The Outcome of Endodontic Regeneration in a Delayed Replanted Immature Permanent Incisor: A TurboReg Analysis of a Case

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Objectives: *The aim of this case report is to address a delayed replantation and successful regenerative endodontic procedure of an avulsed immature permanent incisor which was confirmed by TurboReg analysis.* ***Study design:*** *In this case, regenerative endodontic procedure was performed on an avulsed tooth with a delayed replantation in a 7 year old boy. In the emergency visit after the avulsion accident in February 2017, the tooth was replanted and one week later regenerative endodontic procedure began. After 17 months follow up, in July 2018, root wall thickness and length increase was confirmed by TurboReg analysis.* ***Conclusion.*** *The outcome of this treatment was evaluated by TurboReg analysis which was a remarkable increase in root length and dentinal wall thickness, despite of the delayed replantation.*

Clinical Significance. *This case report helps to add to the literature for treatment plan in avulsion traumatic injuries.*

Key Words: *Avulsion, delayed replantation, immature teeth, regenerative endodontic procedure, TurboReg.*

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INTRODUCTION

Avulsion is a drastic dental injury that occurs predominantly in children aged 7-14 years old when facial growth is not completed [1]. The ideal treatment is immediate replantation to preserve the tooth and surrounding bone until alveolar development is complete [2]. However, immediate replantation is not always possible due to time spent finding the avulsed tooth, finding a medical facility providing emergency care services, insufficient parental education on tooth replantation, and the presence of concomitant severe injuries, such as head trauma. The treatment choice in these clinical situations depends on the root development stage, storage media, and extra-oral time [1]. In immature teeth with extra-oral time of more than 60 minutes, the periodontal ligament (PDL) cells' survival is not expected and, consequently, the replantation prognosis is poor. The purpose of replantation in these situations is for esthetic, functional, and psychological reasons, despite inevitability of tooth loss due to resorption [2].

Generally, complete root development takes place three years after the tooth eruption in the oral cavity. Loss of pulp vitality of immature permanent teeth arrests root development, leaving the root short, weak, and susceptible to fracture, complicating conventional endodontic treatment goals [1]. Apical plug technique using mineral trioxide aggregate (MTA) or the traditional apexification method with long-term use of $Ca(OH)_2$ may resolve symptoms such as pain and apical periodontitis; however, the root canal walls remain fragile and susceptible to fracture [3].

To overcome shortcomings of conventional treatment methods, the regenerative endodontic procedure (REP) was introduced [4].

REP stimulates hard tissue formation and can result in complete root development, root lengthening, dentinal wall thickening, and increased chances of tooth survival and function [3]. The goals of this treatment include eliminating the patient's symptoms, enhancing the healing of surrounding tissues, increasing root length and thickness, and, if possible, achieving a positive vitality test response [5].

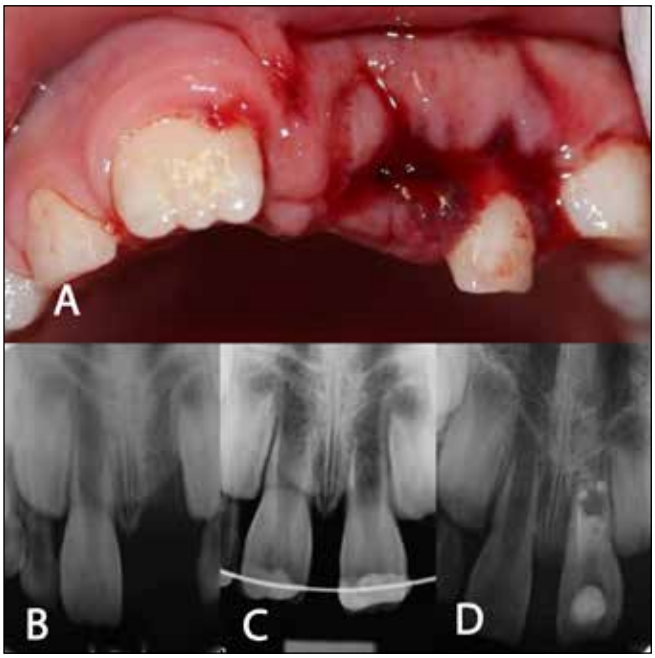
Evaluating REP outcome is mostly based on non-standardized radiographs. To overcome this inconsistency, the TurboReg (Biomedical Imaging Group, Lausanne, Switzerland) plug-in application was introduced. This quantitative method can determine changes in root length and dentinal wall thickness using the mathematical minimization of any dimensional changes that were incorporated into the pre- and post-operative radiographs due to angulation differences to the X-ray central beam [6]. The aim of this case report is to address a rare case of continued root formation of an avulsed immature permanent incisor, with delayed replantation, treated with REP which was confirmed by TurboReg analysis.

Case Report

A 7-year-old boy presented to the Dental Trauma Clinic, Academic Center for Education, Culture, and Research, Mashhad, Iran, in February 2017.

The patient was in a car accident 90 minutes prior to his arrival and his chief complaint was avulsion of tooth no: 21. The tooth had been wrapped in a dry paper tissue. The patient's medical history was non-contributory. No significant findings were noted in extra-oral examination. Intra-oral examination showed soft tissue lacerations, the empty socket of tooth no: 21, and severe lateral luxation of tooth no: 62 (Figure 1A). During emergency visit , a periapical radiograph was taken to check for concomitant injury in the root, alveolar bone, and the adjacent teeth using an intra-oral X-ray unit (Planmeca, Helsinki, Finland) operating at 70 kV and 7 mA and viewed in the day light. A blunderbuss short root with thin, fragile canal walls of tooth no: 11 was evident in the periapical radiograph (Figure 1B). Furthermore, sensibility tests, including Cold Test using a -45 °C refrigerant spray (Frisco Spray, Frechen, Germany) and Electric Pulp Test (EPT) using a digital EPT (Parkell, New York, USA) were performed. At the emergency visit, the responses to these tests for teeth no: 11 and 62 were inconclusive and also for teeth no: 52, 53, and 63 the sensibility tests were within normal response

Figure 1: (A) Avulsion of tooth no:21 and lateral luxation of tooth no:62, (B) initial periapical radiograph of the empty socket of tooth no:21, (C) periapical radiograph of the replanted tooth confirming the correct position of the replanted tooth no:21, (D) periapical radiograph after MTA placement over the blood clot



Although the prognosis seemed to be poor according to *the guidelines for the management of traumatic dental injuries* [2] , despite the delay, it was decided to replant the tooth. The informed consent was signed by the parents. The avulsed tooth surface was covered with dirt, and its pulp hanging out of the apical foramen. Prior to treatment, the root surface was cleaned, and the pulp was completely removed retrogradely from the wide ending of the root canal using a hemostat plier. Local anesthesia was achieved for tooth no: 21 with buccal infiltration of 1.8mL of 2% lidocaine with 1:100,000 epinephrine (DarouPakhsh; Tehran, Iran). Following irrigation of the socket and root surface with sterile normal saline, the tooth no: 21 was replanted by gentle finger pressure and stabilized with a semi-rigid splint made of 0.6mm orthodontic wire-composite from tooth no: 52 to no: 63. The occlusion was checked, and a periapical radiograph confirmed proper positioning of the replanted tooth (Figure 1C). The patient was prescribed 250mg penicillin V (Farabi, Isfahan, Iran) [2] and 325mg acetaminophen (each drug, 4 times a day for 4 days) (TehranDarou. Tehran, Iran), was advised to avoid participation in contact sports, follow a soft diet for two weeks, use a soft toothbrush, and use 0.12% chlorhexidine mouth rinse twice a day for one week. Since the avulsed tooth had been in contact with soil, the patient was referred to a physician for a tetanus booster.

At one-week follow-up, the sensibility tests were repeated as described above and tooth no: 11 demonstrated positive response only to the EPT. Although REP is not generally recommended for avulsed teeth with more than 60 minutes of dry time, as no alternative treatment option was available, after discussion with the parents, the REP was nonetheless performed in order to prevent inflammatory resorption and stimulation of hard tissue formation. Local anesthesia for tooth no: 21 was achieved with buccal infiltration of 1.8mL of 2% lidocaine with 1:100,000 epinephrine. An access cavity was then performed under rubber dam isolation and the canal was prepared using copious, gentle irrigation with 10mL of 1.5% NaOCl (CHLORA, Cerkamed, Stalowa, Poland) and minimal mechanical instrumentation with K-Files (Dentsply Maillefer, Ballaigues, Switzerland) up to #80. The canal was rinsed with 40mL of saline solution, dried with paper points (AriaDent, Tehran, Iran), filled with $Ca(OH)_2$ paste (Sina, Tehran, Iran) using a large carrier (Sepahan Dental, Isfahan, Iran), and sealed with glass-ionomer cement (Ketac Molar, 3M/ESPE Dental Products, MN, USA).

The splint removal session was scheduled for three weeks after the emergency visit; however, the patient missed this session and returned 10 weeks later, upon which the splint was removed, and sensibility tests were repeated for tooth no: 11 which responded positively to both EPT and Cold Test. It's worth reminding that the root canal preparation had been initiated a week after emergency visit. For tooth no: 21, local anesthesia was achieved using buccal

infiltration of 1.8mL of 3% mepivacaine (Inibsa Laboratories, Spain) with no vasoconstrictor. Under rubber dam isolation, temporary filling was removed; the canal was rinsed with 17% EDTA (Cerkamed, Stalowa, Poland), followed by 40mL of normal saline. Bleeding was evoked using a #30 K-File that was introduced 2mm beyond apex. The coronal portion of the canal was dried using a sterile cotton pellet. Finally, MTA (Angelus, Londrina, Brazil) was placed over the blood clot, 4mm below the cemento-enamel junction to minimize further tooth discoloration (Figure 1D). The access cavity was sealed with glass-ionomer and the permanent restoration session was scheduled in one month.

Despite our efforts, the patient did not return to clinic until one year after the incident, when he presented with a localized abscess in buccal of teeth no: 21 and no: 22 in July 2018 (Figure 2A). Tooth no: 21had not been restored and its temporary filling was lost. It was sensitive to palpation and percussion. In periapical radiograph, only some floating portions of MTA was present with no seal and no adaptation to dentinal walls. Nevertheless, continued root formation for the replanted tooth was astonishingly evident in a periapical radiograph (Figure 2B). The apical foramen size had decreased explicitly, and the root length and dentinal wall thickness had increased significantly. PDL space with normal width was evident and there was no evidence of apical pathosis. The diagnosis of the acute apical abscess was made due to localized swelling and the absence of a periodontal pocket. Our clinical approach was designed to repeat the root canal debridement and MTA placement to re-establish the coronal seal and prevent intra-canal re-infection. After buccal infiltration of 1.8mL of 2% lidocaine with 1:100,000 epinephrine under rubber dam isolation, the coronal cavity was debrided, MTA was removed using a fine Mueller bur (Meisinger, Neuss, Germany), and the canal was irrigated with 1.5% NaOCl. Following the final rinse with 40mL of saline solution and drying by paper points, $Ca(OH)_2$ paste was placed using a large carrier (Medesy, Maniago, Italy). The access cavity was sealed with glass-ionomer cement. The patient was prescribed 325mg acetaminophen, 4 times a day for 4 days.

Eight weeks later, after buccal infiltration of 1.8 mL of 3% mepivacaine, the temporary restoration was removed under rubber dam isolation, the canal was rinsed with 40mL of saline solution, and the coronal portion of the canal was dried using sterile cotton pellet. MTA with 4mm thickness was placed with a large carrier in the coronal third of the canal and the access cavity was sealed with glass-ionomer (Figure 2C). One week later, after removing the temporary restoration and examining the complete setting of MTA, the final restoration was performed with composite resin materials (Gradia®, GC Corp., Japan).

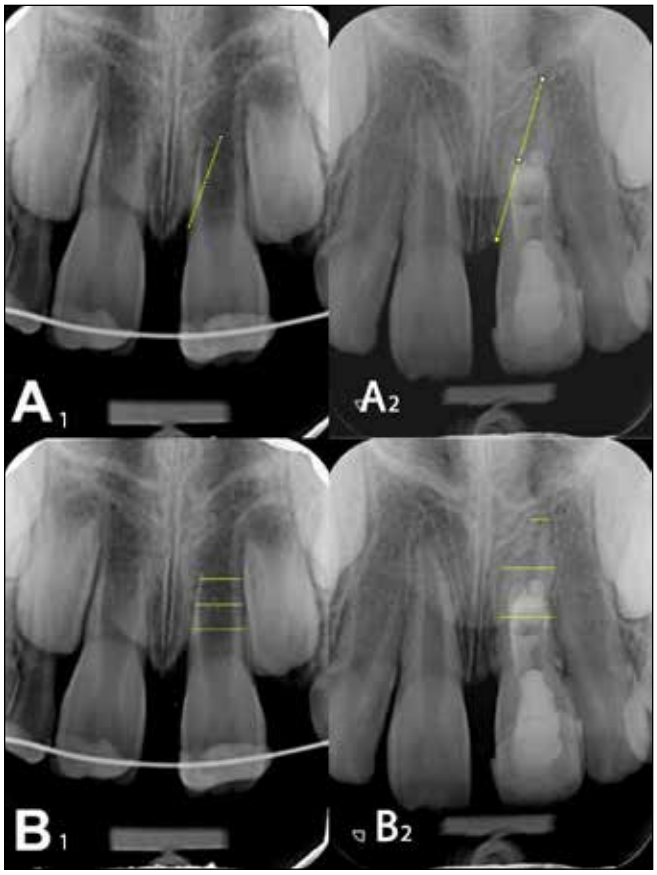
After three months, the patient was clinically asymptomatic. In the new periapical radiograph, intact lamina dura, normal PDL width, and no apical pathosis were noted (Figure 3). The radiographic changes in the thickness and length of the root were calculated using the TurboReg plug-in tool with ImageJ (Version 1.47; National Institutes of Health, Bethesda, MD). TurboReg analysis was set on automatic mode to correct images. Immediate post-operative and final follow-up radiographs (17 months after the first visit) were aligned and normalized to each other using the landmark positions of the source image to adjust the target image with TurboReg [6]. The root length and dentinal wall thickness were calculated using the straight-line tool. The root length was measured as a straight line from the cemento-enamel junction to the radiographic apex. The dentinal wall thickness and pulp width for both the immediate post-operative and final follow-up images were measured at the apical, middle, and cervical thirds of each root. The average root width for these images was calculated as follows: [(cervical root width-cervical pulp width) + (middle root width-middle pulp width) + (apical root width-apical pulp width)]/3 (Figure 4). TurboReg analysis revealed 84% increase in root length and 108% in dentinal wall thickness.

It should be emphasized that the PRICE guidelines have been followed for this case report.

Figure 2: (A) Photograph of the buccal swelling around tooth no: 21. (B) periapical radiograph revealed increase of root length and dentinal wall thickness, (C) periapical radiograph after repeating MTA placement

Figure 3: 17-month recall of tooth no: 21. (A) Clinical photograph, (B) Periapical radiograph

Figure 4: Linear measurements in mathematically aligned radiographic pairs, using TurboReg analysis. (A1) Root length before treatment, (A2) root length after final follow up, (B1) dentinal wall thickness before treatment, (B2) dentinal wall thickness after follow up.



DISCUSSION

For avulsed teeth, especially in patients aged 7-14 years old, treatment protocols should be directed towards management of the pulp and PDL [7]. Alveolar development at these ages is incomplete, hence it is important to save the tooth and its bone until development is completed [8] or at least progressed [9]. In fact, in a still-growing patient, failure to replant the tooth can lead to a catastrophic bone loss, which will have an adverse impact on the insertion of an implant in the future.

Following replantation, a coagulum forms between the root surface and alveolar bone. After one week, the epithelial attachment is re-established at the cemento-enamel junction and the gingival collagen fibers become spliced. This limits bacterial invasion and permits healing to continue [10]. PDL damage and pulpal infection are common consequences of avulsion and can cause root resorption and interrupt normal root development [9,11]. In closed apex teeth, the pulp becomes necrotic due to the severed vascular elements. The same reaction is expected to occur in immature teeth, although revascularization is possible if the tooth is replanted expeditiously [12]. In avulsed immature teeth, the treatment protocol depends on the degree of root development and the condition of the PDL cells [9]. However, according to the guidelines of International Association for Dental Traumatology [2] and the American Association of Endodontists [13], the long-term prognosis of delayed replantation in immature teeth is generally poor.

This case report is one of few that utilized TurboReg analysis to evaluate the outcome of REP. TurboReg analysis is a method for the quantitative determination of changes in root length and dentinal wall thickness. This radiographic analysis technique transforms non-standardized radiographs and estimates the probable success of REP [6,14]. Despite the coronal leakage, an interesting finding of this case report was substantial increase in root length (84%) and dentinal wall thickness (108%), the main criteria for the success of REP. Other studies and case reports (Table 1) have shown much less significant increases in these parameters [15-20]. Since this quantitative method was utilized in our study, the results are comparable with other studies which employed the same TurboReg analysis, therefore the possibility of any misunderstanding for the readers will be low. There are few case reports that performed REP for avulsed teeth; in all these cases, the teeth were replanted within an hour and kept in favorable storage media such as water-filled containers [21-25]. To our knowledge, this is the first case report that performed REP in a delayed replanted incisor with an extra-alveolar time of 90 minutes and yielded favorable outcome of continued root formation.

Normal root morphogenesis is regulated by Hertwig's epithelial root sheath (HERS) in cross-talk with the mesenchymal stem cells of the apical papilla [26] and it is under the influence of genetics, and can be altered by environmental factors. Any damage to HERS may cause cessation of root development. In this case, possible mechanisms for the continued root formation with increasing root length and dentinal wall thickness might include survival of HERS after traumatic injury and the contribution of vital stem cells of the apical papilla to tissue generation [26]. Since there are so many confounding factors, the outcome cannot be anticipated in each case. Parameters that can alter the development of the root length, size, shape are the type of the traumatic injury, type of the tooth, the degree of periodontal ligament injury, immediate or delayed treatment, storage media, age of the patient, and the presence of multipotent cells, which is not the same in different ages and different people.

A negative outcome in delayed replanted teeth, especially in immature cases, is ankylosis, characterized by osteoclastic activity and resorption of the root followed by deposition of bone into the defect. Clinically, an ankylosed tooth is immobile, and percussion test elicits a clear metallic sound. Radiographically, the root structure is replaced by bone and PDL is invisible [12]. In the present case, no ankylosis signs was observed after 17 months. Although ankylosis is an inevitable outcome of the delayed replantation and growth stage of the patient, replantation nonetheless remains

Table 1. Summary of previous studies on percentage increase in root length and dentinal wall thickness using TurboReg analysis

Authors/Year	Root length increase	Dentinal wall thickness increase
Cehreli et al. 2011 [15]	2-18	14-38
Jeeruphan, et al. 2012 [16]	15	28
Cehreli et al. 2012 [17]	18	40-70
Kahler et al. 2014 [18]	Up to 25	Up to 72
Nagy et al. 2014 [19]	12	13
Ulusoy et al. 2019 [20]	Up to 7	Up to 19

a suitable treatment. Since immature teeth have a lower risk for ankyloses [27], replantation should always be considered as it preserves alveolar bone, esthetics, and increases the quality of life until possible tooth loss.

CONCLUSION

This case report represents a successful outcome of REP for a delayed replanted immature tooth with TurboReg analysis and can offer a treatment modality for such cases.

Conflict of Interest

There was no conflict of interest in this study.

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