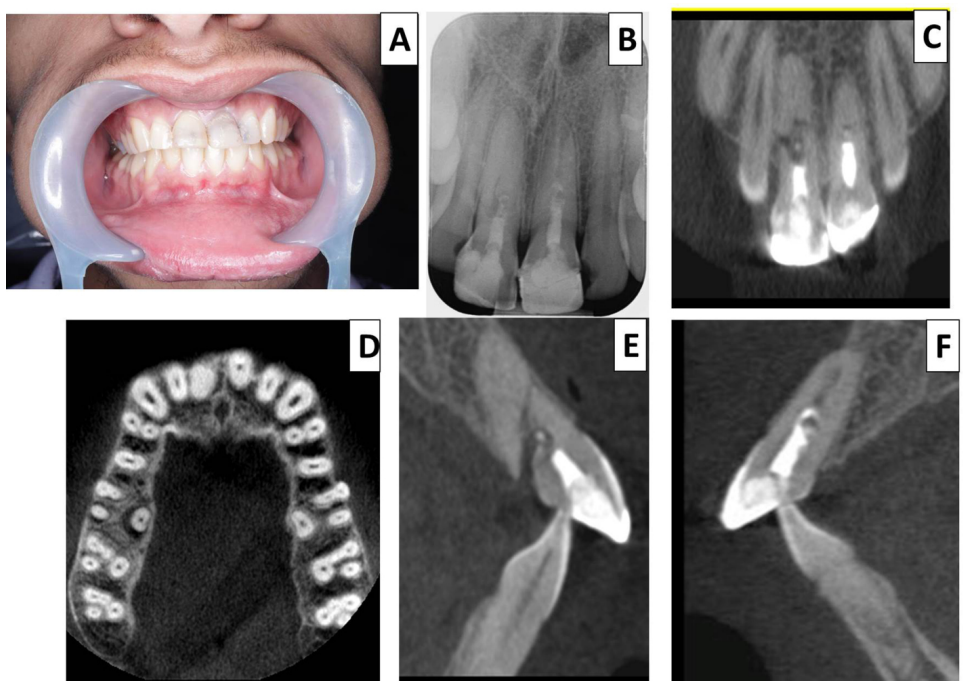

Figure 4: Patient's condition after eight years. (A) Clinical photo. (B) Radiographic healing #11 and #21. (C) CBCT coronal view. (D) CBCT axial view. (E) Sagittal view #11. (F) Sagittal view #21.

larization has been based on asymptomatic functional maintenance and resolution of periapical pathosis, increases in the root length and apical dentin thickness, and apical closure[27]. Chen *et al.*[23] 2012 described five types of responses of immature necrotic teeth to revascularization procedures. The current status of the treated case of tooth #21 corresponds to the first response type form that article[23], with increased thickness of the apical dentin and complete root development at follow-up in the two to three-year time frame. At the 8-year follow-up, severe calcification and a significant reduction of pulp lumen were detected by periapical radiograph and CBCT[28]. For pulp regeneration, higher levels of root canal disinfection are mandatory to promote the healing process. Triple antibiotic paste was used in the current case[29]. The root canal disinfec-

tion with triple antibiotic paste provided a favorable environment for the stem cells present in the induced blood clot to promote the continuation of root development, with root lengthening, dentin wall thickening, and apical closure [13,28]. These findings are supported by a previous study in which triple antibiotic disinfection resulted in the greatest increase of dentin wall thickness [30]. However, Ruparel *et al.* [31] 2012 suggested that a saturated concentration of antibiotic had a detrimental effect on stem cells. The only complaint of the patient was esthetic concern. Due to broken incisors with a sufficient tooth structure and an MTA- orifice seal, a post-free reconstruction technique using microhybrid composite resin via incremental layers was recommended [26].

Regarding tooth #11 with a horizontal tooth fracture, the treatment was performed four years following the trauma. Because of tooth immobilization, there was no needs for splinting, and its prognosis was therefore not affected. This finding was inconsistent with those in previous studies [22,23].

CBCT is a 3-D diagnostic tool used to evaluate traumatized teeth [32]. Unfortunately, the fracture displacement related to tooth #11 was only detected at the 8-year follow-up using CBCT. This coronal displacement may have occurred after treatment during continuous eruption of the coronal segment while the apical segment remained in its original position [4]. Despite this fracture displacement, the treated tooth maintained its immobilization due to the location of the fracture line within the middle of the root. This situation may be the reason for fracture healing in the treated tooth after the revascularization procedures [6]. In agreement with a previous study [9], the radiographic examination of tooth #11 revealed obliteration of the apical canal lumen and the deposition of hard (bone-like) tissue extending from the adjacent alveolar bone to inside the fracture line. It appeared that the pulp's reaction to fracture injuries may have been influenced by the severity of the pulp injury and by the dislocation n of fractured segments.

Revascularization of the fractured tooth at the level of the root displacement along with the coronal seal with MTA showed a successful healing outcome for the fracture. The same finding was made previously by Roig *et al.* [14] 2011. With the displacement of a fractured tooth, the coronal displacement becomes necrotic, while the apical region remains vital. Disinfection of the root canal with triple antibiotic paste leads to the successful outcome of revascularization, enabling the induction of stem cells at the fractured coronal segment. In addition, the placement of MTA provides an alkaline pH environment that is favorable for the healing process [14]. CBCT diagnosis of the treated tooth #11 showed bone growth from the adjacent alveolar process into the fractured segments. During progressive eruption processes of the coronal segment, the growth of the surrounding alveolar bone took place to occlude the space between the fractured segments [4]. The healing of the horizontal root fracture seemed to involve hard tissue deposition in and around the fracture site and calcification in the pulp spaces, both in the apical and the coronal segments. It has been suggested that fracture repair may depend on an intact periodontal ligament [33]. This finding is supported by a previous study that showed calcified tissue healing of horizontal root fracture 19 months after the regeneration protocol [15].

The Prognosis for teeth with horizontal root fracture depends on the modality of repair of the fractured parts [34]. While the outcome is usually favorable (60%–80% of cases), some complications such as root resorption, pulp necrosis and pulp canal obliteration can occur [35]. Splinting is one of several treatment factors that may affect the outcome of root fracture healing. In this case, there was no splinting, as the patient presented with non-mobile teeth and the outcome appears to be favorable [22,23]. Some studies found that root healing is better without immobilization because root consolidation takes place more efficiently under functional stress [23]. In contrast, other studies favored splinting for a long time to provide a matrix for root healing [36].

CONCLUSION

According to the conditions observed in this case report, the delayed treatment of traumatized teeth had no negative impact on the prognosis. Through eight years of follow-up, the revascularization procedures were proven to be successful in treating the traumatized teeth, which included a necrotic immature open apex tooth and a tooth with a horizontally fractured root. The procedure promoted the apical closure of the necrotic open apex tooth and healing of the horizontal root fracture, with calcified tissue extending from the alveolar process.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Research Ethics Committee of the faculty of dentistry at king Abdulaziz University. REC FD10-10-2011. Written informed consent was obtained from the patient.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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