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ORIGINAL PAPER

External root resorptions: cone-beam computed tomography assessment and histopathological characterization

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Abstract

Background: External root resorption (ERR) represents a pathological condition of uncertain etiology and variable clinical presentation that can jeopardize the long-term prognosis of affected teeth. *Aim*: This study aimed to correlate radiological (cone-beam computed tomography – CBCT) and histological findings in three teeth affected by ERR with different localization (apical, middle or cervical), with a focus on the structural changes of the dental hard and soft tissues. *Materials and Methods*: Two monoradicular and one pluriradicular teeth diagnosed with ERR and external cervical resorption (ECR) based on initial periapical radiography were analyzed using CBCT and lesions were measured in all three planes and described after Patel's classification; after extraction/root amputation, samples were decalcified and processed using standard histological techniques (Hematoxylin–Eosin, van Gieson, Masson's trichrome). *Results*: Several key features were noticed at the site of resorptive areas: osteoclasts, large multinucleated cells responsible for the resorption of mineralized tissues positioned along the root surface, resulting in the formation of resorption lacunae. Adjacent to the resorptive areas, granulation tissue, with a dense network of capillaries and inflammatory cells, including fibroblasts. Extensive destruction of dentin, cementum, and enamel, presence of fibrous repair, osteoid formation, and dystrophic calcifications were noticed. *Conclusions*: The combined radiological–histological evaluation enhances diagnostic accuracy and may guide therapeutic strategies.

Keywords: external root resorption, external cervical resorption, cone-beam computed tomography.

Introduction

External root resorption (ERR) is a pathological, non-bacterial process that leads to the almost irreversible destruction of cementum, dentin, and/or enamel, affecting both vital and non-vital teeth because of odontoclastic function [1]. A distinct and increasingly recognized subtype of ERR is external cervical resorption (ECR), which is an insidious, often asymptomatic condition characterized by the progressive loss of dental hard tissues at the cervical area of the root, just apical to the epithelial attachment [2]. It is a multifactorial phenomenon, associated with etiological factors such as orthodontic treatment, dental trauma, internal bleaching, and periodontal surgery [2–4]. Various terms have been used to describe ECR, including invasive cervical resorption, odontoclastoma, idiopathic external resorption, invasive extra-canal resorption, peripheral cervical resorption, supra-osseous inflammatory root resorption, subepithelial inflammatory resorption, and infectious periodontal resorption [5]. ECR frequently presents as an incidental radiographic finding, as the resorptive process typically occurs without pain or overt clinical symptoms [3–5].

The classification and diagnosis of ECR have evolved significantly, especially with the advent of cone-beam computed tomography (CBCT), which provides a detailed three-dimensional (3D) assessment of the lesion's location, depth, and relationship to surrounding structures [6–8]. CBCT allows superior spatial resolution and eliminates superimposition of anatomical structures, thus enabling early detection of resorptive defects that may be missed on periapical radiographs [9–11]. Estrela *et al.* demonstrated that CBCT could identify inflammatory root resorption with greater sensitivity compared to traditional radiography [9]. Patel *et al.* proposed a 3D classification based on the lesion's circumferential spread, height, and proximity to the root canal, which is now widely used in clinical settings [5, 10, 11]. The diagnostic advantages of CBCT have made it the "gold standard" in modern ECR evaluation, facilitating treatment planning and prognosis prediction [7, 12].

Histopathologically, ECR is defined by the presence of resorptive lacunae, multinucleated odontoclasts, inflammatory infiltrate, and reparative attempts in the form of fibrous tissue and osteoid formation [3]. The progression of ECR is marked by its infiltrative nature, often extending through dentin and cementum, and occasionally breaching into the pulp space [3, 6]. ECR is a dynamic and multifactorial process, described by Mavridou *et al.* as occurring in three distinct phases [3, 11]. The initiation phase, which is triggered by a disturbance or damage to the periodontal ligament (PDL) and the protective unmineralized cementum layer. This injury permits an inflammatory response, allowing immune cells such as macrophages to infiltrate the area and form granulation tissue, which attaches to the exposed dentin surfaces [3, 5]. Propagation (extension) phase – as the lesion advances, it spreads in a circumferential and apico-coronal direction along the root surface, destroying cementum, dentin, and possibly enamel. The pulp remains vital during this stage, shielded by a layer of predentin. The lesion may develop internal tunnels or channels, often described as "portals of entry" and "portals of exit", which can interconnect with the PDL [3, 5]. Repair phase, which in certain areas of the lesion, may occur simultaneously with active resorption. Osteoblast-like cells begin to deposit bone-like tissue within the defect. This reparative tissue may resemble lamellar or trabecular bone and may contain osteocytes and osteoid material [3, 5]. The presence of this bone-like tissue represents an attempt by the body to limit or heal the lesion. However, this repair is often incomplete and may not prevent further progression if resorptive stimuli persist [13, 14].

Histological analysis not only confirms the extent of tissue loss but also provides insight into the biological response of the pulp–dentin complex and periodontal structures [13, 14].

The treatment of ECR depends on the lesion's location, extent, and proximity to the pulp [15]. Small, accessible lesions may be treated externally – either surgically or non-surgically – removing granulation tissue and restoring the defect with glass ionomer or bioceramic materials like mineral trioxide aggregate (MTA) or Biodentine. If the lesion is inaccessible externally or perforates the root canal, an internal approach is indicated, requiring endodontic treatment followed by restoration of the defect from within the canal [16, 17]. Bioceramic materials are preferred as they promote regeneration of cementum and bone [18, 19]. Although conservative and minimally invasive treatments are preferred, extraction may become necessary when the resorptive lesion is extensive, inaccessible, or unresponsive to treatment, particularly if it compromises the tooth's structural integrity, prevents adequate sealing, or leads to persistent bleeding and infection [13, 16].

The present study focuses on three cases, exhibiting extensive resorptive lesions, two extracted teeth affected by 3Bp class ECR and one amputated distobuccal root of tooth #1.7, affected by 2Bp class ECR, integrating CBCT with histological findings to better understand the cellular and structural changes induced by the resorptive process.

Aim

The aim of this study was to perform a detailed histological investigation of three clinical cases presenting ERR/ECR, in order to characterize the structural features of the lesions, identify the involved hard and soft tissues, and explore potential correlations between histopathological (HP) findings and etiological factors such as trauma, orthodontic treatment, or periodontal inflammation. This integrated analysis is intended to support improved diagnostic accuracy and guide more effective therapeutic strategies.

Materials and Methods

The present study included three clinical cases diagnosed with external root or cervical resorptions: two extracted teeth and one amputated root, based on the initial periapical radiography and clinical examination.

Teeth were more accurately diagnosed following a CBCT investigation at the beginning of the treatment, with specifications as follows: a 5×5 cm field of view (FOV), an 85 μm voxel size, 90 kV, 6.3 mA, and an 8.70 s exposure time or 8 Å~ 15 cm FOV, 250 μm voxel size, 90 kV, 7.1 mA, and 8.14 s emission. For analysis and measurements, the OnDemand3D software (OP 3D™ Pro, KaVo Dental GmbH, Biberach, Germany). On the CBCT, each lesion was measured in all three planes and classified according to Patel's classification.

Case No. 1 – Tooth #2.2: Advanced combined internal and external root resorption

The patient presented for prosthetic rehabilitation requiring endodontic treatment of tooth #2.2. During access cavity preparation, persistent and profuse bleeding prevented the determination of the working length and the proper instrumentation of the root canal. Initial periapical radiography showed two radiolucent areas overlapping the root canal outline, raising suspicion of combined internal root resorption and ERR (Figure 1).

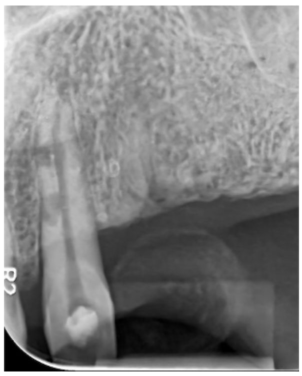

Figure 1 – ***Periapical radiograph of tooth #2.2 showing the presence of two distinct radiolucent areas at two different levels of the root.***

After two sessions of calcium hydroxide used as an interim medication, the tooth still exhibited significant bleeding. At this point, a CBCT-endo, a 3D radiological investigation, was performed to assess the situation (Figure 2).

CBCT imaging revealed two distinct lesions:

▪ A mid-root resorptive lesion, extending subcrestally with a circumferential spread of 90–180°, and clearly perforating into the root canal, was classified as Patel 3Bp class.

▪ A second resorptive lesion, localized at the junction of the middle and apical third, with a circumferential spread <90°, also perforating the root canal, was classified as Patel 4Ap class (Table 1).

Both lesions were located on the mesiobuccal aspect of the root. Due to the unfavorable location and depth of the defects, surgical access was impossible, and apical surgery was contraindicated due to the risk of compromising periodontal support. The tooth was therefore extracted and sent for histological analysis (Figure 3).

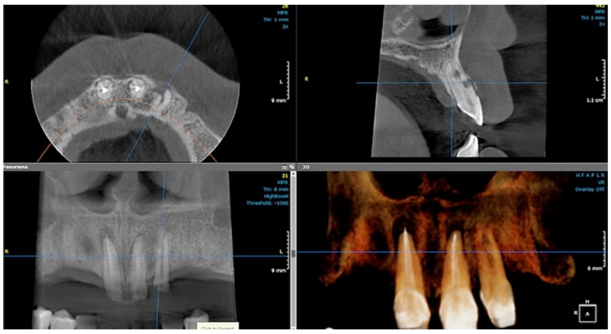

Figure 2 – ***CBCT exposing the presence of the two distinct lesions, the lateral extension of the resorption; the penetration of the lesion into the root canal and the extension under the alveolar crest. CBCT: Cone-beam computed tomography.***

Table 1 – ***Summary of resorptive lesions according to Patel's three-dimensional classification***

Sample	Vertical extension	Circumferential spread	Proximity to root canal	Classification (Patel)
Case No. 1 Tooth #2.2	Apical third	>90°	Probable pulpal involvement	4Ap
	Middle third	90–180°	Probable pulpal involvement	3Bp
Case No. 2 Tooth #1.7 (distobuccal root)	Coronal and middle third subcrestal	90–180°	Probable pulpal involvement	3Bp
Case No. 3 Tooth #3.5	Coronal third, subcrestal	90–180°	Probable pulpal involvement	2Bp

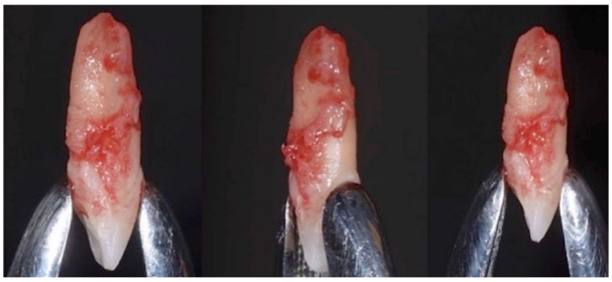

Figure 3 – ***Tooth #2.2 extracted.***

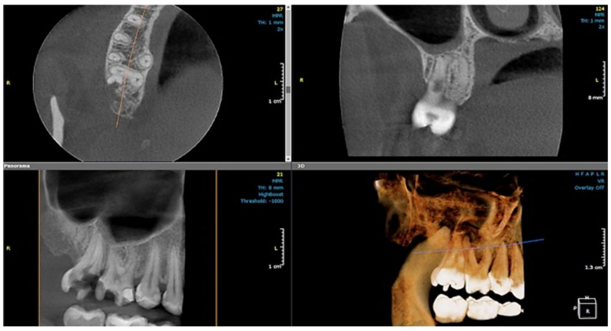

Figure 4 – ***Initial CBCT scans showing the lateral extension of the resorption; the penetration of the lesion into the root canal and the extension under the alveolar crest.***

Case No. 2 – Tooth #1.7: ECR in the distobuccal root and conservative root amputation

The patient reported localized pain in the maxillary right posterior region. Clinical examination revealed a large, infiltrated coronal restoration on tooth #1.7. Sensitivity testing with air and cold stimuli elicited an intense and prolonged pain response. The gingival tissues appeared clinically healthy.

A CBCT scan was performed, which revealed a well-defined ECR lesion affecting the distobuccal root of tooth #1.7 (Figure 4). The lesion extended subcrestally, with a circumferential spread of 90° to 180°, and showed clear communication with the root canal system – consistent with Patel 3Bp class (Table 1). No associated periapical radiolucency or vertical root fracture was detected. Based on the CBCT findings and pulpal diagnosis of symptomatic irreversible pulpitis, a non-surgical internal repair approach was initiated. Calcium hydroxide was placed as an inter-appointment intracanal medicament to control bleeding. Despite two treatment sessions, persistent hemorrhage from the distobuccal canal precluded successful canal debridement and disinfection and prevented assessment of the full extent of the defect internally.

In order to avoid complete tooth extraction and preserve function, a conservative hemisection was performed. The distobuccal root was extracted, while the mesiobuccal and palatal roots were endodontically treated, restored, and maintained in occlusion.

Case No. 3 – Tooth #3.5: Asymptomatic, extensive ECR with pulpal involvement

This patient was asymptomatic, and the lesion was identified incidentally during a routine radiographic examination. Clinical inspection revealed no tooth discoloration, gingival inflammation, or periodontal pathology.

CBCT revealed a well-defined ECR lesion on the mesial surface of tooth #3.5, located subcrestally and characterized by a circumferential spread between 90° and 180°, with perforation into the root canal (Figure 5). The lesion was classified as Patel 2Bp class (Table 1). Its proximity to tooth #3.4 and subgingival location rendered surgical access highly invasive, with potential damage to adjacent periodontal structures. Given these limitations, extraction was indicated.

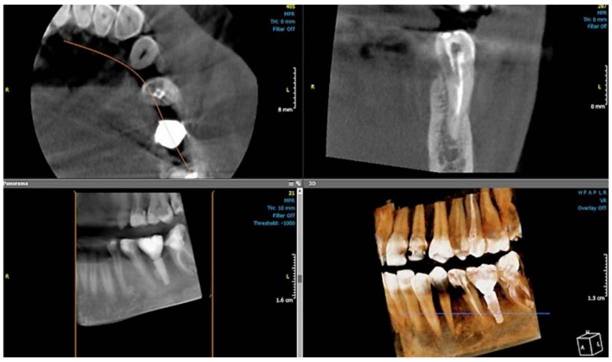

Figure 5 – ***CBCT scans showing the true extent of the resorption in all three dimensions, being classified as a 2Bp class, according to Patel's classification.***

The characteristics of the resorptive lesions observed in the three cases, classified according to Patel's 3D CBCT system, are summarized in Table 1.

All three evaluated samples, the two extracted teeth and one amputated root, followed the same collection and processing protocol after collection, namely:

(*1*) Immediately after extraction/amputation, each sample was placed in containers with fixative solution (10% neutral buffered formalin).

(*2*) Identification and coding of samples: each tooth was assigned a unique code.

(*3*) Histological processing: the samples were decalcified [in a decalcifying solution, *e.g.*, ethylenediaminetetraacetic acid (EDTA) or formic acid, following the laboratory's protocol]. The harvested specimens were fixed in 4% neutral buffered formalin. Four micrometer-thick sections were cut using an automated Leica RM2235 rotary microtome (Leica Biosystems, Nussloch, Germany) and displayed on SuperFrost™ microscope slides (St. Louis, MO, USA).

(*4*) Staining – standard staining techniques: initially, the Hematoxylin–Eosin (HE) technique was performed; to complete the microscopic diagnosis, additional histochemical staining was used. Van Gieson and Masson's trichome staining were also performed for Case No. 3.

(*5*) Analysis and interpretation of histological data: examination of resorption surfaces, identification of cell types (osteoclasts/odontoclasts, fibroblasts, osteoblast-like cells); assessment of the degree of inflammation, presence of granulation tissue, formation of new cementum, or repair areas; integration of histological findings with clinical and radiographic data for a comprehensive interpretation.

Results

Histological analysis

Histological sections stained with HE for Case No. 1 revealed an active external resorption. Numerous multinucleated osteoclast-like cells were observed along the resorptive lacunae on the dentin surface. Adjacent to these areas, granulation tissue rich in newly formed capillaries, inflammatory cells, and fibroblasts, was present. The architecture of the tissue suggested a mixed resorptive and early reparative phase, with no evidence of complete healing. The resorption extended through enamel, cementum, and dentin. These findings confirm the diagnosis of advanced ECR in an active stage, correlating closely with the CBCT findings (Figures 6–8).

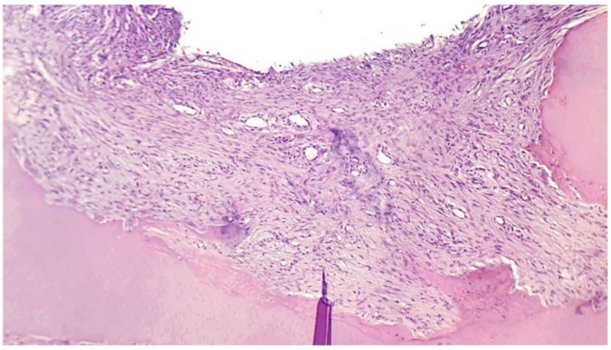

Figure 6 – ***Dentin and granulation tissue with inflammatory cells: the center shows newly formed blood vessels. Hematoxylin–Eosin (HE) staining, ×200.***

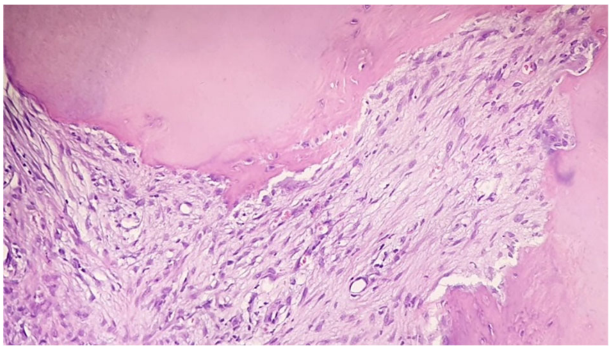

Figure 7 – ***Dentin and granulation tissue with inflammatory cells. HE staining, ×200.***

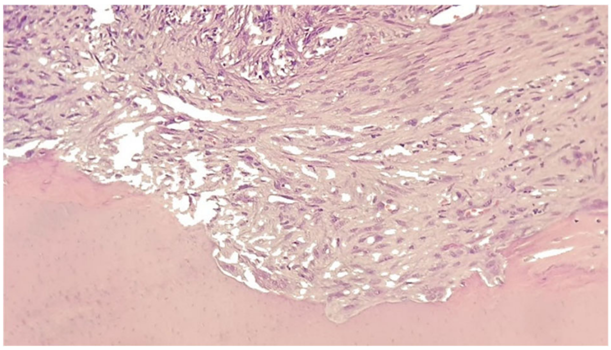

Figure 8 – ***Dentin and granulation tissue with inflammatory cells; at the periphery of granulation tissue, giant osteoclast-like cells are observed. HE staining, ×200.***

Histological examination of the extracted root in Case No. 2 revealed features characteristic of the remodeling phase of ECR. No multinucleated clastic cells or granulation tissue were identified. Instead, the defect was lined with dense, collagenized connective tissue, populated by fibroblasts and fibrocytes, suggesting tissue stabilization and an ongoing reparative response. No active inflammatory infiltrate was present. These findings indicated that although the resorptive process may have been arrested, the location and extent of the lesion, combined with persistent bleeding, necessitated the selective extraction of the affected root to enable effective treatment of the remaining structure (Figure 9).

Histological analysis of the extracted tooth in Case No. 3 demonstrated the complex anatomy of the resorptive lesion. Multiple resorption tunnels were observed, originating from a distinct portal of entry beneath the epithelial attachment, branching in various directions, and communicating with the root canal lumen. The pulp chamber contained gutta-percha, visibly extending both centrally and into adjacent dentinal tubules, confirming previous root canal treatment (Figure 10).

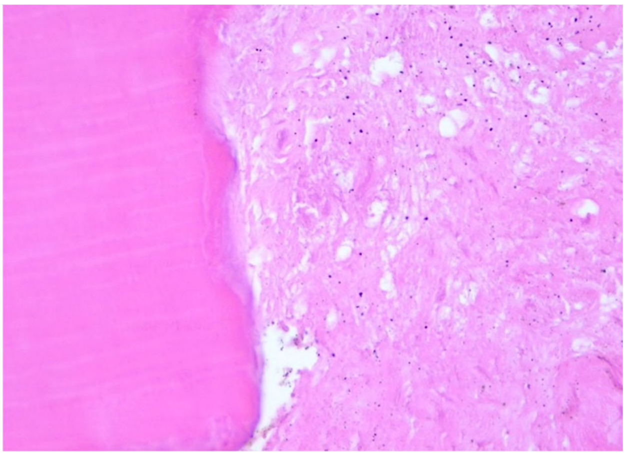

Figure 9 – ***Areas of fibrous repair at the junction with dentin: collagenized connective tissue with fibrocytes and fibroblasts. HE staining, ×400.***

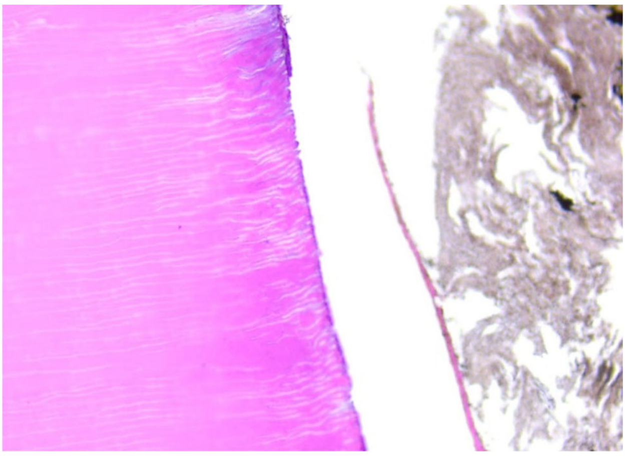

Figure 10 – ***Brown acellular material (gutta-percha) in the central area of the root pulp and enlarged dentinal tubules, with tendency to anastomose. HE staining, ×200.***

The resorptive defect was partially filled with a combination of dense fibrous connective tissue and bone-like reparative tissue, including osteoid, osteoblast-like cells, and osteocytes embedded within a mineralized matrix, indicative of a remodeling phase (Figure 11, A and B; Figure 12, A and B).

Masson's trichrome staining confirmed the presence of dense collagen fibers, both in the periradicular area and within the pulp canal. Additionally, dystrophic calcifications and vascular wall hyalinization were identified, reflecting chronic tissue changes likely resulting from a prolonged inflammatory and reparative process (Figure 13, A and B).

These HP findings suggest that the lesion had transitioned from an active resorptive phase to a stable reparative state, although the extent and complexity of the tissue destruction made functional preservation of the tooth unfeasible.

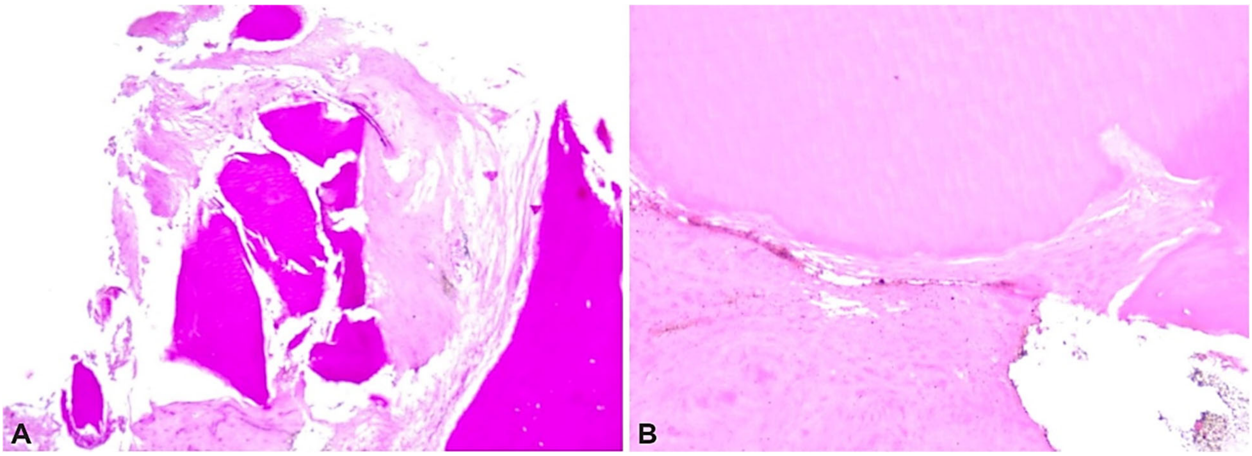

Figure 11 – ***(A) Areas of fibrous repair and bone-like tissue with osteoid formation; (B) Fibrous repair stage and bone-like tissue formation. HE staining: (A and B) ×200.***

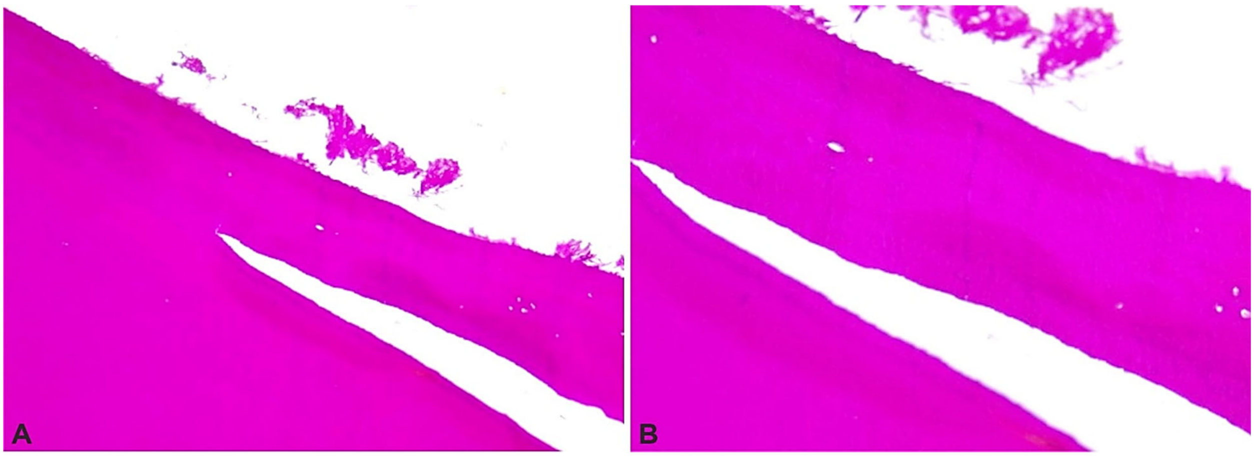

Figure 12 – ***Osteoid formation. Histochemical van Gieson staining: (A) ×100; (B) ×200.***

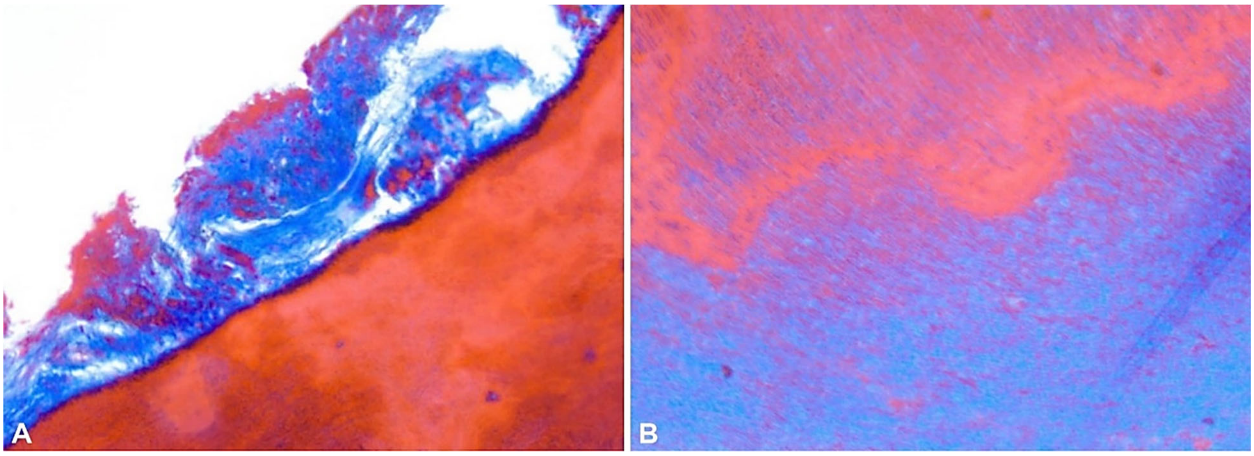

Figure 13 – ***Collagenous areas of fibrosis. Masson's trichrome staining: (A and B) ×200.***

Discussions

The challenge in managing ECR lies in its variable clinical presentation and the complexity of achieving an early and accurate diagnosis. ECR lesions are often asymptomatic in their initial phases, and by the time they become radiographically or clinically apparent, the damage may already be extensive, making therapeutic decisions more difficult and outcomes more uncertain [20].

A successful treatment strategy requires a comprehensive understanding of the lesion's location, vertical and circumferential extent, as well as its relationship to the root canal system and adjacent periodontal structures [21]. This information is critical for determining whether a conservative approach is feasible, or whether surgical intervention or extraction is warranted [7, 22].

In the present study, the three cases analyzed demonstrated distinct morphological patterns and clinical challenges, which led to different therapeutic decisions. The treatment approach was individualized based on CBCT findings and the intraoperative response to therapy.

In Cases Nos. 1 and 2, the initial treatment involved a non-surgical internal approach, consistent with current recommendations for ECR management. Internal treatment typically consists of canal debridement, intracanal disinfection (*e.g.*, calcium hydroxide), and sealing of the defect using bioactive restorative materials [16, 23, 24]. Such an approach is particularly appropriate when the lesion remains confined to the dentin and is accessible through the canal [25].

However, in both cases, the resorptive lesions were not amenable to internal repair, as they were positioned subcrestally and had perforated into the root canal system, making adequate sealing impossible. In addition, persistent hemorrhage during canal instrumentation, despite the use of calcium hydroxide, prevented visualization and proper defect management. These findings are consistent with the literature, which identifies uncontrolled bleeding and perforation as major contraindications to internal repair [16, 26].

Moreover, for Case No. 1, although CBCT revealed a lesion with characteristics of ECR, histological analysis provided additional insights that modified the initial diagnosis. Microscopic examination demonstrated not only classic signs of external resorptive activity – such as resorption lacunae on the root surface lined by multinucleated clastic cells – but also evidence of internal resorption, including irregularly enlarged dentinal tubules radiating from the pulp space. These findings indicate a combined internal–external resorptive process, underscoring the limitations of imaging alone in differentiating resorptive patterns. Similar diagnostic challenges have been reported in the literature, where trauma-induced internal resorption may coexist with external processes, particularly in cases with delayed treatment or complex lesion morphology [27]. This emphasizes the critical value of histological validation, especially when CBCT findings are ambiguous or when clinical progression deviates from typical ECR behavior.

When internal approaches fail or are deemed unsuitable, surgical access may be considered. This involves raising a mucoperiosteal flap to expose the resorptive defect, followed by curettage and restoration with a suitable material [5, 28, 29]. Surgical treatment is often the method of choice for localized, accessible lesions, particularly in the cervical region or on the facial aspect of the root [16].

However, surgical intervention presents several limitations, including tissue trauma, anatomical constraints, and risk to adjacent structures [15, 16]. In Case No. 3, the resorption was located mesially and subcrestally, in close proximity to tooth #3.4. A surgical approach would have required a wide flap and extensive bone removal, potentially jeopardizing the periodontal health of the adjacent tooth. In such cases, extraction may be the only viable and biologically acceptable solution, particularly when prognosis is poor.

Tooth extraction is generally considered a last resort in the management of ECR. However, it becomes necessary when: the lesion is extensive or inaccessible, there is persistent hemorrhage, internal and surgical approaches are contraindicated or unsuccessful and structural integrity is compromised [5, 15, 16].

In this study, two teeth were extracted, and one root was selectively amputated. Notably, extraction allowed for HP analysis, which added diagnostic value and confirmed the stage and biological activity of the lesion.

High-resolution CBCT (HRCBCT) was used in all three cases and proved critical for: localizing the lesion in three dimensions, classifying its extent (using Patel's system), identifying perforations and proximity to the pulp and supporting decisions about feasibility of repair.

CBCT's diagnostic value in general dentistry [30] and endodontics [31] far exceeds that of conventional periapical radiographs and especially in detecting early and subcrestal ECR lesions that are often missed in two-dimensional (2D) imaging [32, 33].

In all cases, CBCT assessment guided the clinical decision-making, helping to determine whether conservative treatment was possible or whether extraction was indicated. The integration of imaging with clinical and histological findings represents a modern, evidence-based approach to ECR management [34, 35].

This study underscores several key clinical considerations in the management of ECR. Persistent bleeding during canal access may indicate the presence of highly vascularized resorptive tissue and should prompt immediate evaluation using CBCT. In multirooted teeth with localized ECR, selective root amputation can offer a conservative alternative to full extraction, allowing for the preservation of occlusal function. Importantly, even in the absence of symptoms, asymptomatic lesions may progress silently, reinforcing the need for routine radiographic monitoring, especially in patients with known risk factors such as prior orthodontic treatment, trauma, or periodontal surgery. Although rarely performed *in vivo*, histological analysis of extracted teeth provides critical post-treatment insights, confirming clinical and radiographic findings and informing future case management strategies.

Conclusions

This study highlights the diagnostic and therapeutic challenges posed by ECR, especially in advanced stages where lesions may extend subcrestally and perforate the root canal system. The three cases analyzed demonstrate the variable progression of ECR and the necessity of individualized treatment strategies, based on clinical presentation, CBCT findings, and intraoperative responses. Histological analysis of the extracted samples confirmed the biological heterogeneity of ECR, revealing active resorptive processes, reparative attempts, and late-stage remodeling. These findings provide valuable insights into the tissue dynamics involved in resorption, including the roles of osteoclasts, fibroblasts, granulation tissue, and osteoid deposition.

HRCBCT proved essential in localizing and classifying the lesions, guiding treatment planning, and predicting restorability. The integration of radiological and HP evaluation enhances diagnostic accuracy, supports clinical decision-making, and allows for a better understanding of the lesion's behavior at different stages. CBCT allows for detailed visualization of the lesion's extent, localization, and relationship with surrounding structures, providing a more comprehensive understanding of the lesion's nature. The high-resolution images from CBCT help identify the 3D characteristics of the resorptive defects, including their depth and involvement of the root canal system, which may not be apparent on conventional radiographs. Furthermore, CBCT helps in the early detection of lesions, especially if they are in the initial phase and may be missed on conventional radiographs. The earlier the lesions are detected, the more conservative the therapeutic approach can be, and the tooth has a greater chance of being saved, treated, and preserved in the arch.

While conservative approaches remain preferable, extraction may be unavoidable in cases of severe tissue destruction, uncontrollable bleeding, or inaccessible defects. In such instances, histological assessment of the extracted tooth not only validates clinical and radiographic findings but also contributes to the broader understanding of resorptive mechanisms.

Conflict of interests

The authors declare no conflict of interests.

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Statement of Human and Animal Rights

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the Victor Babeş University of Medicine and Pharmacy, Timişoara (Protocol Code: 100, Date of Approval: 01.05.2020, revised 2025).

Informed Consent

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from all subjects to publish this paper.

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