

Clinical and radiographic characterization of external root resorption

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ABSTRACT

INTRODUCTION The following bibliographic review was carried out with the purpose of recognizing the clinical and radiographic characteristics that must be considered in the diagnosis of external root resorption, including treatments.

METHODS A bibliographic search was carried out in PubMed/Medline, Cochrane Library and Google Scholar databases under the term "external root resorption", from 2010 to 2022 in Spanish and English. Experimental studies and bibliographic reviews were selected, and finally 17 articles were included.

RESULTS The results indicated that each type of resorption presents specific clinical characteristics that differentiate them, these are: for external inflammatory resorption a negative pulp vitality; for replacement external resorption the absence of mobility and metallic percussion; for cervical external resorption a pink coloration of the crown; superficial external resorption does not present any type of clinical symptoms and transient apical collapse presents a transient change in color.

CONCLUSION External root resorptions require accurate and early diagnosis. A clinical examination should be performed with emphasis on probing, coloration, mobility, and vitality tests.

KEYWORDS Endodontics, external root resorption, narrative review

INTRODUCTION

External root resorption is a loss of cementum and dentin from the dental roots that starts in the periodontal ligament. This resorption is produced by multiple factors that can affect the dental root, and it is not easy to detect since it is usually asymptomatic [1]. It can be considered a physiological process in the primary dentition, corresponding to a normal evolution of exfoliation of a primary tooth, and a pathological process in the permanent dentition, in which the tooth structure is regressively altered [1,2].

Diagnosis is mainly based on radiographic methods, but a complete clinical history and adequate examination are essential to confirm the diagnosis. Such diagnosis is often challenging because it requires radiographic techniques to see the tooth in question and the adjacent bony structures

[2,3]. In addition, the two-dimensional nature of conventional radiographs shows an inaccurate image when locating the site, extent and/or type of resorption [2]. Takeshita [3] indicates that, among all root anomalies, external root resorption is the most difficult to detect with two-dimensional imaging methods. D'addazio [4] showed that in periapical radiographs, it was possible to recognize external root resorption in all cases; however, the exact location and type of resorption could not be identified.

External root resorptions usually occur in response to stimuli such as orthodontic movements, which activate specific molecular pathways that produce a non-physiological stimulation of odontoclasts. Activated odontoclasts attach to the mineral matrix, where they fuse with the cell membrane. Consequently, they release hydrogen ions and proteolytic enzymes, generating an acidic environment, and as a result, dissolution of calcified hard tissue occurs [5]. If there is injury or irritation to the tooth tissues, clastic cells will be attracted to the affected area of the root surface, and resorption occurs as part of the normal scavenging function of the cells [6]. Several factors could cause root resorption, including dental trauma, bacteria, orthodontic treatment, periodontal disease, tooth whitening, viruses, or idiopathic. Some predisposing systemic factors have

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MAIN MESSAGES

- Diagnosing external root resorptions is often challenging and depends on a thorough clinical examination and the correct use of imaging techniques.
- The main clinical and radiographic features for diagnosis were identified, as well as current treatments.
- In addition, new diagnostic perspectives using biomarkers were found, which require further research.

also been associated, such as endocrine alterations and vitamin and mineral deficiency [1].

External root resorption can occur in different ways, which has led to various proposals for its classification in the literature. Andreasen's [7] is fundamental and the most widely spread. Later, Benitez et al. [8] classified root resorptions according to their location and etiology. However, the most recent, and the one currently used, was described by Patel and Saberi [9]. In it, the authors consider the location and pathogenesis of resorption, classifying them as follows:

1. Inflammatory external resorption.
2. External replacement resorption.
3. Cervical external resorption.
4. Superficial external resorption.
5. External resorption of transient apical collapse.

A quick and accurate diagnosis would allow adequate initial management, minimizing the sequelae of this pathology [10]. Meanwhile, misdiagnosis will worsen the prognosis of the tooth [2]. On the other hand, radiographs do not indicate whether root resorption is active or inactive. Considering the limitations of radiography, more sensitive, safe, and specific diagnostic and prognostic methods are required to detect this pathology in the early stages [11].

Because of the difficulty in diagnosing external root resorptions, this review aims to identify studies that describe the clinical, radiographic, and other diagnostic methods that should be considered for the correct diagnosis of this pathology. With this, we seek to establish guidelines that facilitate its recognition, providing tools for timely treatment and a better prognosis.

METHODS

A narrative review was performed [12,13]. Studies in Spanish and English, literature reviews, randomized clinical trials, case-control, and cohort studies conducted in adult permanent teeth from 2010 to 2022 were included. Case report studies, expert opinion, editorials, studies in young primary or permanent teeth, and studies in patients with systemic disease were excluded. A search was carried out in the MEDLINE/PubMed, Cochrane Library, and Google Scholar databases under the term external root resorption, carried out between June and July 2022, in which 257 articles were found. Two individual authors read the titles and abstracts of the publications, discarding the articles irrelevant to the study, leaving 65. The complete texts were read of the selected articles, and 17 were included by consensus. The categorization was

defined into clinical characteristics, radiographic characteristics, and treatment of external root resorptions. Then, the clinical and radiographic characteristics and the treatment of each type of resorption were tabulated in Excel tables.

RESULTS

Seventeen articles were finally included in the review. Of the total number of articles, five refer to the clinical characteristics described in Table 1. Eight deal with the radiographic characteristics described in Table 2, and four deal with the main treatments of external root resorptions, presented in Table 3.

The results obtained are summarized in Table 4. For external inflammatory resorption, according to the evidence collected, the following clinical characteristics are described: discoloration of the crown; sensitivity to percussion or palpation; symptoms of pulpitis or apical periodontitis; mobility; periodontal defects and negative pulp vitality [9,29,30]. Regarding its radiographic characteristics, it is described as a radiolucent area in the form of an undercut in the periapical area of the tooth, an intact root canal at the beginning, and in advanced stages, areas of resorption can be observed inside the canal [9,20]. Regarding managing this resorption, endodontics is the indicated treatment to limit the process, and intracanal medication with calcium hydroxide is recommended [20,27,30].

According to the evidence collected, external replacement resorption presents the following clinical characteristics: metallic percussion sound, absence of mobility, crown without alterations, and preserving pulp vitality. Regarding its radiographic characteristics, periodontal ligament space and bone apposition loss are observed [23,26]. In these cases, periodic control of the lesion is chosen. However, when intervention is necessary, exodontia may be chosen [28].

For cervical external resorption, the clinical characteristics we can find are pink crown coloration, normal pulp vitality or sensitivity to vitality tests, and probing with a "sponge" texture [31]. Radiographically, this resorption can be seen as a radiolucent area at the cervical root level [30]. Various treatment options, from control to exodontia, are described [11].

According to the evidence collected, superficial external resorption describes similar clinical characteristics: a healthy tooth with pulp vitality [9,11]. Radiographically, a loss of root tissue is observed, and the root canal remains intact [9]. When the stimulation ceases, the resorption cavities will heal without incident [10].

Finally, clinical features such as transient tooth discoloration and delayed or absent response to sensitivity testing

Table 1. Clinical characteristics in articles included in the review.

Author and year	Type of study	Clinical characteristics of ERR	Conclusions
Vieira G, 2014 [14]	Case-control	Augment of protein DSPP and DPP.	At the time of writing, no molecular diagnostic kits have yet been developed to detect ERR at the clinical level. So far, more high-resolution protein screening methods are still required to identify new molecular markers. MALDI-TOF is the technique of choice for this task.
Mavrido A, 2016 [15]	Descriptive study	RREC: changes in crown color, periodontal sacs associated with the defect, bleeding on probing, granulomatous tissue.	CER is a dynamic and complex condition involving periodontal and endodontic tissues. Using clinical, histological, radiographic, and scanning microscopic analyses, a better understanding of the evolution of CER is possible. Based on experimental findings, a 3-stage mechanism for the initiation and growth of CER is proposed.
Patel S, 2018 [9]	Narrative revision	EIRR: crown discoloration change, symptoms of apical periodontitis, negative vital signs. RERR: metallic sound on percussion, positive vital signs. CERE: periodontal defect, pink coloration of the crown, negative or positive vital signs. SERR: healthy clinical appearance TAR: transient discoloration change, delayed response to vital signs.	Accurate diagnosis is required for clinical decision-making, treatment planning, and treatment execution. A CBCT is indicated to confirm the diagnosis and/or aid management.
Mona M, 2021 [16]	Narrative revision	Increased DMP, DSPP, and its functional domains (DPP and DSP), inflammatory markers such as TNF- α , IL-6 and IL1- β and MicroRNA-29.	The field of proteomic biomarkers is relatively new in dental disorders. Such a diagnostic approach has excellent potential to avoid unnecessary invasive procedures. It has promising uses and may significantly impact the healthcare system.
Kapoor P, 2022 [17]	Bibliographic revision	Increase in dentin proteins, enzymes, and protein metabolites. Decrease in IL-1 α .	Several biomarkers in biofluidics indicate active resorption, while the severity of resorption was associated with DSPP and GM-CSF in GCF, as well as some salivary proteins. However, a robust study design is mandatory in the future.

Abbreviations. ERR, external root resorption. MALDI-TOF, two-dimensional electrophoresis followed by mass spectrometry. DMP, dentin matrix acid phosphoprotein. DSPP, dentin sialophosphoprotein. DPP, dentin phosphoprotein. TNF- α , tumor necrosis factor-alpha. IL-6, interleukin-6. IL-1 β , interleukin-1beta. IL-1 α , interleukin-1 alpha. EIRR, External inflammatory root resorption. CBCT, cone beam computed tomography. CERE, cervical external root resorption. SERR, superficial external root resorption. CER, external cervical resorption. RERR, replacement external root resorption. TAR, transient apical resorption. GM-CSF, Granulocyte Macrophage Colony Stimulating Factor. GCF, Gingival crevicular fluid.
Source: Prepared by the authors.

are described for transient apical collapse resorption. Its radiographic manifestations are initially seen as widening the periodontal ligament and a blurred appearance of the apical lamina dura [29]. Its management will depend on the disappearance of signs and symptoms, which should resolve within one year [32].

DISCUSSION

The diagnosis of root resorption has been somewhat controversial, as a broad spectrum of features makes it difficult to reach. Early detection and subsequent intervention remain a challenge for dentists. This study aims to promptly identify clinical and radiological characteristics to evaluate the presence of these lesions, with clear guidelines that allow us to identify external root resorption.

Inflammatory external radicular resorption

Inflammatory external root resorption is a pathology associated with prolonged stimuli, resulting in a localized inflammatory response.

Its treatment includes the use of intracanal medication. According to the evidence collected, calcium hydroxide is recommended because it is the most widely used and has numerous properties [20,27]. Other temporary medications have been mentioned in the literature, all comparable to calcium hydroxide, such as antibiotic pastes, acetazolamide, and Ledermix. The latter is a commercial water-soluble paste containing 1% triamcinolone, a corticosteroid, and 3% demeclocycline, a tetracycline [27].

Recent studies indicate that, in addition, an apical sealant can be used to supplement therapy. Adding mineral trioxide has resulted in easier management of root resorption [30]. Biodentine has also been successful in endodontic treatment. Patel [28] and Esteves [32] emphasize that using mineral trioxide

Table 2. Radiographic characteristics in articles included in the review.

Author and year	Type of study	Radiographic characteristics	Conclusions
Llamas-Carrera J, 2012 [18]	Case-control	RRES: Apical diminution of approximately 2.5 millimeters.	There was no significant difference in the amount or severity of superficial external root resorption during orthodontic movement between incisors with obturated roots and their teeth with vital pulps.
Takeshita WM, 2015 [3]	Retrospective study	Apical distortion Root length decrease Volumetric changes	The study demonstrated that CBCT showed the best results in diagnosing ERR. The diagnosis of ERR was the least accurate, with panoramic radiography being inadequate for diagnosis. CBCT and conventional periapical radiography obtained similar results for its evaluation.
Samandara A, 2019 [19]	Systematic revision	Linear and volumetric changes of the root. Alveolar bone loss.	CBCT appears reliable for examining orthodontically induced external root resorption during or at the end of orthodontic treatment. Although the average ERR measured with CBCT seems to lack clinical relevance, certain factors may affect it.
Marinescu I, 2019 [20]	Cohort study	Funnel-shaped root apex; the alveolar bone shows a diffuse radiolucency that appeared to be the image of a chronic diffuse apical periodontitis.	The description of the radiological aspects of the different types of root resorption on the panoramic digital radiograph allows a quicker diagnosis. Even so, in some cases, CBCT may be recommended to confirm the diagnosis.
Pustulka K, 2021 [21]	Cohort study	Loss of root length Changes in root morphology	The prevalence of external root resorption in teeth under orthodontic forces occurs mainly in anterior teeth, predominantly incisors.
Ferreira M, 2022 [22]	Observational cross-sectional study	RREC: hypodense or hyperdense image, diffuse margins, extension from the crown to the apical third of the root.	The prevalence of cervical resorption was 1.35%, with a higher prevalence in male patients. Mandibular and maxillary central incisors were the most commonly affected teeth.
Dao V, 2023 [23]	Observational cross-sectional study	ERRR: lesion in the coronal third. IER: radiolucent defect along the apical and middle third of the root surface with or without root involvement. Flattening of the root apex. CER: effacement of the periodontal ligament space and the lamina dura, with localized fusion of the tooth with the bone.	This study demonstrated a high rate of root resorption and, in particular, a high rate of radiographic finding of resorption. Systematic evaluation, early diagnosis, and astute intervention are recommended for optimal prognosis.
Baena de la Iglesia T, 2023 [24]	Systematic review	Root crater: volume, area, total or partial mineral loss changes.	The highest and lowest sensitivity and specificity of CBCT for diagnosing external root resorption are 42 to 98% and 49.3 to 96.3%. The minimum and maximum effective doses of dental CBCT for diagnosing external root resorption are 34 μ Sv and 1073 μ Sv.

Abbreviations: ERR, external root resorption. μ Sv, microsievert. IER, inflammatory external root resorption. CBCT, cone beam computed tomography. CER, cervical external root resorption. ERRR, external root resorption replacement.

Source: Prepared by the authors.

would be the most effective treatment, presenting better periapical healing of the tooth to be treated. At the same time, Marão [33] indicates that mineral trioxide can be considered a viable option for root canal obturation in cases of external root resorption.

External replacement root resorption

Replacement root resorption is a lesion that occurs due to severe luxation or avulsion injuries [1]. In these cases, periodic control of the lesion is chosen. However, when intervention is necessary, tooth exodontia and repositioning can be performed with the application of Emdogain in the affected root area. If it progresses to resorption with ankylosis, a decoronation

and submersion technique is recommended, which consists of removing the crown and leaving the root in the socket for subsequent replacement with bone [15].

Cervical external root resorption

Cervical external root resorption is a localized lesion of the cervical area of the root below the epithelial junction [10]. The results obtained indicate a variability of radiographic characteristics. Other authors point out that the lesion may appear radiolucent if identified in its active resorption phase, radiopaque in the repair phase, or a combination of both phases [22]. It is recommended that these lesions be diagnosed and evaluated with the aid of cone beam computed tomography

Table 3. Articles included in the review regarding treatment.

Author and year	Type of study	Treatment	Conclusions
Kandalgaonkar S, 2013 [25]	Narrative revision	CERR Complete removal of resorption tissue + chelating agent + restoration with ionomer glass, composite resin, MTA. Endodontic treatment when the lesion is very close to the pulp.	Cervical-type lesions contain fibrovascular tissue with resorbed clastic cells adjacent to the dentin surface. More advanced lesions show fibro-osseous features with deposition of ectopic bone-like calcifications both within the resorbed tissue and directly on the dentin surface.
Bansode P, 2018 [26]	Narrative revision	ERRR: surgical repositioning with Emdogain application. Decoronation and submersion. RREI: treatment: endodontic treatment with intracanal medication such as ledermix, MTA, and calcium hydroxide. RREC: surgical access if necessary + 90% trichloroacetic acid + curettage and restoration of the defect.	Early diagnosis, correct case selection, appropriate restorative material, and adequate treatment are essential for long-term tooth retention with root resorption.
Zare M, 2019 [27]	Narrative revision	RREI: endodontic treatment + intracanal medication.	Calcium hydroxide is the most commonly used intra-oral medication comparable to MTA, Ledermix, and acetazolamide.
Patel S, 2022 [28]	Narrative revision	SERR: elimination of ethiological facto. CER: excavation of the resorption tissue, restoration of the lesion +- endodontic treatment. The use of trichloroacetic acid is suggested. EIRR: endodontic treatment with strict canal disinfection protocols + intracanal medication with calcium hydroxide or Ledermix. RRER: treatment is variable and ranges from control to extraction. TAR: if there is no pulp risk, it should be controlled; if there is pulp risk, endodontic treatment should be performed.	A thorough and systematic clinical evaluation and radiographic examination are paramount to ensure proper management. The prognosis of root resorption depends on an accurate and early diagnosis.

EIRR: External inflammatory root resorption . CER: cervical external root resorption. MTA: mineral trioxide. ERRR: external root resorption replacement. SERR: superficial external root resorption. TAR: transient apical resorption. CERR: cervical external root resorption.
Source: Prepared by the authors.

before establishing a treatment plan, which varies according to the depth of the lesion, the size of the lesion, and whether pulp damage is present [34]. Endodontic treatment should be performed when the lesion is very close to the pulp, followed by intra-canal medication and filling with a thermoplastic technique [30]. Patel mentions that treatment aims to maintain the tooth in a functional state and improve esthetics when necessary. Thus, he proposes the following treatment options:

- External repair without/with endodontic treatment.
- Internal repair and endodontic treatment.
- Intentional reimplantation.
- Periodic control in case of intractable teeth.
- Exodontia [29].

Superficial external root resorption

Superficial external root resorption is a defect that occurs due to minimal stimulus on the root surface and is accompanied by a transient lesion that is repaired, and the pulp remains vital [34]. According to the evidence collected, no pathologic features are described. Singh [30] reports no signs of resorbed tooth are observed on clinical examination. Other authors indicate a loss of root tissue of approximately 2.5 millimeters [18]. When the stimulation ceases, the resorption cavities will heal without incident [10].

Transient apical collapse resorption

Transient apical collapse is a phenomenon related to a repair process in the pulp associated with trauma that returns to normal after the repair is complete [32]. It is currently poorly described in the literature, but this phenomenon is essentially

Table 4. Essential aspects of external root resorptions.

	External inflammatory resorption	External replacement resorption	Cervical external resorption	External superficial resorption	Transient apical collapse
Clinical findings	Sensitivity to percussion or palpation. Symptoms of pulpitis or apical periodontitis. Mobility. Periodontal defects of bone resorption type.	Sound of metallic percussion. Absence of mobility.	Sponge-textured probing.	None	None
Clinical appearance	Coronary discoloration	Healthy	Pink coloration of the crown	Healthy	Coronary discoloration
Pulp vitality	Negative	Positive	Positive	Positive	Negative or retarded
Radiographic characteristics	Radiolucent area or in the periapical area. Root canal intact in early stages.	Loss of periodontal ligament space. Bone apposition.	Radiolucent zone at the cervical level. Radiopaque areas in the repair stage.	Radiolucent zone in any area of the root.	Widening of the periodontal ligament. Blurred appearance of the apical lamina dura.
Treatment	Endodontics with intra-canal medication.	Control. Decoronation and submersion technique. Exodontia.	External without/with endodontic treatment. Internal repair and endodontic treatment. Intentional reimplantation. Periodic control. Exodontics.	Control	Control
Differential	Internal root resorption	Internal root resorption	Cervical caries	Internal root resorption	Internal root resorption

Source: Prepared by the authors.

an inflammatory external resorption with a short phase of resorption followed by repair [29]. Its management will depend on the disappearance of signs and symptoms, which should resolve within one year [32].

Biomarker diagnosis

All these diagnostic guidelines mentioned above are static and cannot indicate whether the root resorption process has stopped or is in progress. One of the new diagnostic methods mentioned in the literature is the detection of specific biomarkers associated with the disease [14]. Vieira [14] and Mona [16] conducted studies to find possible gingival or salivary crevicular fluid-associated root resorption biomarkers. Mah and Prasad [35] concluded that further studies are required to develop more sensitive assays and correlate measurements with clinical findings to produce a practical test for clinical use. Huang [11] detected alterations in dentin protein levels in human crevicular fluid. Mohd [36] detected six proteins (S100A9, IGJ, HSPA1A, IGHV4-34, TYMP, and VTN) that showed significant increases during the early phase of orthodontic treatments, making them candidates as potential biomarkers that can be exploited for the detection of root resorption. Recent studies indicate which biomarkers found in saliva show a significant increase in interleukin-7, interleukin-10, interleukin-12p70, interferon γ , proteins and metabolites, and a significant decrease in interleukin-4 when inflammatory external

root resorption is present [17,36]. Despite finding a relationship between biomarkers in gingival crevicular fluid and the development of root resorption, more evidence about the clinical use of these biomarkers is needed [17].

Cone beam computed tomography versus conventional radiography

Regarding radiographic diagnosis, several authors say cone beam computed tomography is the best tool for diagnosing external root resorption. Takeshita [3] concludes that cone beam computed tomography was the most accurate imaging method in diagnosing external root resorption. Yi [37] suggests this tool has greater diagnostic efficacy than periapical radiography [19,21,25]. The most recent study concludes that using cone beam computed tomography has a sensitivity of 60.8% and a specificity of 60% [24].

In the case of cervical resorptions, Patel et al. [38] proposed a three-dimensional classification model to accurately document the true nature of these, which covers three main aspects of the lesion:

1. Corono-apical extension.
2. Circumferential extension.
3. Proximity to the root canal.

As the first classification system that accurately delineates the spatial structure of the lesion, it significantly improves diagnostic accuracy [39].

CONCLUSIONS

Correctly diagnosing external root resorption in the early stages significantly improves the prognosis. A complete clinical history is essential before proceeding to intraoral examination. A complete clinical examination should emphasize probing, staining, mobility, and vitality testing.

However, cone beam computed tomography and periapical radiography are the main tools to evaluate the presence of external root resorptions, the former being the most accurate method. The clinical features, radiographic characteristics, and treatment of each type of external root resorption are different. Also, their most common differential diagnoses are internal root resorption and cervical carious lesions.

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Características clínicas y radiográficas de reabsorciones radiculares externas

RESUMEN

INTRODUCCIÓN La siguiente revisión bibliográfica se realizó con el propósito de reconocer las características clínicas y radiográficas que deben ser evaluadas para el diagnóstico de las reabsorciones radiculares externas incluyendo también sus tratamientos.

METODOLOGÍA Se llevó a cabo una búsqueda en las bases de datos MEDLINE/PubMed, Cochrane Library y Google Scholar bajo el término *external root resorption*, incluyendo estudios experimentales y revisiones bibliográficas desde 2010 a 2022 en español e inglés, incluyendo finalmente 17 artículos.

RESULTADOS Los resultados obtenidos señalaron que cada tipo de reabsorción radicular externa presenta características clínicas específicas que las diferencian. Estas diferencias son: para la reabsorción externa inflamatoria la vitalidad pulpar negativa; para la reabsorción externa de reemplazo la ausencia de movilidad y percusión metálica; para la reabsorción externa cervical una coloración rosada de la corona; la reabsorción externa superficial no presenta ningún tipo de sintomatología clínica y la reabsorción de colapso apical transitorio presenta un cambio de coloración transitorio.

CONCLUSIÓN Las reabsorciones radiculares externas requieren un diagnóstico preciso y temprano. Se debe realizar un examen clínico con énfasis en sondaje, coloración, movilidad y pruebas de vitalidad.



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