SPANDIDOS PUBLICATIONS

Regenerative endodontic treatment for premolars with apical root segment separation and extensive periapical lesions secondary to severe inflammatory root resorption: A report of two cases

QIAN WU and DANIEL J. YEN

Department of Endodontics, Dongyang People's Hospital Affiliated to Wenzhou Medical University, Dongyang, Zhejiang 322100, P.R. China

Received November 14, 2025; Accepted August 11, 2026

DOI: 10.3892/etm.2026.13292

Abstract. Inflammatory root resorption (IRR) frequently causes hard-tissue defects within the root canal system. The present report describes two cases in which regenerative endodontic treatment (RET) was used to manage premolars complicated by severe IRR, apical root segment separation and extensive periapical lesions. The first case involved an 11-year-old male patient with a fractured premolar (tooth 20) that exhibited IRR-induced apical segment separation. Case 2 involved a 15-year-old male patient presenting with severe IRR in tooth 20, characterized by an open, anomalous apical foramen and a large periapical lesion. Both teeth were managed by RET. In case 1, a regenerative scaffold was created by inducing periapical bleeding. In case 2, due to inadequate periapical bleeding, an alveolar-derived autologous blood clot obtained via aspiration from the maxillary terminal alveolar bone was utilized as the scaffold. Clinical and radiographic outcomes were documented over 2- and 3-year follow-up periods, respectively. At the 2-year follow-up in case 1, the tooth exhibited complete resolution of clinical symptoms, healing of the periapical lesion and arrest of IRR. Radiographic assessment revealed re-approximation of the apical root segment separated from the main root canal. However, the newly mineralized tissue deposition was insufficient to fully restore root continuity. At the 3-year follow-up in case 2, the patient remained asymptomatic, with complete healing of the periapical lesion and arrested IRR. These two cases suggest that RET may be beneficial for severe IRR complicated by apical root segment separation and large periapical lesions; however, further clinical studies are warranted to confirm these findings.

Correspondence to: Dr Qian Wu, Department of Endodontics, Dongyang People's Hospital Affiliated to Wenzhou Medical University, 60 Wuning West Road, Dongyang, Zhejiang 322100, P.R. China
E-mail: 2322669331@qq.com

Key words: root segment separation, alveolar-derived autologous blood, root resorption, regenerative endodontic treatment, paracentesis

Introduction

Inflammatory root resorption (IRR) is a pathological process characterized by the progressive loss of dental hard tissues and adjacent alveolar bone, primarily triggered by pulp infection and/or traumatic injury (1). Clinically, IRR is classified as either internal or external, with distinct radiographic presentations for each classification. Internal IRR typically presents as a well-defined round or oval radiolucency confined within the root canal space. External IRR often manifests as a saucer-shaped radiolucent defect along the root surface, frequently accompanied by apical irregularity or 'ragged' root morphology (2). The clinical consequences of IRR are diverse and may be severe. Advanced resorption may lead to root perforations (3), compromising the integrity of the root canal system and impairing endodontic sealing efficacy (4). Such structural compromise is associated with reduced long-term tooth survival (5). Moreover, extensive IRR can critically diminish the biomechanical strength of the affected teeth, predisposing them to catastrophic root fractures under functional or parafunctional loading (6,7). IRR-related perforations also facilitate the translocation of endodontic pathogens into the periodontal ligament space, which can lead to the development of sinus tracts (8,9) and periradicular radiolucencies (10). Early detection through radiographic assessment and prompt intervention are essential for mitigating these sequelae.

Treatment selection for teeth with IRR should be guided primarily by the stage of root development. For mature teeth, conventional root canal therapy (RCT) is a conservative and reliable approach. However, when perforation is present, adjunctive interventions, such as surgical flap procedures or intentional replantation, may be required to achieve optimal outcomes (11). For immature teeth with open apices, treatment options include apexification, apical barrier techniques and regenerative endodontic treatment (RET) (11). RET aims to achieve the regeneration of pulp tissue, reconstruct the normal structure of dental pulp tissue, restore the inherent physiological functions of the pulp, and thereby promote continued root development. It typically involves the disinfection of the root canal system followed by the induction of a blood clot or placement of a scaffold, often using a triple antibiotic paste or calcium hydroxide as an intracanal medicament, and subsequent coronal sealing with a bioceramic material. RET has demonstrated particular efficacy not only in arresting resorptive processes but also in facilitating hard-tissue deposition to repair perforations (5). Given its dual therapeutic potential, emerging evidence supports the use of RET in both immature and mature teeth affected by IRR (8,12-18). For instance, a previous clinical study demonstrated that injectable platelet-rich fibrin (PRF) revascularization led to resolution of periapical radiolucencies and reduced root resorption volume in teeth with internal IRR (17). Injectable platelet-rich fibrin (i-PRF) revascularization is a type of RET that uses i-PRF as a biological scaffold to promote tissue regeneration. Similarly, Erdogan *et al* (18) reported radiographic outcomes of RET showing favorable healing and minimal progressive external resorption compared with traditional apexification.

When periapical bleeding fails to produce a clot sufficient to fill the root canal, platelet-rich plasma (PRP) and PRF serve as scaffold alternatives. However, as PRP and PRF are derived from peripheral venous blood, these scaffolds differ biologically from native blood within the alveolar bone. To address this limitation, a novel technique involving paracentesis of autologous blood from the maxillary alveolar bone was developed in our previous study as a potentially refined approach for RET (19). This procedure can be performed independently by dentists without the need for additional medical personnel qualified to perform venipuncture. This autologous blood was subsequently used for RET (19).

In the first case of the present report, a fracture of an anomalous central cusp resulted in pulpal necrosis and extensive IRR in the mandibular premolar, ultimately causing complete intra-alveolar separation of the root segment from the remaining tooth structure. The current report describes the application of RET to functionally reconnect a separated root segment in a tooth diagnosed with severe IRR. The second case describes the application of RET in a non-traumatized tooth presenting with external IRR and apical periodontitis. A key feature of this procedure is an innovative technique that uses an alveolar-derived autologous blood (ADAB) clot, harvested from the maxillary terminal alveolar bone near the maxillary tuberosity, as a novel scaffold in RET. To the best of our knowledge, this is the first report applying ADAB-based RET for the treatment of root resorption.

Case report

Case 1. An 11-year-old male patient was referred to the Department of Endodontics at Dongyang People's Hospital Affiliated to Wenzhou Medical University (Dongyang, China) in August 2023 with a 2-day history of localized pain in the left mandibular region. The medical and dental histories were unremarkable, with the patient explicitly denying any prior dental trauma or underlying systemic conditions. Intraoral evaluation revealed a fractured anomalous central cusp on the occlusal surface of tooth 20. Teeth were numbered according to the Universal Numbering System. Furthermore, the tooth exhibited sensitivity to percussion accompanied by localized gingival swelling and purulent discharge. Tooth 20 (20) had a probing depth of <3 mm (indicating that the periodontal tissues around the tooth are healthy, with no detectable periodontal pockets, inflammation or marked attachment loss, consistent with a clinically healthy periodontium) and grade I mobility (defined as mobility greater than physiological but only in the buccolingual horizontal direction, indicating that the tooth retains adequate periodontal support to maintain its position and function). Radiographic evaluation using panoramic imaging (Sirona ORTHOPHOS XG 5; Dentsply Sirona) revealed a notable hard-tissue defect within the middle third of the root canal, leading to a separated apical root fragment (Fig. 1). Additionally, slight radiolucency was observed surrounding the area of root resorption (Fig. 1). Therefore, tooth 20 was diagnosed with IRR and pulp necrosis. At the initial visit, the resorptive lesion had already resulted in a complete mid-root separation of the apical fragment. Given this advanced stage, the radiographic features required to differentiate between internal and external resorption were no longer discernible. Following a thorough explanation of the diagnosis and proposed treatment alternatives, written informed consent was obtained from the legal guardian before RET initiation.

First treatment visit. Following local infiltration anesthesia (2% lidocaine containing 1:100,000 epinephrine), the tooth was isolated with a rubber dam. Access cavity preparation was initiated using a fissure bur with copious irrigation. The working length was estimated using an electronic apex locator (PROPEX Pixi; Dentsply Sirona), with readings corroborated by radiographic confirmation and conservatively set 0.5-1 mm short of the radiographic apex. The infected root canal system was debrided using manual H-files under continuous irrigation with 1.5% sodium hypochlorite to achieve chemomechanical disinfection. After the canal was dried with sterile paper points, calcium hydroxide paste was used as an intracanal medicament. The access cavity was temporarily sealed with glass ionomer cement (GIC), and the patient was scheduled for re-evaluation after 4 weeks.

Second treatment visit. At the second treatment visit, tooth 20 was asymptomatic and the gingival swelling had resolved. A RET procedure was now followed. After rubber dam isolation, the affected tooth was thoroughly disinfected using 2% povidone-iodine solution, and the temporary filling material was carefully removed. Following this, the calcium hydroxide paste was washed out using sterile saline solution, aided by ultrasonic activation. The ultrasonic irrigation was performed using a piezoelectric ultrasonic unit at a frequency of 25-40 kHz, with the irrigant at ambient temperature, activated in cycles of 20 sec each, repeated 2-3 times per canal with fresh irrigant replenished between cycles. Subsequently, the canal was meticulously dried, irrigated with 20 ml 17% EDTA solution, and dried again. Controlled periapical bleeding was induced under a dental microscope by gently puncturing the periapical tissue with a 25 K-file. This mechanical stimulation of the periapical tissue resulted in hemorrhage that filled the canal space up to the cementoenamel junction. After a 20-min waiting period for blood coagulation, a 3-mm layer of iRoot BP Plus (Innovative BioCeramix, Inc.) was placed below the cementoenamel junction. The access cavity was then sealed with a layered restoration of GIC (as the base) and resin composite (as the final layer) to ensure optimal coronal

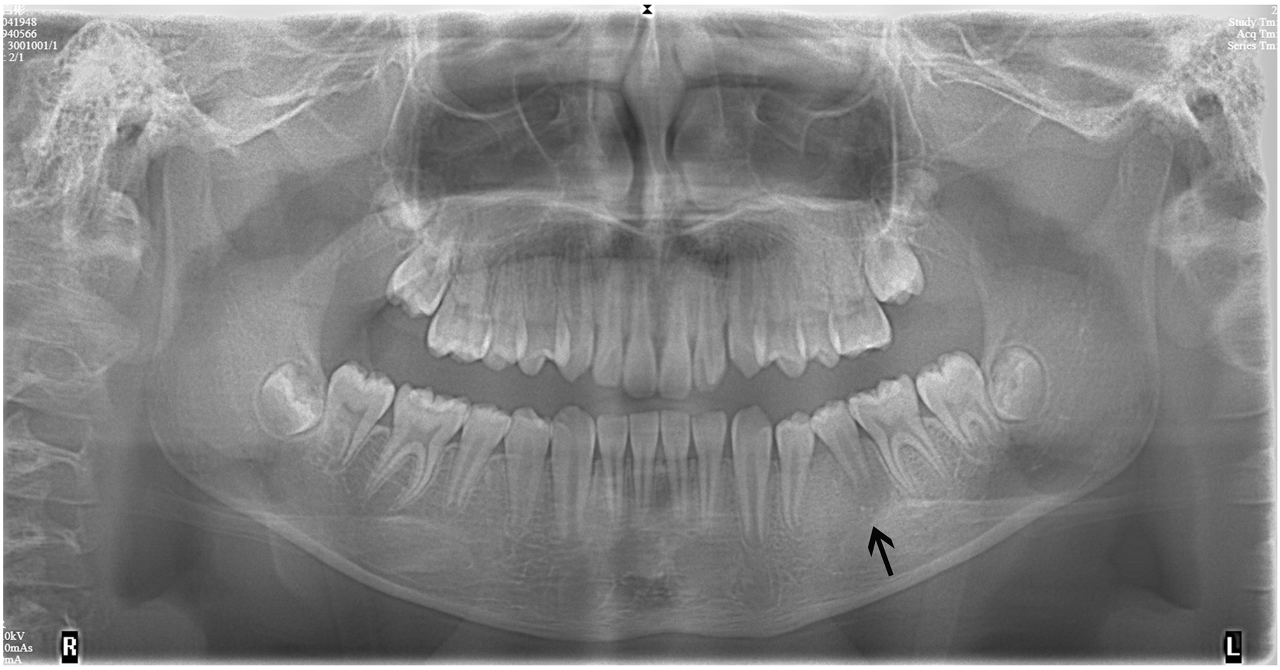

Figure 1. Preoperative panoramic radiograph of case 1. Tooth 20 demonstrated extensive mid-root resorption, resulting in detachment of the apical fragment (black arrow) and a subtle adjacent radiolucency.

sealing. Postoperative periapical radiographs were obtained to document RET completion (Fig. 2A). Due to concerns regarding radiation exposure, the guardian of the patient declined cone-beam computed tomography (CBCT) for three-dimensional evaluation of the internal resorption.

Follow-up examination. At the 1-month follow-up, tooth 20 remained clinically asymptomatic, with physiological mobility. Radiographic assessment indicated that the separated apical fragment had shifted coronally, and the resorption-induced gap between the fragment and the main canal was almost completely closed, allowing the fragment to re-establish contact with the coronal root (Fig. 2B). Additionally, radiographic imaging at the 1-month follow-up (Fig. 2B) revealed complete regression of the radiolucent lesion surrounding the resorption area. Complete regression of the periapical radiolucency was assessed qualitatively by the absence of the preoperative lesion on the follow-up periapical radiograph, corroborated by clinical signs of healing. While preoperative and follow-up imaging modalities differed, the healing pattern was unequivocal. The IRR process was arrested, as evidenced by the re-establishment of a distinct periodontal ligament space around the affected root. Moreover, compared with the immediate postoperative radiograph (Fig. 2A), minimal mineral redeposition contributed to the subtle lengthening of the main root canal. At the 12-month follow-up, tooth 20 was clinically asymptomatic. Radiographic examination (Fig. 2C) revealed mesial displacement of the detached apical root fragment, resembling the imaging characteristics of a horizontal root fracture. At the 24-month follow-up, the patient remained asymptomatic, with no pain, swelling or sinus tract involvement. The tooth was non-tender to percussion and palpation. Periodontal probing depths were within normal limits (≤3 mm), with physiological mobility. Radiographic assessment at the 24-month follow-up (Fig. 2D) showed stable positioning of the apical root fragment, with no appreciable displacement relative to prior imaging (Fig. 2C). The periodontal ligament space surrounded both the retained apical fragment and main root, confirming that it remained free of infection. A few scattered radiopacities were confined to the main root canal adjacent to the coronal filling material; however, no canal obliteration was observed. Notably, the apical fragment maintained close proximity to the mesial root canal while demonstrating clear separation from the distal canal space. The positional relationship between the separated root segment and the main root could not be definitively assessed at 24 months due to the absence of CBCT. The patient has been scheduled for annual follow-up reviews to monitor long-term stability.

Case 2. A 15-year-old male patient presented to the Department of Endodontics at Dongyang People's Hospital Affiliated to Wenzhou Medical University in June 2022 with recurrent pain in the left mandibular tooth for 1 month. The tooth had been treated at another dental clinic a year prior; however, the reason for the initial visit and the specifics of the treatment were not clearly recalled by the patient's mother. The patient unequivocally denied any history of dental trauma or systemic diseases. During the intraoral examination, tooth 20 showed a white filling on its occlusal surface. Additionally, the tooth tested positive on percussion; however, no sinus tract or gingival swelling was detected. Tooth 20 had a probing depth of <3 mm and grade I mobility. Radiographic examination revealed a restoration extending close to the root canal orifice and an extensive radiolucent area on the mesial aspect of the root (Fig. 3A). Furthermore, tooth 20 showed oblique inflammatory resorption that resulted in an open apical foramen, thin canal walls and irregular apical root configuration (Fig. 3A). The diagnosis was chronic apical periodontitis with IRR. The patient was informed of the diagnosis and treatment options,

Figure 2. Periapical radiographs of case 1. (A) Postoperative radiograph following RET. Root integrity was disrupted by IRR, leading to separation of the apical segment from the main root (white arrow). The radiolucency adjacent to the resorptive defect appeared less pronounced compared with that observed on the preoperative panoramic radiograph. (B) Radiograph at the 1-month postoperative follow-up. Arrest of IRR was observed, evidenced by the presence of the periodontal ligament space and notable resolution of the periapical lesion. Reconnection between the main root canal and the apical fragment was observed, attributed to coronal displacement of the separated apical segment and slight mineral redeposition (white arrows). (C) Postoperative radiograph at the 12-month follow-up. The radiograph showed a mesially displaced apical root fragment with imaging characteristics similar to horizontal root fracture (white arrows). (D) Radiograph at the 24-month follow-up after RET. The radiograph showed stable positioning of the apical fragment compared with the 12-month follow-up radiograph (white arrows), with a visible periodontal ligament space surrounding both the fragment and the main root. Focal radiopacities were noted near the coronal filling material; however, no canal obliteration was observed. The apical fragment was closely opposed to the mesial canal wall; however, it remained distinctly separate from the distal canal space. RET, regenerative endodontic treatment; IRR, inflammatory root resorption.

and written informed consent was obtained from the legal guardian before undergoing RET.

First treatment visit. The procedure in case 2 followed a protocol identical to that described for case 1, including root canal disinfection, induction of bleeding, scaffold placement and coronal sealing.

Second treatment visit. During the second visit, tooth 20 exhibited no symptoms. The procedure prior to inducing apical bleeding was identical to that used in case 1. The blood obtained through apical tissue bleeding was inadequate to fill the entire root canal. An 18-gauge needle was inserted through the mucosa at the oral vestibular sulcus of the terminal maxillary molar. The needle was oriented perpendicular to the buccal surface of the alveolar bone, with incremental force applied to advance the tip into the underlying tissue to a depth of <2 mm. Gentle suction was then applied to aspirate blood from the alveolar area. (Fig. 4). Blood was injected into the root canal under a dental operative microscope. After a 20-min wait, the blood was coagulated, and a 3-mm layer of iRoot BP Plus was placed below the cementoenamel junction. The access cavity was filled with a combination of GIC and a resin composite to ensure coronal sealing. A final radiograph was obtained after RET (Fig. 3B). The guardian of the patient refused CBCT because of concerns regarding radiation dosage.

Follow-up examination. At the 3-month follow-up, tooth 20 was asymptomatic, with normal physiological mobility, and was non-responsive to pulp vitality testing. Pulp vitality was assessed using an electric pulp tester, with the probe tip placed on the mid-buccal surface of the crown after coating with a conductive medium. The stimulus was gradually increased until a response was elicited or maximum output was reached. The oral radiograph showed mineral deposition along the mesial root canal wall and apical area (Fig. 3C) compared with the postoperative radiograph. However, recovery of the alveolar bone deficiency was not obvious, as indicated by radiographic alveolar bone density at the mesial aspect of the root canal. By the 6-month follow-up, there was no tenderness upon percussion or palpation, although pulp vitality testing yielded no response. Radiographically, there was an increase in alveolar bone density and a reduction in radiolucent areas along the

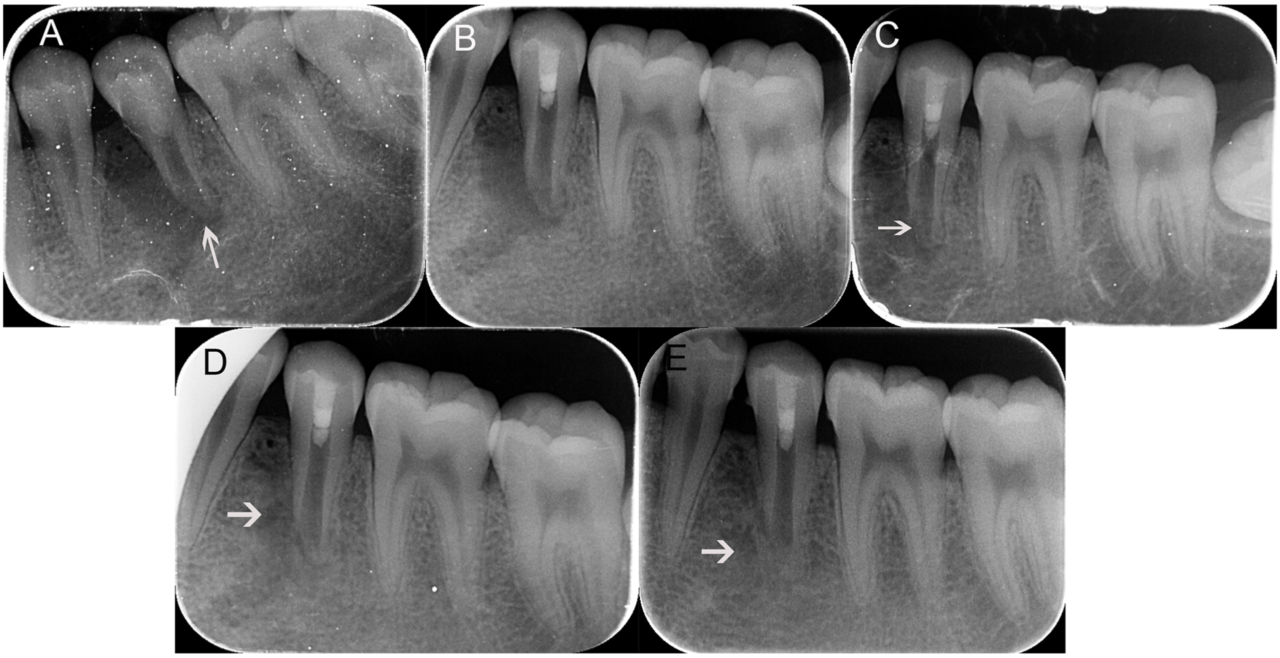

Figure 3. Periapical radiographs of case 2. (A) Preoperative radiograph of tooth 20. An extensive radiolucent area at the mesial aspect of the root and an oblique inflammatory resorption resulted in an open apical foramen, thin canal walls and an anomalous configuration of the root apex (white arrows). (B) Postoperative radiograph of tooth 20 immediately after RET. (C) Periapical radiograph obtained at the 3-month follow-up. Slight mineral deposition was observed at the mesial root canal wall and apical area compared with the postoperative radiograph, as indicated by a white arrow. (D) Periapical radiograph obtained at the 6-month follow-up. There was an obvious increase in radiographic alveolar bone density and a decrease in the radiolucent area along the mesial side of root (white arrows). (E) Periapical radiograph obtained at the 36-month follow-up. The alveolar bone density of the periapical lesion at the mesial side of the root was almost identical to that of normal alveolar bone (white arrows). RET, regenerative endodontic treatment.

Figure 4. Clinical image showing collection of alveolar-derived autologous blood. The aspiration site was the maxillary terminal alveolar bone.

mesial side of the root, suggesting gradual resolution of the periapical lesion and containment of the EIR (Fig. 3D). At the 36-month follow-up, the patient remained asymptomatic, with no pain, swelling or sinus tract involvement. The tooth was non-tender to percussion and palpation, with probing depths ≤3 mm and physiological mobility. At the 36-month follow-up, almost complete resolution was observed, as evidenced by the similar image density in the periapical lesion area and normal alveolar bone (Fig. 3E). The patient has been scheduled for annual follow-up reviews to monitor long-term stability.

Discussion

A morphological anomaly, often referred to as an abnormal central cusp, is frequently observed on the occlusal surface of the premolars (21). The central occlusal cusp is susceptible to fractures during oral functional activities. It is common for dental pulp tissue to protrude into this abnormal central cusp (22). When the pulp tissue is exposed due to a fracture of the central cusp, it can pave the way for bacterial intrusion, ultimately leading to pulp necrosis (23). Both teeth discussed in the present report were premolars. In case 1, a fractured anomalous central cusp was observed on the occlusal surface of tooth 20. However, in case 2, determining the cause of the pulpal infection was challenging because of the unclear medical history of the patient. Nevertheless, the presence of central filling material in the tooth crown suggests the possibility of a defect or caries in the occlusal center.

RET was initially considered an optimal treatment strategy for immature permanent teeth with pulpal necrosis because it promotes root development through mineral redeposition. RET has been successfully applied to address various forms of IRR, including internal IRR (17,24,25), external IRR (14,16,18,25-30), root perforation (8,12,13,15) and periapical lesions (31). The current literature primarily comprises case reports and case series, whereas robust

Table I. Published studies on teeth with inflammatory root resorption treated using regenerative endodontic treatment.

First author/s, year	Study type	Type of root resorption	Follow-up duration, months	(Refs.)
Nayak and Nayak, 2015	Case report (1 case)	External	24	(30)
Santiago *et al*, 2015	Case report (3 cases)	External	30, 18 and 15	(29)
Chaniotis, 2016	Case report (1 case)	External	24	(28)
Priya *et al*, 2016	Case report (1 case)	Internal, external	12	(25)
Saoud *et al*, 2016	Case report (1 case)	Perforation	19	(12)
Kaval *et al*, 2018	Case report (1 case)	Internal, perforation	24	(13)
Tzanetakis, 2018	Case report (1 case)	External	30	(27)
Lu *et al*, 2020	Case report (1 case)	External, perforation	30	(15)
Yoshpe *et al*, 2020	Case report (4 cases)	External	30, 22, 24 and 12	(14)
Arnold, 2021	Case report (1 case)	Internal, perforation	36	(8)
Lin *et al*, 2022	Review	External	10-60	(26)
Loroño *et al*, 2022	Case report (1 case)	Internal	48	(24)
Nageh *et al*, 2022	Clinical trials (n=10)	Internal	12	(17)
Lu *et al*, 2023	Clinical trials (n=20)	External	36	(16)
Erdogan *et al*, 2024	Clinical trials (n=92)	External	Not reported	(18)

clinical trials remain scarce. Therefore, stronger evidence from well-designed clinical studies is required to support the use of RET for managing root resorption. Numerous cases of internal IRR, external IRR and root perforations have been documented (Table I). In case 1 of the present report, complete mid-root separation with a detached apical fragment was an uncommon radiographic finding in the context of periapical pathology. To the best of our knowledge, such an advanced presentation has rarely been documented in RET literature. The present cases add to the existing literature by illustrating a severe form of root resorption.

Several treatment options are available for managing apical root segment separation associated with IRR. i) Treatment option 1: Apical barrier technique with conventional RCT (32,33). This technique involves retaining the separated apical segment *in situ* while sealing the root canal with an apical barrier [such as mineral trioxide aggregate (MTA) or bioceramic materials]. However, the long-term retention of the apical fragment may theoretically predispose the tooth to persistent or recurrent infections. In cases with an infected retained segment, surgical intervention through invasive endodontic microsurgery remains the only definitive treatment option. ii) Treatment option 2: RET (12,14). RET is designed to stimulate hard-tissue formation at the resorption site, potentially promoting the reattachment of the separated apical segment to the main root structure. Nevertheless, as with option 1, the viability of the remaining pulp tissue in the separated segment remains uncertain. Should infection develop in the retained fragment, clinicians would face the same therapeutic dilemma as described for the apical barrier technique. iii) Treatment option 3: Endodontic microsurgery with retrograde filling (34,35). This approach involves surgical removal of the separated apical segment, followed by retrograde obturation of the root apex using biocompatible materials. Compared with options 1 and 2, this technique may provide more favorable clinical outcomes with higher predictability. However, as an invasive surgical procedure, it carries inherent risks, such as postoperative discomfort and potential complications associated with surgical intervention.

Based on the principles of minimally invasive dentistry and the preservation of root mechanical resistance, option 2 may offer potential advantages over options 1 and 3 in selected cases, including the induction of mineral deposition to enhance root fracture resistance and the avoidance of surgical trauma.

Although apical root segment separation is most frequently observed in horizontal or vertical root fractures (36), its occurrence secondary to severe IRR is rarely reported. In conventional root fractures, the separated fragment and retained main root can be reassembled to reconstruct the original anatomical contour of the tooth (37-39). However, when root separation occurs in the context of IRR, the condition is typically accompanied by notable loss of dental hard tissue (5,6). As a result, even with re-approximation of the separated fragments, complete anatomical restoration may not be possible unless mineral redeposition facilitates hard-tissue regeneration (13,40). In case 1, tooth 20 demonstrated an initial reconnection between the main root canal and the apical fragment at the 1-month postoperative follow-up, which appeared to be associated with slight mineral redeposition and coronal displacement of the apical segment. However, no progressive mineral redeposition was observed at the 12-month follow-up, and the apical root segment exhibited mesial displacement. This outcome can be attributed to insufficient hard-tissue regeneration and persistent alveolar bone deficiency. Incomplete mineral redeposition may have prevented the full restoration of structural integrity between the apical fragment and the main root, resulting in an unstable connection susceptible to masticatory forces. In addition, the bone loss associated with IRR was not fully resolved, potentially creating a space that permitted movement of the separated root segment. Although RET can theoretically stabilize the apical fragment by enhancing the root and alveolar bone repair, this case did not demonstrate clear evidence of such stabilization. Furthermore, the positional relationship between the separated root segment and the main root at the 24-month follow-up remains uncertain because of the lack of three-dimensional imaging.

Although it remained untreated, the apical root segment in case 1 remained non-infected throughout the 24-month follow-up period. This finding suggested that the infected pulp tissue was confined to the coronal region of the resorption area. This clinical behavior mirrors that observed in horizontal root fractures (12). Current management protocols for horizontal root fractures with preserved pulp vitality recommend conservative monitoring without intervention (12). If coronal pulp necrosis occurs, treatment should be limited to the affected coronal segment, because the apical fragment characteristically maintains vitality (12). It is reasonable to postulate that,in contrast to horizontal root fractures, in which pulpal pathology develops secondary to the fracture event (41,42), pulpal vitality in apical segments separated by severe IRR carries greater prognostic uncertainty. This distinction likely arises from the fundamental difference in the pathogenic sequence: In IRR cases, pulpal inflammation initiates the resorptive process that ultimately leads to root separation (5,43), whereas in traumatic fractures, mechanical separation precedes any pulpal changes (42,44).

However, a major limitation of the present case report was that CBCT was not performed. CBCT is currently considered the gold standard for the accurate assessment of root resorption, as it allows three-dimensional visualization and more reliable differentiation between internal and external resorption. Without CBCT, morphological assessments of the resorptive defects in both cases are inherently limited. In case 2, this limitation prevented a definitive distinction between internal and external resorption. In case 1, the resorptive process had already resulted in complete mid-root separation at the time of initial presentation. Although the advanced destruction of normal anatomical landmarks makes retrospective identification of the original resorption type difficult, regardless of the imaging modality, CBCT would still have provided valuable information regarding the spatial configuration of the separated fragments and the surrounding bone. Therefore, the morphological interpretations presented in the current report should be regarded as tentative, and the diagnostic uncertainty regarding resorption types, particularly the internal vs. external distinction, should be acknowledged. This limitation does not invalidate the observed clinical outcomes following ADAB application in case 2. However, it highlights the need for future studies to incorporate high-resolution three-dimensional imaging to enable more reliable morphological assessment.

MTA has been a benchmark endodontic material since its introduction in the 1990s (45). The beneficial properties of MTA, such as biocompatibility, bioactivity (calcium ion release promoting hard-tissue formation), alkaline pH with antibacterial effects and superior sealing ability (46-48), have made it the material of choice for vital pulp therapy, apexification/RET, perforation repair and retrograde filling (49). However, MTA has well-recognized drawbacks, including a prolonged setting time, difficult handling and notable coronal discoloration owing to the presence of bismuth oxide (48,50). Specifically, interactions between bismuth oxide and sodium hypochlorite irrigant, dentine, collagen or blood can generate dark precipitates, resulting in clinically visible tooth discoloration (51). Notably, not all MTA-derived materials exhibit this drawback. Newer formulations that replace bismuth oxide with alternative radiopacifiers, such as zirconium oxide, have demonstrated improved color stability. For instance, Biodentine (Septodont Holding), which uses zirconium oxide as a radiopacifier, exhibits notably less tooth discoloration than bismuth oxide-containing MTA (52). A systematic review further noted that Biodentine has a low risk of discoloration (51). iRoot BP Plus (Innovative BioCeramix, Inc.) belongs to the same zirconium oxide-based category; it not only prevents the discoloration risk associated with traditional MTA but also offers favorable biocompatibility and osteogenic properties (45,53). In the present case report, iRoot BP Plus was selected as the coronal sealing material.

Sodium hypochlorite is widely used as a benchmark irrigant in endodontics because of its strong antimicrobial activity and its capacity to dissolve organic tissues (54). A recent systematic review reaffirmed its superior disinfection efficacy while cautioning that improper handling is associated with a higher risk of adverse events (55). When sodium hypochlorite is inadvertently extruded beyond the root apex, patients typically present with a triad of sudden-onset severe pain, soft tissue edema and ecchymosis, while neurological impairment and tissue necrosis have also been documented (56,57). Preventive strategies include the routine use of a rubber dam, irrigation with side-vented needles, gentle rather than forceful flushing and positioning the needle tip at least 2 mm coronal to the working length (58). In the event of an accident, the recommended management consists of pain relief with analgesics, application of extraoral cold compresses and antibiotic administration when a secondary infection is suspected. With conservative measures alone, 76% of patients achieve complete recovery, whereas the remaining 24% may ultimately require surgical intervention (56). No sodium hypochlorite-related adverse events were observed in either of the present cases.

It is widely acknowledged that autologous platelet concentrates (APCs), including PRP and PRF, are useful alternatives to periapical blood clot frequently employed in RET to provide scaffolds rich in growth factors (59,60). However, the acquisition of PRP and PRF from peripheral blood relies on the expertise of a qualified and well-trained nurse rather than being a task typically performed by a dentist. The preparation of PRP or PRF is a relatively complex and time-consuming process, encompassing blood sample collection, anticoagulant administration, high-speed centrifugation and blood cell removal (61). Therefore, the aforementioned modified method of harvesting ADAB from the intraoral maxillary region was developed, which differs from conventional PRF preparation. This technique can be performed by a dentist alone, without the assistance of a nurse, and is particularly useful in cases where periapical blood is insufficient to adequately fill the root canals.

Additionally, unlike APCs that are derived from peripheral venous blood, ADAB originates from the alveolar bone, a feature that may theoretically offer a therapeutic advantage in the management of periapical lesions. This local origin may provide a more favorable biological milieu for bone regeneration. However, further studies are required to confirm this hypothesis. The cellular composition of ADAB (white blood cells, red blood cells, platelets, neutrophils, lymphocytes, monocytes, eosinophils and basophils) is similar to that of peripheral blood (62). Moreover, bone marrow stromal cells (BMSCs) are considered one of the most promising cell types for dental pulp regeneration (63). A previous study reported the successful extraction and *in vitro* expansion of BMSCs using aspirated fluid from the alveolar bone (64). However, whether ADAB contains BMSCs requires supporting evidence, as the puncture depth in this procedure does not reach the bone marrow, in contrast to the alveolar bone exposure described previously (64). Finally, the platelet count in ADAB is ~50% of that in the peripheral venous blood, as confirmed in our previous study (41). Given this reduction, the platelet-derived growth factor (PDGF) level in ADAB is likely to be lower than that in the peripheral venous blood. However, the concentrations of other growth factors relevant to pulp regeneration and alveolar bone reconstruction are yet to be determined. A high-density apical image suggestive of rapid osteogenesis was reported in our previous study (62), which is typically seen in stage IV teeth (65). This finding indirectly suggests that despite potentially lower PDGF levels, ADAB may contain relatively higher levels of other osteogenic growth factors, which may become concentrated within the narrow apical foramen of stage IV teeth to enhance healing. Thus, ADAB may offer potential benefits in periapical defect recovery. However, as no direct comparative studies between ADAB and APCs or periapical clots have been conducted, this hypothesis requires further investigation in future studies. Collectively, the novelty of the ADAB-harvesting method lies in its dentist-performed, nurse-independent intraoral approach, its origin from alveolar bone rather than peripheral blood and its potential to concentrate osteogenic growth factors despite the possibly lower PDGF levels.

An ADAB clot was first employed in a mature permanent premolar with apical periodontitis (19) and was later introduced in immature teeth to facilitate root regrowth (62) in our previous studies. However, neither of these prior investigations addressed the management of root resorption. Therefore, to the best of our knowledge, case 2 is the first report of the use of ADAB to manage IRR in a mature premolar associated with a periapical lesion. This represents a novel extension of the clinical indications for ADAB-based RET. In the present case, marked healing of the periapical bone defect was observed, with no discernible progression of the preexisting external IRR. These observations indicate that an ADAB clot may be a suitable scaffold for RET. Based on the present case and a previously published report (19), the use of ADAB in RET appears to have the potential to address both the healing of periapical defects and IRR.

However, the advantages of ADAB remain hypothetical at this stage for several reasons. First, the biological rationale is based on indirect evidence from a study on bone marrow aspirates, rather than on direct ADAB research (64). Second, the platelet count in ADAB is ~50% of that in peripheral blood (62), and the concentrations and types of growth factors relevant to pulp and bone regeneration remain unknown. Third, controlled clinical or biological validations have not been conducted. Therefore, although the outcomes are encouraging, the observed findings do not constitute proof of ADAB efficacy. Preclinical and clinical studies are required before ADAB can be recommended for routine use in the treatment of periapical lesions and IRR.

Reiterating operational safety measures and precautions regarding ADAB acquisition is considered necessary, although these details were thoroughly discussed in our previous case report (19). Postoperative pain and the risk of hematoma or damage to anatomical structures are primary concerns. The choice of an 18-gauge needle was based on technical necessity: The alveolar bone is relatively hard, and a finer needle (such as 25G) would be prone to bending or breaking under the required force, as well as clogging or yielding an insufficient aspirate volume. Therefore, an 18-gauge needle was used to ensure adequate sample volume, prevent obstruction and avoid needle fracture. Nevertheless, this larger gauge may theoretically increase the potential risks of pain, bleeding, hematoma damage to adjacent structures (such as tooth roots and the maxillary sinus) and infection. However, these risks can be effectively minimized by careful control of the puncture angle and depth. The insertion point was located at the oral vestibular sulcus of the terminal maxillary molar. An incremental force was applied to the intraoral tissues rather than a sudden, excessive force. The puncture angle was maintained perpendicular to the buccal surface of the alveolar bone at the level of the oral vestibular sulcus, with the puncture depth limited to <2 mm. No pain, bleeding, hematoma or infection was observed at the puncture site after the procedure in case 2. Nevertheless, the therapeutic assessment of ADAB clots is currently limited to a few case reports, and comprehensive clinical trials are lacking. Furthermore, the constituents of ADAB need to be ascertained, as the cell types and growth factors present in ADAB are currently unknown. Osteogenic and pulp regeneration-related growth factors in ADAB may represent promising research directions.

Based on the present two cases, it is suggested that RET can be considered for managing IRR, including complex cases with perforations or separated apical segments. ADAB clots obtained via maxillary terminal alveolar bone paracentesis may be feasible for managing the associated periapical lesions and IRR. Nevertheless, given the inherent limitations of these case reports (such as small sample size and lack of CBCT), and the fact that the cellular composition, growth factor profile and comparative efficacy of ADAB vs. peripheral blood remain largely undefined, further clinical and laboratory studies are required to validate these findings.

Acknowledgements

Not applicable.

Funding

No funding was received.

Availability of data and materials

The data generated in the present study are included in the figures and/or tables of this article.

Authors' contributions

QW contributed to the conception and design of the study, performed the clinical procedures, acquired the clinical and radiographic data, analyzed and interpreted the data, and drafted the original manuscript. DJY contributed to the conception and design of the study, provided supervisory guidance throughout the clinical management and data interpretation, and critically reviewed and revised the manuscript for important intellectual content. QW and DJY confirm the authenticity of all the raw data. Both authors have read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Written informed consent was obtained from the patients' parents/legal guardians for publication of this case report and any accompanying images.

Competing interests

The authors declare that they have no competing interests.

References

1. Lin S, Moreinos D, Kaufman AY and Abbott PV: Tooth resorption - part 1: The evolvement, rationales and controversies of tooth resorption. Dent Traumatol 38: 253-266, 2022.
2. Patel S and Saberi N: The ins and outs of root resorption. Br Dent J 224: 691-699, 2018.
3. Lin S, Marvidou AM, Novak R, Moreinos D, Abbott PV and Rotstein I: Pathogenesis of non-infection related inflammatory root resorption in permanent teeth: A narrative review. Int Endod J 56: 1432-1445, 2023.
4. Estrela C, Decurcio DA, Rossi-Fedele G, Silva JA, Guedes OA and Borges ÁH: Root perforations: A review of diagnosis, prognosis and materials. Braz Oral Res 32 (suppl 1): e73, 2018.
5. Patel S, Saberi N, Pimental T and Teng PH: Present status and future directions: Root resorption. Int Endod J 55 (Suppl 4): S892-S921, 2022.
6. Heboyan A, Avetisyan A, Karobari MI, Marya A, Khurshid Z, Rokaya D, Zafar MS and Fernandes GVO: Tooth root resorption: A review. Sci Prog 105: 368504221109217, 2022.
7. Aktemur Türker S, Uzunoğlu E, Deniz Sungur D and Tek V: Fracture resistance of teeth with simulated perforating internal resorption cavities repaired with different calcium silicate-based cements and backfilling materials. J Endod 44: 860-863, 2018.
8. Arnold M: Reparative endodontic treatment of a perforating internal inflammatory root resorption: A case report. J Endod 47: 146-155, 2021.
9. Abdullah D, Eziana Hussein F and Abd Ghani H: Management of perforating idiopathic internal root resorption. Iran Endod J 12: 257-260, 2017.
10. American Association of Endodontists (AAE): Glossary of endodontic terms. AAE, Chicago, IL, 2020.
11. Liu ZY and Yuan GH: Clinical manifestations, pathogenesis, and management strategies for permanent teeth with external root resorption after trauma. Zhonghua Kou Qiang Yi Xue Za Zhi 58: 1190-1196, 2023 (In Chinese).
12. Saoud TM, Mistry S, Kahler B, Sigurdsson A and Lin LM: Regenerative endodontic procedures for traumatized teeth after horizontal root fracture, avulsion, and perforating root resorption. J Endod 42: 1476-1482, 2016.
13. Kaval ME, Güneri P and Çalışkan MK: Regenerative endodontic treatment of perforated internal root resorption: A case report. Int Endod J 51: 128-137, 2018.
14. Yoshpe M, Einy S, Ruparel N, Lin S and Kaufman AY: Regenerative endodontics: A potential solution for external root resorption (Case Series). J Endod 46: 192-199, 2020.
15. Lu J, Liu H, Lu Z, Kahler B and Lin LM: Regenerative endodontic procedures for traumatized immature permanent teeth with severe external root resorption and root perforation. J Endod 46: 1610-1615, 2020.
16. Lu J, Lu Y, Lu Z and Kahler B: Clinical and radiographic outcomes of regenerative endodontic procedures for traumatized permanent necrotic teeth with apical periodontitis and external root resorption. Int Endod J 56: 802-818, 2023.
17. Nageh M, Ibrahim LA, AbuNaeem FM and Salam E: Management of internal inflammatory root resorption using injectable platelet-rich fibrin revascularization technique: a clinical study with cone-beam computed tomography evaluation. Clin Oral Investig 26: 1505-1516, 2022.
18. Erdogan O, Casey SM, Bahammam A, Son M, Mora M, Park G, Fox D, Flake N, Khan A and Gibbs JL: Radiographic evaluation of regenerative endodontic procedures and apexification treatments with the assessment of external root resorption. J Endod 50: 1420-1428.e1, 2024.
19. Wu Q: Regenerative endodontic treatment using autologous blood from alveolar bone for mature permanent premolar with apical periodontitis: A case report. Clin Oral Investig 27: 4869-4874, 2023.
20. American Dental Association (ADA): ADA Universal Tooth Designation System. ADA, Chicago, IL, 1994.
21. Rao YG, Guo LY and Tao HT: Multiple dens evaginatus of premolars and molars in Chinese dentition: A case report and literature review. Int J Oral Sci 2: 177-180, 2010.
22. Ge LH: Pediatric Dentistry. People's Medical Publishing House, Beijing, 2013.
23. Du Y WL, Zhou ZF, Chen YJ and Wang XJ: New advances in clinical prevention and treatment of fractured dens evaginatus. Chinese Journal of Stomatological Research (Electronic Edition) 11: 45-18, 2017.
24. Loroño G, Jesús Conde A, Estévez R, Brizuela C, Cisneros R and Alfayate RP: Regenerative endodontic procedure in an immature permanent incisor with internal root resorption: A case report. J Dent (Shiraz) 23: 155-160, 2022.
25. Priya MH, Tambakad PB and Naidu J: Pulp and periodontal regeneration of an avulsed permanent mature incisor using platelet-rich plasma after delayed replantation: A 12-month clinical case study. J Endod 42: 66-71, 2016.
26. Lin S, Moreinos D, Wisblech D and Rotstein I: Regenerative endodontic therapy for external inflammatory lateral resorption following traumatic dental injuries: Evidence assessment of best practices. Int Endod J 55: 1165-1176, 2022.
27. Tzanetakis GN: Management of intruded immature maxillary central incisor with pulp necrosis and severe external resorption by regenerative approach. J Endod 44: 245-249, 2018.
28. Chaniotis A: The use of a single-step regenerative approach for the treatment of a replanted mandibular central incisor with severe resorption. Int Endod J 49: 802-812, 2016.
29. Santiago CN, Pinto SS, Sassone LM, Hirata R Jr and Fidel SR: Revascularization technique for the treatment of external inflammatory root resorption: A report of 3 cases. J Endod 41: 1560-1564, 2015.
30. Nayak MT and Nayak A: External inflammatory root resorption in mandibular first molar: A case report. Malays J Med Sci 22: 63-66, 2015.
31. Glynis A, Foschi F, Kefalou I, Koletsi D and Tzanetakis GN: Regenerative endodontic procedures for the treatment of necrotic mature teeth with apical periodontitis: A systematic review and meta-analysis of Randomized controlled trials. J Endod 47: 873-882, 2021.
32. Liu H, Lu L, Xu K and Shen Y: Treatment outcomes and prognostic factors of the apical barrier technique with premixed calcium silicate-based putty in necrotic permanent teeth with open apices: A retrospective cohort study with up to six years follow-up. Clin Oral Investig 28: 425, 2024.
33. Torabinejad M and Chivian N: Clinical applications of mineral trioxide aggregate. J Endod 25: 197-205, 1999.
34. Setzer FC, Shah SB, Kohli MR, Karabucak B and Kim S: Outcome of endodontic surgery: A meta-analysis of the literature-part 1: Comparison of traditional root-end surgery and endodontic microsurgery. J Endod 36: 1757-1765, 2010.
35. Kim S and Kratchman S: Modern endodontic surgery concepts and practice: A review. J Endod 32: 601-623, 2006.

36. Raza M, Pasha SK and Valli SZ: Nonsurgical management of horizontal root fracture associated external root resorption and internal root resorption. Indian J Dent Sci 8: 150-153, 2016.
37. Özler CO and Cehreli ZC: Conservative management of a cervical horizontal root fracture by long-term stabilisation: A case report. Aust Endod J 48: 338-341, 2022.
38. Vo TTT and Do TNA: Delayed management of concurrent coronal extrusions and root fractures in two traumatized maxillary immature permanent central incisors: A case study. J Clin Med 14: 3605, 2025.
39. Westphalen VPD, Carneiro E, Fariniuk LF, da Silva Neto UX, Westphalen FH and Kowalczuck A: Maintenance of pulp after horizontal root fractures in three maxillary incisors: A thirteen-year evaluation. Iran Endod J 12: 508-511, 2017.
40. Dadpe AM, Shah DY, Natanasabapathy V, Sureshbabu NM, Hindlekar AN and Modi K: Regenerative endodontic procedures in teeth with root resorption: A systematic review. Eur Endod J 8: 170-186, 2023.
41. Welbury R, Kinirons MJ, Day P, Humphreys K and Gregg TA: Outcomes for root-fractured permanent incisors: A retrospective study. Pediatr Dent 24: 98-102, 2002.
42. Wölner-Hanssen AB and von Arx T: Permanent teeth with horizontal root fractures after dental trauma. A retrospective study. Schweiz Monatsschr Zahnmed 120: 200-212, 2010.
43. Patel S, Ricucci D, Durak C and Tay F: Internal root resorption: A review. J Endod 36: 1107-1121, 2010.
44. Herweijer JA, Torabinejad M and Bakland LK: Healing of horizontal root fractures. J Endod 18: 118-122, 1992.
45. M R, Shetty K, Mallya L and Shetty KP: Endodontic bioceramics: Current and futurity aspects. Front Oral Health 6: 1699547, 2026.
46. Rabello CZ, Kopper PMP, Ferri LJM, Signor B, Hashizumi LN, Fontanella VRC, Grecca FS and Scarparo RK: Physicochemical properties of three bioceramic cements. Braz Oral Res 36: e069, 2022.
47. Escobar-García DM, Medina-Rosas MG, González-Amaro AM, Méndez-González V, Flores H and Pozos-Guillén A: MTA-Based cements: Biocompatibility and effects on the gene expression of collagen type 1 and TGF-β1. Biomed Res Int 2022: 2204698, 2022.
48. Palczewska-Komsa M, Kaczor-Wiankowska K and Nowicka A: New bioactive calcium silicate cement mineral trioxide aggregate repair high plasticity (MTA HP)-A systematic review. Materials (Basel) 14: 4573, 2021.
49. Dong X and Xu X: Bioceramics in endodontics: Updates and future perspectives. Bioengineering (Basel) 10: 354, 2023.
50. Torabinejad M, Parirokh M and Dummer PMH: Mineral trioxide aggregate and other bioactive endodontic cements: An updated overview - part II: Other clinical applications and complications. Int Endod J 51: 284-317, 2018.
51. Misra R, Toprani N, Bhagwat S, Vaishnav A, Dureja A and Bhosale O: Efficacy of mineral trioxide aggregate versus biodentine as a direct pulp capping material in carious human mature permanent teeth: A systematic review. Cureus 17: e89154, 2025.
52. Oliveira LV, da Silva GR, Souza GL, Magalhães TEA, Barbosa GLR, Turrioni AP and Moura CCG: A laboratory evaluation of cell viability, radiopacity and tooth discoloration induced by regenerative endodontic materials. Int Endod J 53: 1140-1152, 2020.
53. Zheng JJ, Kang XY, Li SM, Liu JC, Sun K, Gao L and Hou TZ: Effects of MTA, iRoot SP and AH Plus on proliferation and differentiation of human periodontal ligament stem cells. Shanghai Kou Qiang Yi Xue 29: 449-455, 2020 (In Chinese).
54. Zehnder M: Root canal irrigants. J Endod 32: 389-398, 2006.
55. Fiorillo L, D'Amico C, Meto A, Mehta V, Lo Giudice G and Cervino G: Sodium hypochlorite accidents in endodontic practice: Clinical evidence and state of the art. J Craniofac Surg 35: e636-e645, 2024.
56. Kartit Z, Delacroix C, Clement C, Beurrier M, Mouton-Faivre C and Petitpain N: Sodium hypochlorite accident diagnosis and management: Analysis from the literature and the French pharmacovigilance database. Fundam Clin Pharmacol 38: 630-639, 2024.
57. Motta MV, Chaves-Mendonca MA, Stirton CG and Cardozo HF: Accidental injection with sodium hypochlorite: Report of a case. Int Endod J 42: 175-182, 2009.
58. Kleier DJ, Averbach RE and Mehdipour O: The sodium hypochlorite accident: Experience of diplomates of the American board of endodontics. J Endod 34: 1346-1350, 2008.
59. Riaz A and Shah FA: Regenerating the pulp-dentine complex using autologous platelet concentrates: A critical appraisal of the current histological evidence. Tissue Eng Regen Med 18: 37-48, 2021.
60. Ulusoy AT, Turedi I, Cimen M and Cehreli ZC: Evaluation of blood clot, platelet-rich plasma, platelet-rich fibrin, and platelet pellet as scaffolds in regenerative endodontic treatment: A prospective randomized trial. J Endod 45: 560-566, 2019.
61. Kobayashi E, Flückiger L, Fujioka-Kobayashi M, Sawada K, Sculean A, Schaller B and Miron RJ: Comparative release of growth factors from PRP, PRF, and advanced-PRF. Clin Oral Investig 20: 2353-2360, 2016.
62. Wu Q, Zhang L and Lu Y: An observational study of alveolar-derived autologous blood clot used in regenerative endodontic treatment for immature permanent teeth with pulp necrosis. Clin Oral Investig 29: 103, 2025.
63. Gomez-Sosa JF, Cardier JE, Wittig O, Díaz-Solano D, Lara E, Duque K and Ramos-González G: Allogeneic bone marrow mesenchymal stromal cell transplantation induces dentin pulp complex-like formation in immature teeth with pulp necrosis and apical periodontitis. J Endod 50: 483-492, 2024.
64. Matsubara T, Suardita K, Ishii M, Sugiyama M, Igarashi A, Oda R, Nishimura M, Saito M, Nakagawa K, Yamanaka K, *et al*: Alveolar bone marrow as a cell source for regenerative medicine: Differences between alveolar and iliac bone marrow stromal cells. J Bone Miner Res 20: 399-409, 2005.
65. Cvek M: Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. Endod Dent Traumatol 8: 45-55, 1992.

Copyright © 2026 Wu and Yen. This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) License.