CASE REPORT

Restorative challenges and successful outcome of apexification and revascularization in adjacent traumatized immature teeth

ABSTRACT

Aim: *To describe the successful outcome of adjacent traumatized immature teeth treated with revascularization and apexification and discuss some important aspects of regenerative endodontics and restorative alternatives.*

Summary: *An eight-year-old male was referred for endodontic treatment of traumatized teeth #11 and #21. Although revascularization was originally planned for both fractured teeth with pulp exposure, the lack of bleeding into the root canal of tooth #21 changed the treatment plan towards apexification with an apical MTA plug. Seven months later, a glass-fiber post was placed into the root canal of tooth #21 and reinforced with a polyethylene fiber strip. Then, both teeth were restored with multi-layered composite restorations that provided a natural appearance. The three-year follow-up confirmed the absence of painful symptoms and composite infiltration, while CBCT images revealed no root fractures or periradicular lesions, and maintenance of root thicknesses and lengths. Comprehensive restorative treatment can be performed after revascularization or apexification through the collaboration of endodontic and restorative dentistry specialists, which is important to ensure successful outcomes in terms of root development, maintenance of pulp vitality, and pleasant esthetic.*

Key learning points:

- *Dental trauma is a common condition, particularly for children and adolescents, that can lead to several consequences (from tooth discoloration to avulsion).*
- *A flexible plan is crucial to treat traumatized immature teeth.*
- *Revascularization can lead to maintaining root development and avoiding periapical pathologies.*

João Daniel Mendonça de Moura[1*]
Ana Raquel Lopes dos Santos Miranda[1]
Náyra Rêgo Da Silva[1]
Marcelo Figueiredo Lobato[2]
Paloma Rayse Zagalo de Almeida[1]
Antonio Guilherme Maneschy Faria[3]
Carlos Eduardo Fontana[4]
Patrícia de Almeida Rodrigues[1]

[1]University Center of Pará, CESUPA, Belém, Pará, Brazil.
[2]Implantar Dental School, Santarém, Pará, Brazil, Brazil.
[3]Federal University of Pará, Belém, State of Pará, Brazil.
[4]Pontifical Catholic University, Campinas, São Paulo, Brazil.

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Corresponding Author
João Daniel Mendonça de Moura | Faculty of Dentistry, University Center of Pará, Tv. 9 de Janeiro 927, Fátima, Belém PA | Brazil
Phone: +55 91 988 247 321 E-mail: joaodanielmoura@gmail.com

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Introduction

Accidents and occupational incidents commonly traumatize maxillary anterior teeth of all age individuals (1-3). Accurate pulp and periapical diagnosis based on clinical characteristics and radiographic findings is mandatory to correctly choose between conservative or invasive treatments (4, 5), particularly for immature teeth with an open apex and pulp-related issues (6, 7). Traditional apexification with calcium hydroxide requires multiple treatment sessions, patient compliance, and long-term follow-up; however, the use of mineral trioxide aggregate (MTA) provides an apical barrier for immediate obturation (8).

Regenerative endodontic procedures have gained popularity as an alternative to treating immature teeth with necrotic pulp tissue and immature apices (9-11). However, the description of these procedures as revascularization, regeneration, and revitalization is still questioned (12, 13) since histological studies have shown that the pulp-dentin complex is not truly regenerated (14-16). The revascularization procedure requires bleeding induction into the root canal, which provides a scaffold for stem cells to attach, proliferate, and differentiate into vital components of the pulp-dentin complex (6). Successful cases of revascularized teeth have shown increased root canal wall thickness, apex narrowing, and root lengthening (17-19). However, the intracanal cervical barrier impairs the placement of glass-fiber posts to retain coronal restoration (20).

Composites are versatile restorative materials with biomechanical characteristics that support masticatory loads and optical properties that resemble natural tooth structures (21). Composite restorations can be directly or semi-directly performed by the clinician in a single appointment or manufactured by a lab technician and luted in the second appointment (22). Nevertheless, composite restorations should be incrementally built with small oblique and horizontal layers (21).

The following clinical case describes the successful outcome of apexification and revascularization procedures in a patient with traumatized and necrotic maxillary central incisors and discusses some important aspects of regenerative endodontics and restorative alternatives.

Case Report

This case report was written following the PRICE 2020 guidelines (23). An eight-year-old boy presented to the Endodontics Specialization Course clinic at the University Center of Pará (CESUPA) 20 days after traumatizing both maxillary central incisors. The patient reported mild gum discomfort without intense tooth pain or systemic alterations. Both teeth #11 and #21 presented crown fractures with pulp exposure, negative response to thermal, percussion, and apical palpation, and absence of tooth mobility. Radiographic images revealed incomplete root formation of both #11 and #21 (Figure 1A).

After being properly informed, the patient's legal guardian agreed on the revascularization of both teeth and explicitly approved the anonymous publication of this case report. After infiltrative anesthesia with 2% mepivacaine hydrochloride with 1:100,000 epinephrine (DFL, Rio de Janeiro, RJ, Brazil) and rubber dam isolation, the root canals of both teeth were explored using thin endodontic files (K-file, Dentsply Maillefer, Ballaigues, Switzerland) and irrigated with 2.5% sodium hypochlorite solution (Asfer Industria Química, São Paulo, SP, Brazil). Pulp necrosis was confirmed by the bleeding absence.

A periapical radiograph and an electronic apex locator (Romiapex A-15, Romidan, São Paulo, SP, Brazil) were used to determine the working lengths of both teeth. The root canals were not shaped to preserve dentin tissue; thus, disinfection was obtained through irrigation and intracanal medication (24). An ultrasonic tip (Irrisonic E1, Helse Ultrasonic, São Paulo, SP, Brazil) coupled to an ultrasonic device (Profi Neo, Dabi Atlante, São Paulo, SP, Brazil) was carefully inserted at 2 mm from the working length to passively agitate a 2.5% sodium hypochlorite solution, a 17% EDTA

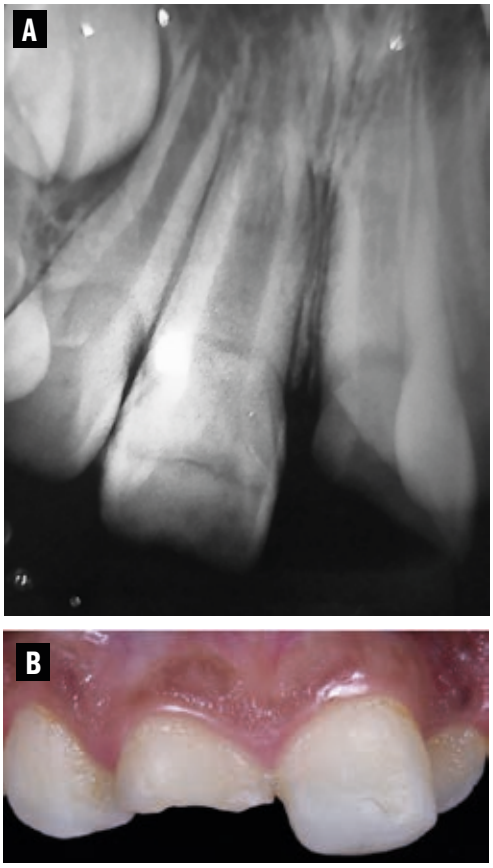

Figure 1
A) Initial periapical radiograph of teeth #11 and #21; **B)** Clinical aspect after endodontic treatments.

solution, and once again a 2.5% sodium hypochlorite solution (three 20-sec times each solution). Then, a calcium hydroxide paste (Calen, SSWhite Duflex, Rio de Janeiro, Brazil) was placed into both root canals, and the coronal accesses were sealed with glass ionomer cement (Maxxion R, FGM, Joinville, Santa Catarina, Brazil).

The intracanal medication was removed after 15 days by agitating a 2.5% sodium hypochlorite solution against the root canal walls with the aid of thin endodontic files. After repeating the abovementioned ultrasonic irrigation protocol, the root canals were irrigated with 20 mL of 17% EDTA to optimize smear layer removal and dried with sterile absorbent paper points. A #30 sharp-edged file (Hedstrom, Dentsply Maillefer, Ballaigues, Switzerland) was manually used to induce bleeding into the root canal of tooth #11; thus, a collagen sponge (Hemospon, Maquira, Paraná, Brazil) was placed into the root canal middle third to enhance blood clotting. Since bleeding into the root canal of tooth #21 was not achieved despite multiple attempts, the treatment plan was modified to apexification. Then, MTA plugs (MTA Repair HP, Angelus, Paraná, Brazil) were placed at the cemento-enamel junction (CEJ) level of tooth #11 and at the apical root third of tooth #21. Finally, both root canals were cleaned and the root accesses were temporarily sealed with glass ionomer cement and layered with composite to minimize the risk of contamination (Figure 1B).

The patient attended to the first follow-up appointment only after seven months due to COVID-19 pandemic restrictions and reported no pain or discomfort since then. Cone beam computed tomography (CBCT) images revealed complete apex closure for both teeth without pathology signs (Figure 2).

After rubber dam isolation, the temporary root sealing of tooth #21 was removed. A glass-fiber post was cleaned with 70% alcohol and received two layers of silane (Prosil, FGM). After 2 min and 30 sec wait after each silane application, an adhesive resin layer (Ambar Universal APS, FGM) was applied for 30 sec on each surface of the post (buccal, palatal, and tip). The tip of the post was layered with a small increment of A2E-shaded composite (Forma, Ultradent, Indaiatuba, SP, Brazil) and passively inserted into the root canal of tooth #21, which was previously lubricated with water-soluble gel, and light-cured for 5 sec. The customized post was removed from the root canal and additionally light-cured for 60 sec, while the root canal was irrigated with saline solution and dried with absorbent paper points. The customized post was cleaned with 70% alcohol and received a layer of adhesive resin (Ambar Universal APS, FGM). After filling the root canal with an A2-shaded dual-curable composite cement (Allcem Core, FGM) dispensed from an auto-mixing syringe, the customized post was placed, the composite cement excess was removed, and the post was light-cured for 60 sec. A periapical radiograph was taken to confirm the proper placement of the customized post into the root canal. The post was sectioned to an appropriate height and the root access was filled with composite (Figure 3A).

After infiltrative anesthesia with 3% prilo-

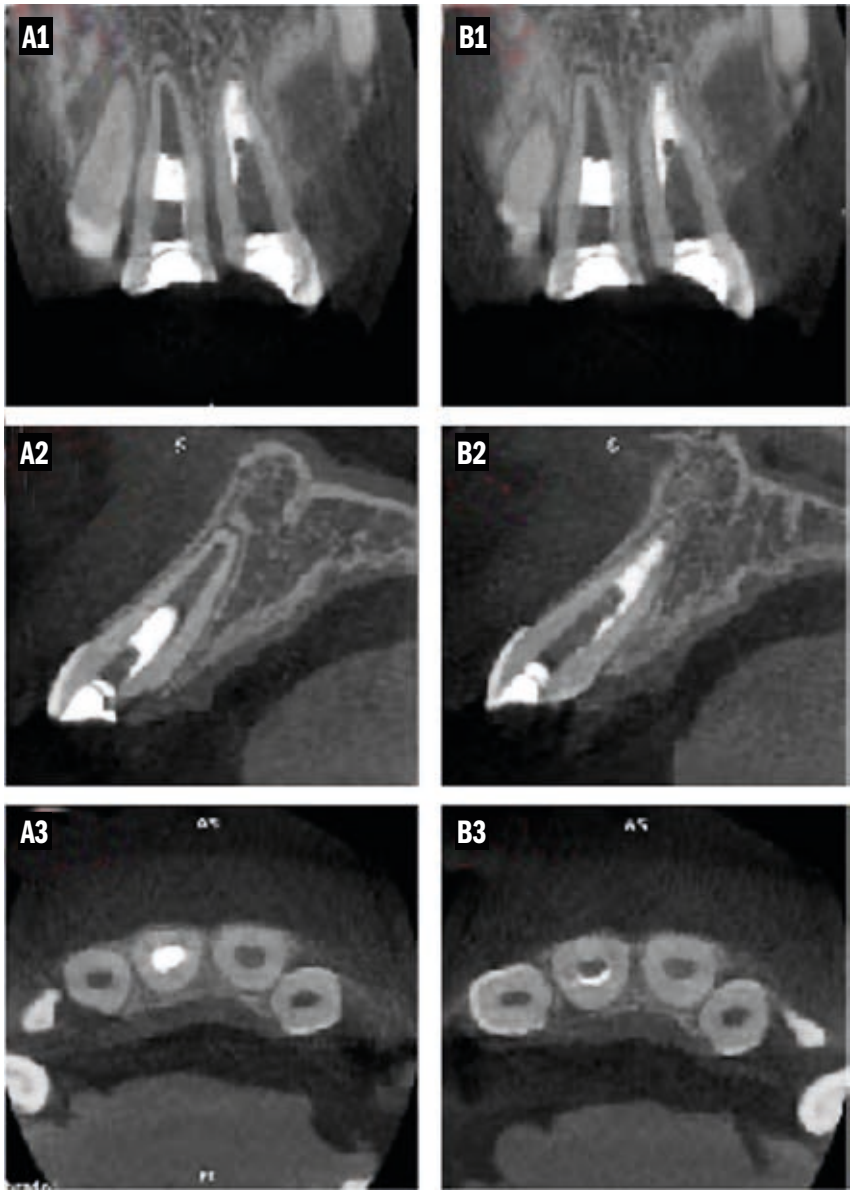

Figure 2
CBCT images of teeth #11 and #21 seven months after endodontic treatments. **A1, A2**, and **A3** Coronal, sagittal, and axial view of tooth #11. **B1, B2,** and **B3** Coronal, sagittal, and axial view of tooth #21.

caine hydrochloride (DFL, Rio de Janeiro, RJ, Brazil), the root canal sealing of tooth #11 was removed using diamond burs (Invicta, American Burrs, Palhoça, SC, Brazil) mounted on a high-speed handpiece and the MTA plug was completely exposed. The surrounding enamel of both teeth was etched with 35% phosphoric acid (Potenza Attacco 35%, PHS Group, Joinville, SC, Brazil) for 30 sec, rinsed, and air-dried. Then, a two-step adhesive system (Scotchbond Universal, 3M ESPE, Saint Paul, MN, USA) was applied and light-cured with an LED unit with an output of 1,300 mV/cm² (Valo, Ultradent). A flowable A2-shaded composite (Filtek Supreme Flowable Restorative, 3M ESPE) was used to seal the root canals. A translucent composite layer (Filtek Z350 XT BT, 3M ESPE) was placed over transparent polyester matrix strips (TDV, TDV Dental, Pomerode, SC, Brazil) to restore the palatal surfaces (Figure 3B). Next, a 3-mm-thick polyethylene fiber strip (Ribbond, OralTech, Ibiporã, PR, Brazil) was placed on the tooth #21 to better stress distribution throughout the subsequent composite layers, which were individually placed with spatulas (Condensa, LM Dental, Quinelato, São Paulo, SP, Brazil), and light-cured for 20 sec. An OPA2-shaded 0.5-mm-thick composite layer (Palfique LX5, Tokuyama, Ibaraki, Japan) was placed over the polyethylene fiber to mimic dentin morphology and reinforce the internal structure (Figure 3C). Then, a translucent composite layer (Filtek Z350 XT BT, 3M ESPE) was placed on the incisal area to reproduce the natural translucency of young teeth (Figure 3C). An EB1-shaded composite layer (Estelite ÔMEGA, Tokuyama) was used to cover the entire buccal surface (Figure 3D).

After removing rubber dam isolation, occlusal contacts under maximum intercuspation and jaw protrusion/excursions were verified with carbon paper (Accufilm, Parkell, New York, NY, USA), and composite excess was removed using fine and extra fine grit diamond burs (#3168 and #3118, American Burrs). Diamond flame- (One Gloss Set, Shofu, Kyoto, Japan) and spiral-shaped tips (Twist Gloss, American Burrs), and 0.5-µm grit paste (Diamond Polish, Ultradent) were used for surface texturing and polishing. The immediate aspect exhibited appropriate color, shape, and light scattering (Figures 3E and 3F).

A three-year follow-up confirmed the absence of painful symptoms and composite infiltration. CBCT images revealed no root fractures or periradicular lesions, and maintenance of root thicknesses and lengths (Figure 4).

Discussion

This case report addresses a relevant dilemma regarding endodontic treatment of

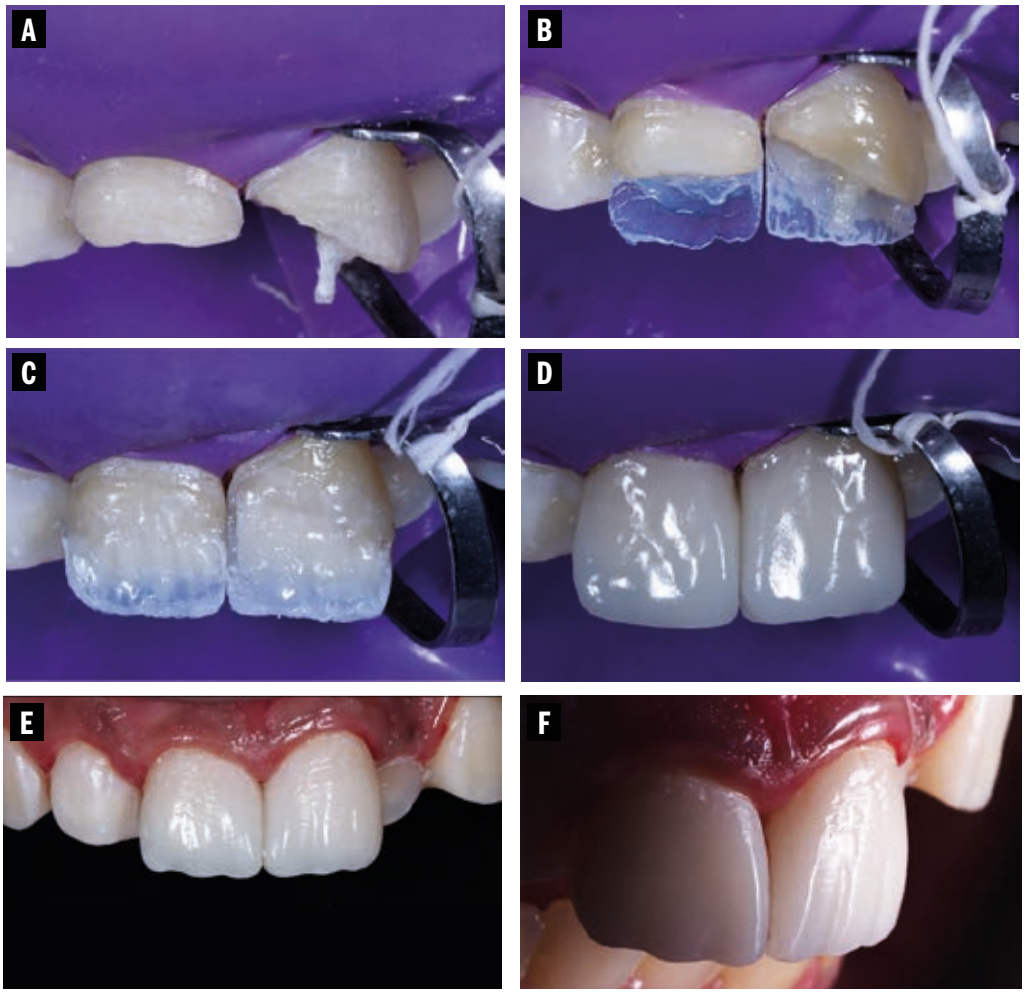

Figure 3
A) Rubber dam isolation with aid of metallic clamp; **B)** Palatal surfaces of both teeth restored with translucent composite and polyethylene fiber placed on tooth #21; **C)** Placement of dentin and incisal composite layers; **D)** Placement of enamel composite layer; **E** and **F)** Clinical aspect after occlusal adjustment, finishing, and polishing.

traumatized teeth, in which a choice between apexification and revascularization has to be made. To the best of the author's knowledge, this is an original case that reported the successful outcomes of both treatments conducted in the same patient and brings valuable insights for clinicians. There are several aspects to be considered in cases of dental trauma and the treatment plan can often change. In this particular case, the lack of bleeding into the root canal of tooth #21 impaired the revascularization to be performed and changed the treatment plan toward apexification. This highlights the importance of clinicians to master diverse treatment approaches for trauma cases. Although the revascularization and apexification protocols used in this study are well-supported in the literature, the treatment choice must be carefully based on individual aspects of patients and clinical indications. In addition, this case addressed the important challenge of restoring a revascularized tooth that often does not allow the placement of intraradicular posts. This case report showed practical solutions and guidance to restore traumatized teeth through the combination of glass-fiber post and esthetic composite restorations.

Accurate diagnosis is essential to establish an adequate treatment plan for immature permanent teeth (25). In this case, conservative pulp treatments were not feasible due to the necrotic pulp status of both teeth; thus, revascularization and apexification were performed to treat asymptomatic apical periodontitis. Moreover, the diagnosis of the young patient was performed by an experienced clinician who used several diagnostic tools and minimized potential complications that can arise from inadequate dental trauma management. Compli-

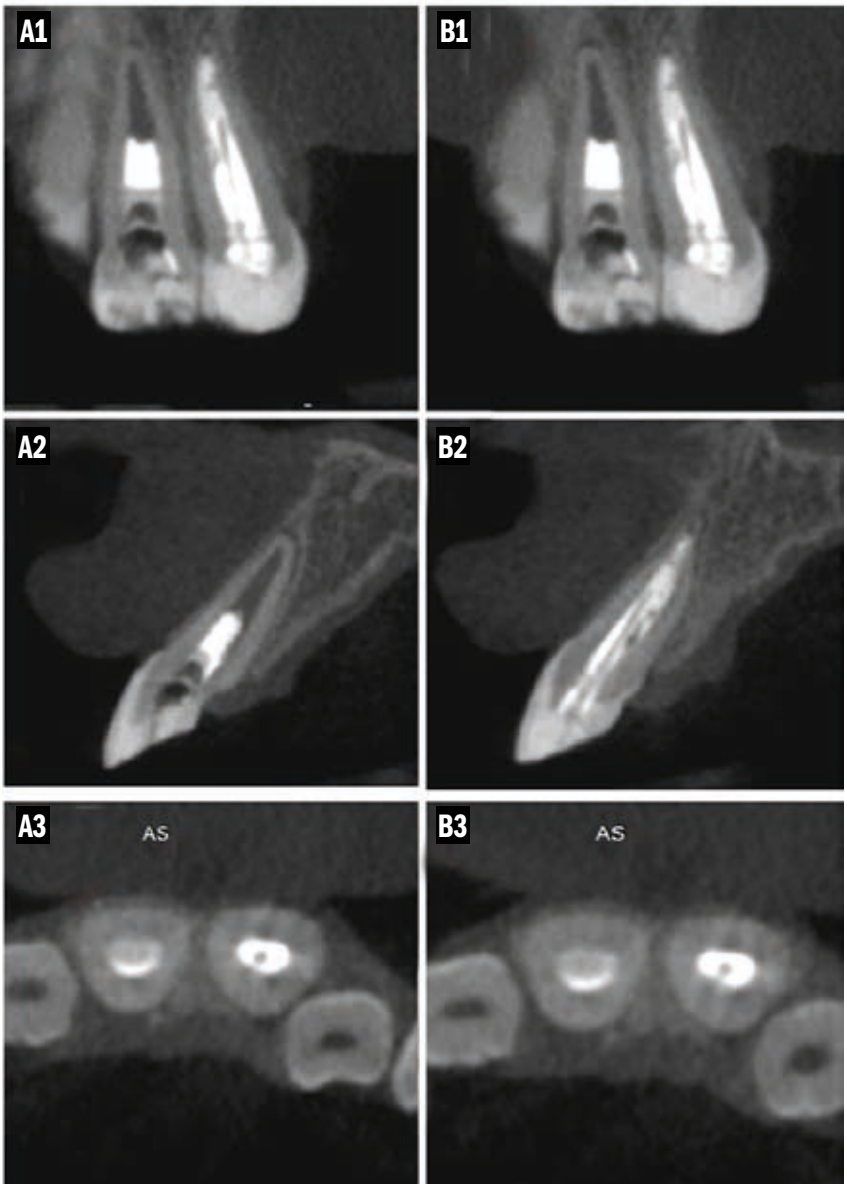

Figure 4
Three-year CBCT follow-up. **A1, A2**, and **A3** Coronal, sagittal, and axial view of tooth #11. **B1, B2,** and **B3** Coronal, sagittal, and axial view of tooth #21.

cations such as root resorption, surface resorption, apical radiolucency, gingival recession, inflammatory resorption, arrested root development, disturbed root development, and pulp necrosis can occur irrespective of the root formation stage (26).

A tooth crown fracture in patients with incomplete apices often requires a multidisciplinary treatment with endodontists and restorative dentistry specialists in order to achieve optimal rehabilitation (18). The revascularization has a similar success rate when compared to apexification with calcium hydroxide and promotes both root length and thickness formation. Moreover, revascularization is less time-consuming and does not require multiple changes of intracanal medication that may weaken tooth structures (20, 25). Nevertheless, the apexification known as the "apical MTA plug" can be completed in a single session and a follow-up appointment after material setting for root canal filling. Although excellent success rates have been reported, the apical MTA plug does not stimulate root development (27, 28). The absence of bleeding despite multiple attempts suggested insufficient blood supply in the root canal of tooth #21 for revascularization; thus, the MTA plug was placed to seal the root apex and prevent bacteria contamination.

A prospective randomized controlled study on 118 patients reported a 100% success rate for both of apexification and revascularization. The revascularization technique demonstrated remarkable root length and thickness improvements of 81.16% and 82.60%, while the apexification technique exhibited only 26.47% and 0%, respectively (29); however, the study only reported a one-year follow-up that seems relatively short for establishing long-term success. In addition, a systematic review with meta-analysis also indicated similar success rates for both techniques performed in immature permanent teeth (20). Although revascularization and apexification are highly effective treatments, the first leads to root length and thickness improvements. Furthermore, the success of these procedures relies on the knowledge of the clinician to deal with incomplete apices. Factors such as inadequate root thickness or length often indicate the need for revascularization and may limit the use of intraradicular retainers (6). Thus, alternative restorative techniques and/or materials must be considered to overcome the limitations of the cervical barrier presence and provide adequate retention (30). An effective coronal sealing plays a key role in revascularization and apexification success since it prevents microleakage of oral microbes and reduces the risk of reinfection (31). The lack of adequate coronal sealing is an important reason for failure; thus, the restorations of revascularized teeth should be often followed up (32).

Regarding the significance of materials in these treatments and the importance of proper coronal sealing, another extremely relevant factor is biomaterials. The success of regenerative endodontic treatments is largely attributed to the properties of these biomaterials. Recent studies emphasize the role of biocompatible and bioactive endodontic sealers, highlighting their cytotoxicity, cell viability, and influence on tissue healing and regeneration. For instance, calcium silicate-based sealers demonstrate superior biocompatibility and bioactivity, enhancing treatment outcomes by promoting cellular responses conducive to tissue repair and growth (33, 34, 35).
Esthetics should also be considered when restoring traumatized teeth with incomplete apices in alignment with evidence-based and patient-specific treatments. Restoring the natural appearance of the maxillary anterior teeth is important for patient satisfaction and self-esteem. Therefore, restorative materials with optimal optical properties and techniques that promote seamlessly integrated them into the remaining tooth structure should be ideally selected. However, esthetic considerations must not overlap with long-term endodontic prognosis. The clinician must carefully balance the immediate benefits of esthetic restorations and the long-term uncertain outcome of regenerative treatments. This emphasizes the need for a reasonable approach that accommodates the further endodontic implications and the esthetic aspiration of the patient.

Conclusion

Predictable rehabilitation protocols are essential in cases of traumatized teeth with incomplete apices. Comprehensive restorative treatment can be performed after revascularization or apexification through the collaboration of endodontists and restorative dentistry specialists, which is important to ensure successful outcomes in terms of root development, maintenance of pulp vitality, and pleasant esthetic. Further clinical trials are needed to improve and validate these treatment protocols for traumatized teeth with incomplete apices.

Clinical Relevance

The study delineates a strategic approach to endodontic treatment of immature teeth, emphasizing rehabilitation aspects. This research aids clinicians in determining the optimal treatment plan for managing teeth with incomplete apex formation, focusing on the potential for natural tissue regeneration and avoiding more invasive procedures. Such insights are pivotal for enhancing clinical outcomes and fostering tooth preservation in the context of dental rehabilitation.

Conflict of Interest

None.

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