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CASE REPORT

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Use of CBCT cinematic rendering to evaluate the healing of an oblique root fracture with conservative management. A case report and literature review

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Abstract

Background: Dental trauma can cause root fractures involving the pulp and periodontal tissues. It is important to manage these injuries appropriately, as conservatively as possible, to promote healing of the affected hard and soft tissues while maintaing functionality and esthetics. **Case**: This report describes a case of conservative treatment of a palatally displaced oblique root fracture of an immature maxillary central incisor in a 7-year-old boy, using cinematic Cone Beam Computed Tomography (CBCT) rendering to monitor and provide accurate information about the healing process of the fracture line. The clinical examination revealed some degree of mobility and palatal displacement of the coronal fragment of the left maxillary incisor. Radiographic examination using X-ray films revealed a root fracture in the left maxillary central incisor and an incompletely formed root. The tooth showed a slightly positive response to the cold test. After tooth reduction, repositioning, and splinting of the tooth with orthodontic wire and composite for 6 weeks, the tooth was followed up for 24 months for vitality tests and periapical radiographs to monitor root development and/or any pathological root resorption. Finally, 37 months after the trauma, a CBCT was taken and the healing process of the root fracture and tooth maturation by cinematic CBCT rendering. **Conclusions**: This report underscores the importance of accurate diagnosis, decision-making, and conservative clinical management in the healing process following root fractures. Integration of new technologies, such as cinematic CBCT rendering, enhances the diagnostic accuracy and treatment planning of root fractures.

Keywords

Cinematic rendering; Cone-beam computed tomography; Healing; Root fracture; Traumatic dental injury

1. Introduction

Traumatic dental injuries (TDIs) result from accidental or frontal impacts, most frequently affecting the anterior teeth. These injuries can affect the pulp, periodontal ligament, root, and bone [1–4]. In addition, tooth fractures can negatively impact a child's self-esteem and social behavior [5].

One TDI that poses a challenge for endodontic diagnosis is root fractures. These root lesions affect dentin, cementum, and periodontal ligament, and may also involve fracture of the alveolar bone cortex. The root fracture or fracture line can exhibit different patterns, including variations in orientation and location to the root third (with a poorer prognosis for cervical fractures than for those in the apical third). Dental trauma can also cause bone damage. The more cortical bone is affected, the greater the damage to the supporting tissues [6].

Radiographic examinations are routinely used to diagnose root fractures. Anterior occlusal and periapical radiographs have been the most commonly used imaging modalities for diagnosing this type of TDI, but they have many limitations. For the radicular fracture image to be visible on the periapical radiograph, the fracture direction must coincide with the angle of the incident X-ray beam, which often does not occur. Additionally, bone overlaps may project lines onto images of tooth roots on periapical radiographs and simulate the presence of a root fracture, resulting in false positive findings [6]. Cone-beam computed tomography (CBCT) scans have significantly greater sensitivity in diagnosing root fractures and root resorption than periapical radiography [6–8].

The primary clinical decision-making goal in TDI cases is to preserve the tooth, even in cases with a discouraging prognosis. Thus, understanding their etiology, healing responses, diagnosis, management, and prognosis is essential [9]. Despite advances in imaging technologies, such as new CBCT software, the dental literature lacks clinical information on new visualization strategies for volumetric reconstructions,

including CBCT cinematic rendering. Therefore, this report describes a case of root fracture with conservative management of a maxillary central incisor and incomplete root development in a 7-year-old boy, in which CBCT cinematic rendering provided precise information regarding the healing process of root fracture.

2. Case report

A 7-year-old male patient from western Mexico was brought by his parents to the Endodontic Postgraduate Clinic of the University of Guadalajara, México, on 13 August 2019. The Ethics, Research, and Biosafety Committees approved the present case, with the number CI-01125.

The parents reported that four days prior, the child had suffered trauma while playing with his skateboard, falling and hitting the concrete floor. The patient sustained wounds on his nose and lips, resulting in profuse bleeding. He was promptly taken to the Red Cross emergency room, where he underwent evaluation and monitoring for six hours to rule out neurological damage. The soft tissue wounds were cleaned and disinfected, and the patient was prescribed Tylenol 100 mg to be taken every 8 hours. Since the day of the trauma, the patient had reported pain in the region of the maxillary incisors and difficulty biting food with them, resorting to lateral biting. The patient's parents did not report any prior pathological history, allergies, or surgical interventions in the child's medical history, although they mentioned that he exhibited physical hyperactivity.

During the clinical examination, an apparent hematoma and color change were observed in the gingiva surrounding tooth #9, with spontaneous bleeding at the gingival sulcus. The tooth appeared extruded and displaced palatally compared to its contralateral counterpart (Fig. 1A). The parents noted that the maxillary deciduous lateral incisors had recently exfoliated naturally. Cold pulp sensitivity tests were performed using tetrafluoroethane spray (lot 20250415, Endo-Ice; Hygenic Corp, Akron, OH, USA), revealing a positive but decreased response in tooth #9 compared to its counterpart and the primary canines, which showed a response similar to that of the mandibular incisors. Pain was reported upon palpation of the crown, and extensive mobility was observed, suggesting a root fracture of tooth #9.

An examination was conducted using digital periapical radiography (Schick 33 sensor, Dentsply-Sirona, Mokena, IL, USA), revealing a root fracture between the middle and cervical thirds and a palatally displaced coronal fragment. The root portion showed thin dentin walls and incomplete root development (Fig. 1B). Due to the recent trauma, accurately determining the status of the dental pulp was considered complex. Given the tooth displacement, gingival bleeding, and hematoma present in the vestibular gingiva, a vestibular cortical bone fracture was deemed highly probable (Fig. 1A).

Two treatment options were presented to the parents. The first option was conservative treatment, involving reduction of the coronal fragment, splinting, and regular clinical and radiographic follow-up. In the event of pulp necrosis, intervention on the coronal fragment would be necessary. The second option was to remove the coronal fragment and leave the root fragment in place to avoid alveolar ridge collapse. The advantages and disadvantages of each procedure, both in the short and long term, were thoroughly explained to them.

The prognosis of the case was considered guarded, given the time elapsed between the trauma and therapeutic intervention, the severity of the root fracture, and the condition of the pulp.

The mother, as a legal guardian, decided on conservative treatment after discussing it with him and signed the informed consent. Anesthesia was carried out with 3% Mepivacaine (lot B34836AD, Scandonest 3%, Septodont, Saint-Maur-des-Fossés, France), using the infraorbital technique, with an additional palatal injection.

The reduction of the coronal fragment of tooth #9 was performed using digital pressure, holding the dental crown with sterile gauze. The correct repositioning of the coronal fragment was verified with periapical radiography (Fig. 1C), and a splint was placed using 0.035-inch orthodontic wire (3M, Saint-Paul, MN, USA) and composite (Brilliant NG A2, Coltène/Whaladent GmbH, Langenau, BW, Germany) (Fig. 1D). Immediate post-operative radiography was taken to verify the reduction of the root fracture (Fig. 1E). Postoperative instructions were given to the patient and his parents. No antibiotics were prescribed; only Tylenol 100 mg was recommended if necessary.

The first follow-up was conducted 2 weeks after treatment. During this visit, the patient presented without any painful symptoms since treatment, and responded positively to the cold sensitivity test for all teeth. Tooth #9 exhibited a quicker response to cold compared to the initial appointment, although it was still less responsive than its contralateral counterpart.

The next follow-up appointment was scheduled for 2 months after treatment. During this visit, the child's mother reported that the child had experienced another fall from the skateboard in the sixth week, resulting in the splint becoming dislodged and a small enamel fracture on tooth #8. Both maxillary central incisors responded normally and similarly to the cold tests with Endo-Ice (lot 20250415, Coltène/Whaladent GmbH, Langenau, BW, Germany). Radiographic imaging showed a slight increase in the thickness of the root dentin walls (Fig. 2A).

After 6 months, a subsequent follow-up was conducted, during which the patient remained asymptomatic, exhibited a positive response to cold, and showed a further increase in the thickness of the dentin walls. The union of both segments became slightly more evident, and continued root development was observed (Fig. 2B).

Due to the COVID-19 pandemic, clinical consultations were halted, resulting in the loss of the 12-month follow-up. Therefore, the next evaluation did not occur until the 14-month mark. Despite the delay, the patient still exhibited a positive response to cold, remained free of painful symptoms, and demonstrated a continued increase in dentin wall thickness, with a slight narrowing of the root canal space in tooth #9 (Fig. 2C). Clinically, an enamel fracture of the incisal edge of tooth #8 was observed, necessitating restoration with composite resin (Fig. 2D).

Another clinical and radiographic follow-up was performed after 24 months (Fig. 2E). The patient reported being symptom-free during the entire period without contact, and the tooth appeared in its correct position without any gingival inflam-

FIGURE 1. Preoperative clinical status and initial management. (A) Clinical presentation of tooth #9; (B) Preoperative periapical radiograph displaying an oblique root fracture between the middle and cervical thirds, with a palatally displaced coronal fragment and incomplete root development; (C) Reduction of the coronal fragment achieved using sterile gauze and digital pressure; (D) Splint placement, including both central incisors and primary canines; (E) Immediate postoperative radiograph demonstrating successful reduction of the fracture.

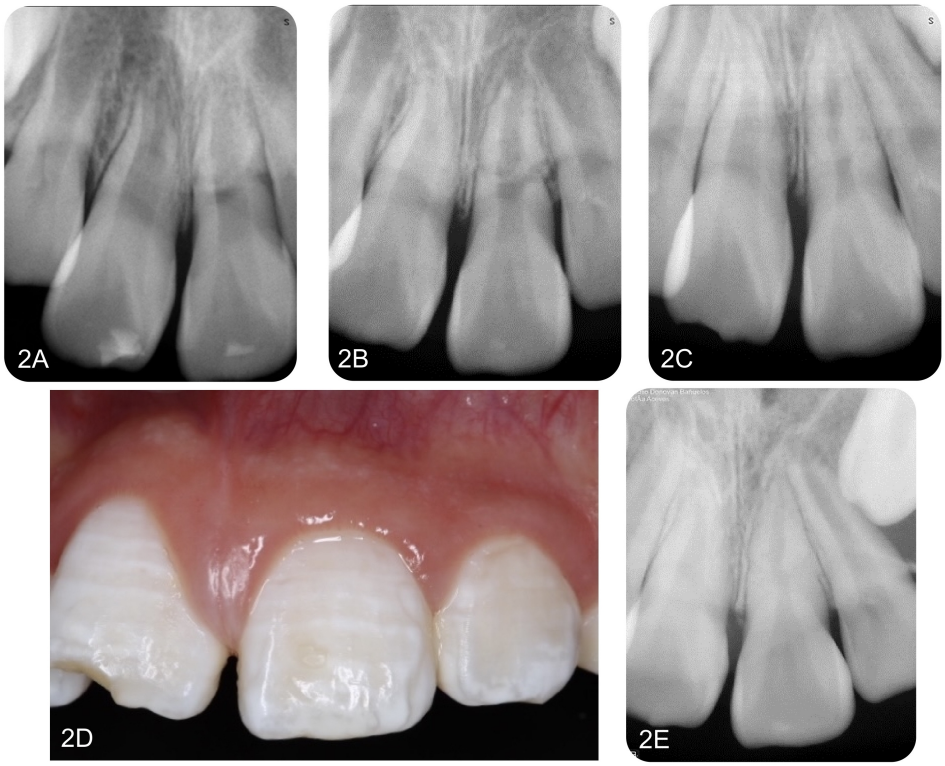

FIGURE 2. Follow-up evaluation from 2 to 24 months. (A) Follow-up at 2 months. The patient lost the splint two weeks prior due to a subsequent fall; (B) Follow-up at 6 months; (C) Follow-up at 14 months; (D,E) Clinical and radiographic follow-up 24 months post-trauma. The clinical crown exhibits a color and tone similar to its counterpart.

mation. The cold sensitivity test yielded a positive and similar response in all incisors. The patient did not report discomfort with horizontal or vertical percussion or palpation. The soft tissues exhibited good coloration, and there was no sinus tract, periodontal pockets, or any other pathologies observed. Additionally, it was noted that tooth #8 had not been restored with resin.

Upon radiographic review, healing of the fracture line was evident, indicating a hard tissue repair with a normal periapical appearance (Fig. 2E).

After 37 months of follow-up, a CBCT scan was obtained (Fig. 3). The Digital Imaging and Communications in Medicine (DICOM) data were imported and analyzed using CBCT e-VolDX software (version 6.03.52, CDT software, São José dos Campos, SP, Brazil), which standardizes image adjustments for volume analysis across different tools, configurations, and adjustments. CBCT images in various planes demonstrated healing of the fracture line, albeit with a faint residual fracture line, and normal tissue appearance. Complete root formation is evident. Multiplanar reconstruction (MPR) lines were identified to delineate the region of the root fracture in axial, sagittal, and coronal planes, illustrating the healing process of the oblique root fracture (Fig. 3). Fig. 4 presents CBCT scan without lines, offering MPR with high definition to characterize tissue normality after 37 months of follow-up. Fig. 5 depicts CBCT cinematic rendering providing a comprehensive view with volumetric details of root normality, including the fracture line. Additionally, CBCT scan shows MPR in the axial plane with high-definition tissue normality after 37 months of follow-up.

3. Discussion

The present case describes the clinical management of a maxillary central incisor with immature root development, which subsequently experienced trauma from a skateboard fall, resulting in an oblique root fracture. Following anamnesis, clinical and radiographic examinations, a conclusive diagnosis of an oblique root fracture was made. The clinical characteristics observed were tooth mobility, dislocation, and sensitivity, with a slight positive response to the cold test. Imaging using periapical radiography revealed root separation into two fragments between the middle and cervical thirds, with incomplete root development. Immediate care is essential in this clinical condition as it minimizes further damage to the tissues involved, particularly pulp contamination and/or further displacement of the coronal fragment. In this case, care involved repositioning the displaced coronal fragment, splinting, and regular follow-up.

This root fracture represents a complex TDI that can cause damage to various tissues, including the pulp, dentin, cementum, and periodontal ligament [1, 9, 10].

In root fractures, the pulp and periodontal tissue generally sustain less damage as part of the trauma energy is dissipated during the force required to produce the fracture. In this type of TDI, due to the wide foramen and increased pulp vascularity, the chance of pulp tissue survival is greater than that of necrosis, thereby reducing the necessity for endodontic treatment [11]. Conversely, in cases without root fracture but with a similar magnitude of traumatic force, the periodontal tissues and pulp may absorb the full impact of the force [12]. Studies have indicated that oblique fractures tend to have a better prognosis than transverse fractures due to the reduced mobility of the coronal fragment [12, 13]. Additionally, fractured roots with immature apices are associated with better prognoses than those with mature apices [11–15]. Table 1 (Ref. [2, 3, 10, 12, 13, 15–23]) presents various studies detailing the outcomes of root fractures based on case series and systematic reviews.

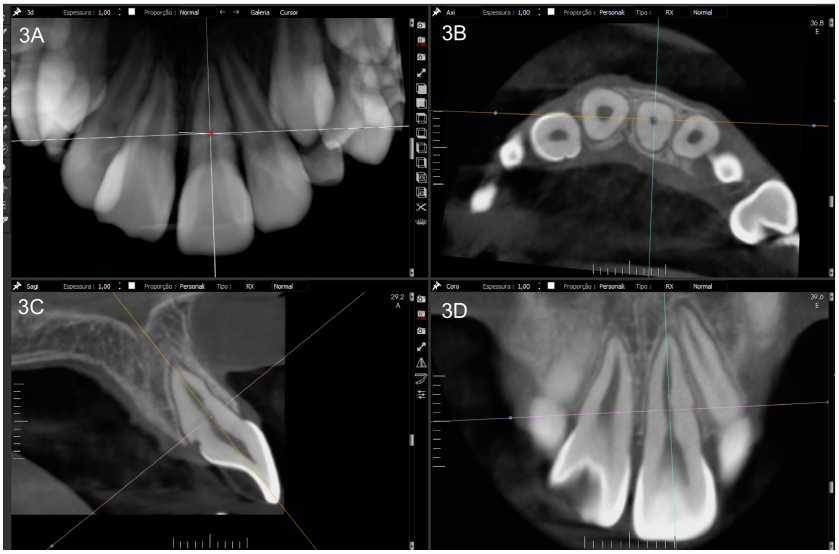

FIGURE 3. CBCT image obtained after 37 months of follow-up. CBCT images in various planes illustrate the healing of the fracture line, albeit with a slight fracture line and normal tissue. Root development is now complete. Multiplanar reconstruction (MPR) lines delineate the fracture region in the (A,D) coronal, (B) axial and (C) sagittal planes, illustrating the healing progression of the oblique root fracture.

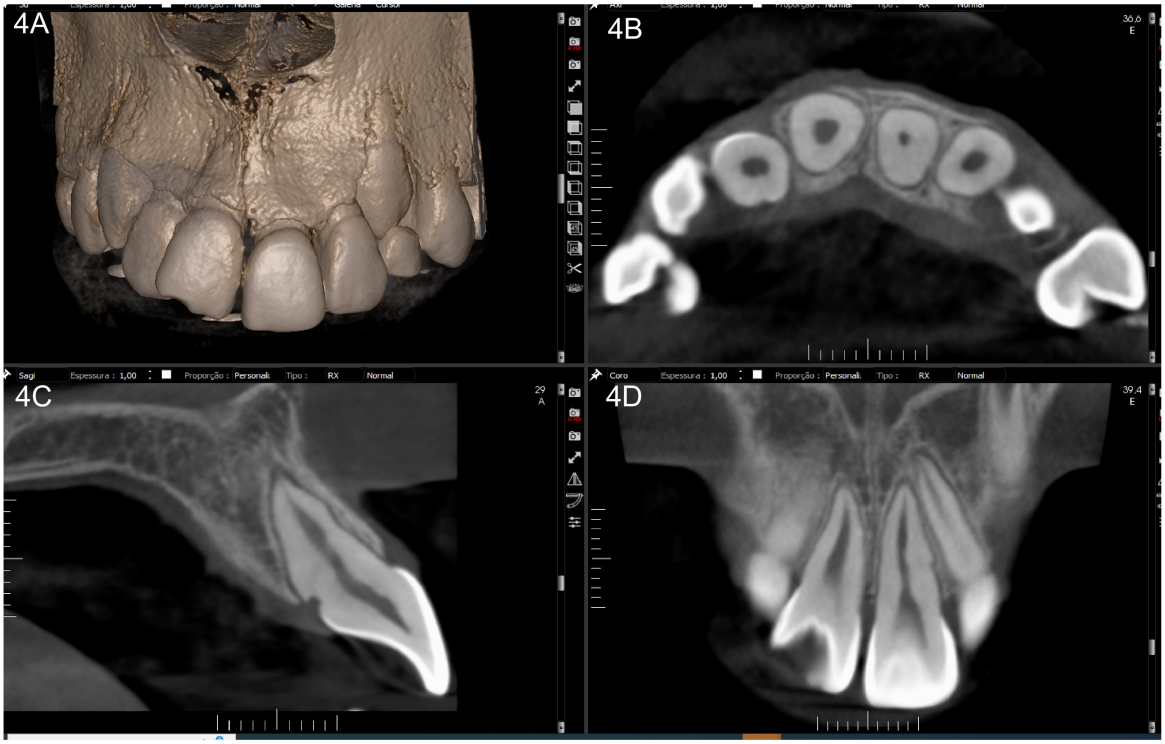

FIGURE 4. CBCT images without delineated lines after 37 months of follow-up. (A) High-resolution MPR showing normal vestibular bone tissue. (B) Axial section showing dentin formation at the fracture site, as well as a reduction in root canal diameter. (C) In the cervical third of the palatal root, there is a slight loss of root surface attributed to trauma. The integrity of both cortical bones is evident. (D) The periapical tissues appear normal.

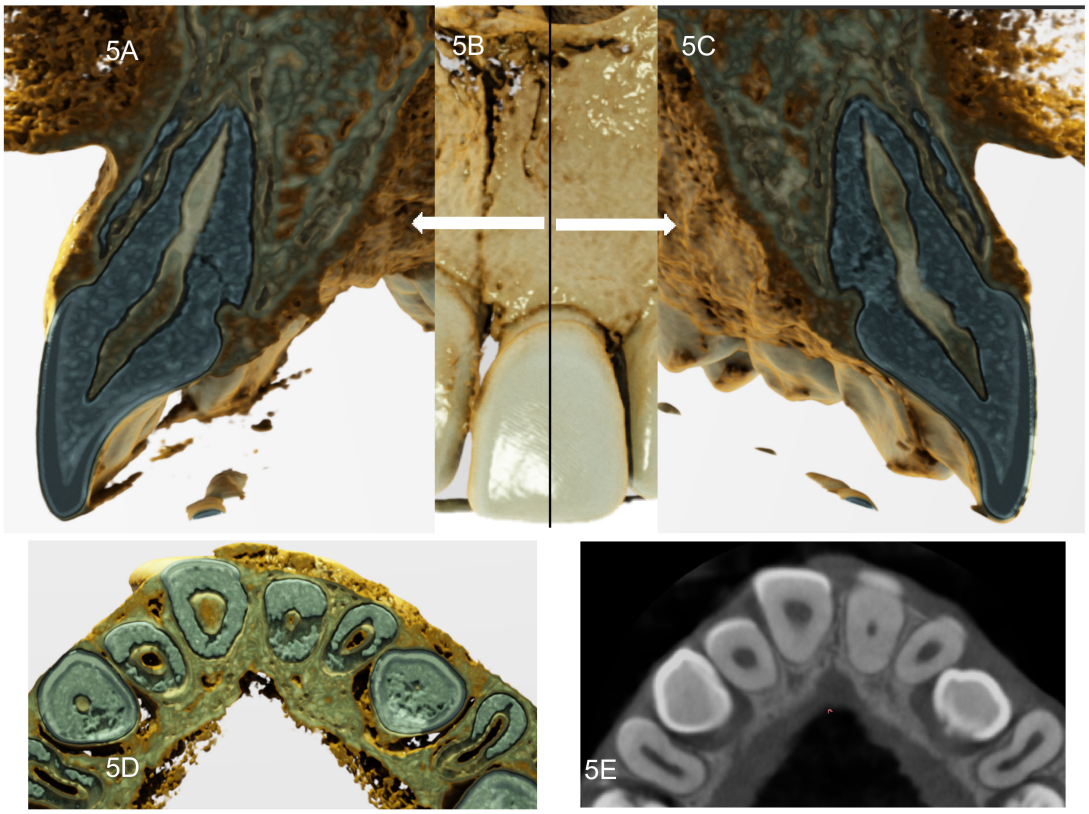

FIGURE 5. Cinematic representation of CBCT with 3D volumetric details. Fig. 5B shows the view from the left (A) or right (C) side of the central incisor in a digital sagittal section, as well as an axial view (D). The root's integrity and normality are evident, including the healing of the root fracture line and the presence of normal periodontal structures. (E) CBCT axial section showing the difference in dentin wall thickness between the two central incisors, with the fractured tooth having thicker walls.

TABLE 1. Outcomes of root fractures in case series or systematic reviews.

Reference	N	Gender	Teeth	Most relevant clinical-radiographic findings	Follow-up
Jacobsen [16], 1976 (Norway)	7	ND	7 MXCI with immature apex	Four of the teeth did not respond to sensibility tests at baseline. Two presented with a crown dislocation. Five out of the 7 teeth healed with the formation of hard tissue and apparent repair of the fracture. In the other two, a line was observed between fragments and rounding of the fragment edges. Three teeth did not show pulpal obliteration; three of them had partial obliteration; one showed complete obliteration.	Min 1.5 yr Max 19 yr
Andreasen *et al.* [12], 1989 (Denmark)	95	-	-	The positive factors associated with a better prognosis were immature apices, minimal fragment displacement, reduced mobility, and absence of periodontal disease.	Min 2 mon Max 11 yr
Yates [3], 1992 (United Kingdom)	22	71% M 29% F	21 MXCI 1 MNCI	Twenty roots had a fracture in the middle third, and two in the apical third. Only two teeth had an immature apex. The rest had mature apices. Five teeth were necrotic. Seventeen teeth showed healing with fibrous or hard tissue. Twenty out of 22 teeth showed sclerosis of the apical portion of the canal. Six showed pulp calcification in the coronal portion.	Min 6 mon Max 11.5 yr
Cvek *et al.* [13], 2002 (Sweden)	94	70% M 30% F	85 MXCI; 9 MNCI only teeth with transverse or oblique RF in the cervical third.	Pulp sensibility and immature apex at the time of fracture was significantly related to clinical attention and healing and hard tissue formation. The type of splint and its duration do not seem to have relevance in the prognosis. Teeth with oblique fractures had a better prognosis than those with transverse fractures.	Min 13 mon Max 159 mon
Welbury *et al.* [17], 2002 (North Ireland)	84	95% M 5% F	80 MXCI 4 MNCI	Teeth with cervical fractures had a worse prognosis (39%), compared to those in the middle third (87%) or apical third (100%). The factors associated with a better prognosis included pulp vitality at baseline, and absence of coronal fracture. Rigid splints did not significantly affect pulp vitality or the type of root tissue union.	Min 1 yr Max 10 yr
Majorana *et al.* [18], 2002 (Italy)	31	ND	24 MXCI 7 MNCI	The delay in initial care and the greater separation of the fragments affected healing. Teeth with immature apices had a better prognosis. 40% of fractured teeth were associated with alveolar bone fracture.	6 mon
Quin *et al.* [19], 2002 (China)	31	ND	Different types of TDI in children from 6 to 12 yr.	The use of removable splints in various types of dental trauma was evaluated in the short term. A total of 227 teeth experienced different types of trauma, of which only 31 exhibited root fractures. Five of these teeth required endodontic treatment while being treated with removable splint within three years.	3 yr
Andreasen *et al.* [2], 2004 (Denmark)	400	69% M 31% F	388 MXCI 12 MNCI	The positive factors for healing included incomplete root development; pulp sensibility at the time of clinical attention; minimal fragment separation; and reduced mobility. Cervical fractures had a slightly better prognosis, probably due to the shorter distance for revascularization.	Min 1 yr Max 3 yr

TABLE 1. Continued.

Reference	N	Gender	Teeth	Most relevant clinical-radiographic findings	Follow-up
Cvek *et al*. [15], 2008 (Sweden)	492	66% M 33% F	461 MXCI 31 MNCI	In a minimum 7-year follow-up, out of 534 teeth with root fractures, 80% remained *in situ*, while 20% were extracted. Among the extracted teeth, 70% exhibited horizontal fractures in the cervical third. A second trauma led to the extraction of 40% of the teeth.	Min 7 yr Max 17 yr
Westphalen *et al*. [20], 2008 (Brazil)	6	1 M 2 F	MXCI	In one case involving two maxillary incisors with root fractures and immature apices, treatment consisted of repositioning and splinting only. After three years, pulp calcification and bone formation were observed between the fragments. The other incisors had mature apices and underwent only splinting, without root canal treatment. All teeth demonstrated positive pulp sensibility.	3 yr
Kirzioglu *et al*. [21], 2008 (Turkey)	17	60% M 40% F	17 MXCI	Some cases were treated with root canal treatment extending to the fracture line. Positive factors for healing included incomplete root development; younger age; less displacement of fragments; and reduced mobility. Longer splinting duration was associated with greater hard tissue healing, however, evidence remains limited and not statistically significant.	Min 1.5 yr Max 5.5 yr
Lauridsen *et al*. [22], 2016 (Denmark)	223	56% M 44% F	91 patients with alveolar fracture RF	Dental complications following oral trauma and alveolar fracture were reviewed. In teeth with immature apices, the risk of complications was very low. In teeth with mature apices, there was a risk of pulp necrosis. The type or duration of splinting or antibiotic administration did not affect the likelihood of pulpal necrosis. Teeth with alveolar fractures and immature apices have a favorable prognosis.	Min 1 yr Max 10 yr
Khandelwal *et al*. [23], 2021 (India)	NA	-	SR	Twelve clinical case reports and two case series were included. Only one clinical case article did not involve endodontic treatment; all others required it. The short to medium-term success was good.	Min 3 mon Max 7 yr
Sheikhnezami *et al*. [10], 2024 (Iran)	125	64% M 36% F	114 MXCI 11 MNCI	Patients with immature apices required fewer endodontic treatments and had a better prognosis. Male patients required fewer endodontic treatments than females. A delay of one week or more in initial trauma care increased the need for endodontic treatment.	Min 12 mon

N: number of teeth; M: male; F: female; SR: Systematic review; MXCI: Maxillary central incisors; MNCI: mandibular central incisor; RF: root fracture; NA: Not applicable; ND: Not described; Min: Minimum; Max: Maximum; TDI: Traumatic dental injuries.

While periapical radiography is commonly used for detecting root fractures, it is important to note that this two-dimensional imaging modality has limitations in diagnosing such fractures. For a root fracture to be visible on a periapical radiograph, its direction must align with the angle of the incident X-ray beam, which is often not the case. Moreover, bone overlaps may project lines onto tooth root images on periapical radiographs, simulating the presence of a root fracture, resulting in false-positive findings [6].

Extensive root fractures are generally easier to identify compared to subtle fracture lines. CBCT scans offer significantly greater sensitivity in diagnosing root fractures than periapical radiography [6–8, 16]. A critical review [6] has discussed relevant clinical factors associated with root fractures visualized using new CBCT software, particularly those that are difficult to identify, such as fracture lines. Therefore, professionals need to possess adequate knowledge to identify different patterns of fracture lines and their impact on adjacent bone tissues, as well as to analyze artifacts that may obscure or resemble fracture lines [24–26]. Careful analysis is required to distinguish true fracture lines and root fractures from phantom conditions that mimic fractures [26]. CBCT is the recommended imaging modality for identifying root fractures. Furthermore, the success of diagnosis is augmented when professionals possess scientific knowledge, training, and proficiency in advanced CBCT software [6, 27–30].

An advancement in imaging examinations involves three-dimensional (3D) data visualization, constituting a novel method of cinematographic rendering reconstruction [29–33]. This technique enables the production of photorealistic 3D images from conventional CBCT data. Image post-processing and subsequent visualization rely on software for three-dimensional navigation and the application of rendering and indexing tools to provide clinically useful information based on volumetric data sets. Image post-processing significantly impacts the quality of diagnosis [30]. The cinematic rendering reconstruction technique, which generates photorealistic 3D images, shows promise and has great potential for application in clinical practice, research, and teaching. It has previously been utilized in anatomical and imaging studies [28–31].

Limitations of this report are that individual clinical cases alone do not allow for the establishment of treatment guidelines for all cases with certain clinical similarities in root fractures. Several factors can negatively influence the patient's healing response in cases of traumatic dental injuries involving root fractures. These factors include a more cervical location or transverse root fracture [13, 15, 17], a mature apical foramen [12], greater displacement of the coronal fragment [21], pulp necrosis [13, 17], delay in splinting [10, 18], periodontal disease [12], lack of adherence to treatment [10], or a secondary trauma to the area [13]. Patient-specific factors, such as age [21] and each patient's unique immune system, can cause each case to respond differently. Additionally, long-term follow-up of at least 10 years is essential to monitor potential late-onset changes, such as complete obliteration of the root canal [3, 16]. The clinical management and prognosis of complex dental trauma must consider all these factors.

4. Conclusions

The utilization of the cinematographic rendering reconstruction technique in the present case, using CBCT e-Vol Dx software, enabled enhanced visualization of anatomical details that might otherwise go unnoticed in multiplanar reconstruction (MPR), such as the union of root fragments.

Proper examination and diagnosis, as well as meticulous clinical management of a root fracture, and well-informed decision-making and planning, may yield a satisfactory prognosis. The positive outcome of the case underlines the challenge of immediately determining the pulp status post-trauma, as sensitivity tests may yield negative or inconclusive results. Stabilization of the fractured fragment and regular monitoring of pulp vitality are recommended. Oblique root fractures have a better prognosis compared to transverse fractures. The undeniable limitations of periapical radiography compared to CBCT imaging highlight the value of CBCT with cinematic rendering, facilitated by sophisticated post-processing software, in providing comprehensive volumetric details of root integrity.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed in this report are available upon reasonable request from the corresponding author. This is due to national law protecting children's personal information. Parents must consent to the release of any additional information requested.

AUTHOR CONTRIBUTIONS

AC—conceptualization, writing and editing. MU—conceptualization, editing and reviewing. GG, KSA-L, LRAE—methodology and investigation. MRB—editing and analysis. CE—writing, analysis and reviewing. All authors contributed to manuscript revisions and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Ethics, Research, and Biosafety Committees approved the present case, with the number CI-01125. Informed consent was obtained from the parents of the patient for publishing this case report.

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Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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