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RADIOGRAPHIC DIAGNOSIS OF INTERNAL AND EXTERNAL ROOT RESORPTIONS

DIAGNÓSTICO RADIOGRÁFICO DE REABSORÇÕES RADICULARES INTERNAS E EXTERNAS

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ABSTRACT

Root resorption corresponds to the progressive loss of mineralized dental tissues and may occur in a physiological, pathological, or idiopathic manner. This resorption can affect both the internal and external surfaces of the tooth, presenting different etiological mechanisms, radiographic patterns, and therapeutic implications. Early diagnosis is crucial for the prognosis of the dental element and for defining the most appropriate clinical approach; however, diagnosis often occurs sporadically during routine clinical and radiographic examinations, making a favorable prognosis more difficult. Conventional radiographs, such as periapical and panoramic images, are widely used as initial evaluation methods; nevertheless, because they are two-dimensional examinations, they present important limitations, including structural overlap, distortions, and low sensitivity for early lesions, with computed tomography being the most satisfactory examination for diagnosing this condition. This study is characterized as a narrative literature review, conducted through a systematized survey of scientific literature in the PubMed, Scopus, and Web of Science databases, using the descriptors “Tooth Resorption,” “Root Resorption,” “Radiography,” and “Diagnosis,” combined with Boolean operators; articles published in the last five years, available in full text and directly addressing the use of radiographic methods in the diagnosis of internal and external root resorptions were included, while duplicate studies, isolated case reports, and publications lacking

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methodological rigor were excluded. The selection process occurred in stages, including the reading of titles and abstracts and the critical analysis of full texts. The results demonstrate that Cone Beam Computed Tomography presents greater sensitivity and specificity compared to conventional radiographs, enabling detailed three-dimensional visualization, better differentiation between types of resorption, and volumetric analysis of root loss, leading to the conclusion that CBCT is a fundamental tool for the diagnosis and monitoring of root resorptions, especially in complex cases involving recovery and orthodontic movement.

Keywords: Tooth Root Resorption. Internal Root Resorption. Cone Beam Computed Tomography. Dental Radiography.

RESUMO

A reabsorção radicular corresponde à perda progressiva de tecidos dentários mineralizados, podendo ocorrer de forma fisiológica, patológica ou idiopática. Essa reabsorção pode acometer tanto a face interna quanto a face externa do dente; apresentando diferentes mecanismos etiológicos, padrões radiográficos e implicações terapêuticas. O diagnóstico precoce é determinante para o prognóstico do elemento dental e para a definição da conduta clínica mais adequada. Entretanto, o diagnóstico ocorre de maneira esporádica, durante um exame clínico e radiográfico de rotina, dificultando um prognóstico favorável para o elemento dental. As radiografias convencionais, como periapicais e panorâmicas, são amplamente utilizadas como métodos iniciais de avaliação; entretanto, por se tratarem de exames bidimensionais, apresentam limitações importantes, incluindo sobreposição de estruturas, distorções e baixa sensibilidade para lesões iniciais. Sendo que a tomografia computadorizada (TC) é o exame mais satisfatório para o diagnóstico dessa lesão. Este estudo caracteriza-se como uma revisão bibliográfica narrativa, realizada por meio de levantamento sistematizado da literatura científica nas bases de dados PubMed, Scopus e Web of Science. Foram utilizados os descritores “Tooth Resorption”, “Root Resorption”, “Radiography” e “Diagnosis”, combinados por operadores booleanos. Incluíram-se artigos publicados nos últimos cinco anos, disponíveis na íntegra e que abordassem diretamente a utilização de métodos radiográficos no diagnóstico das reabsorções radiculares internas e externas. Foram excluídos estudos duplicados, relatos de casos isolados e publicações sem rigor metodológico. A seleção ocorreu em etapas, contemplando leitura de títulos, resumos e análise crítica dos textos completos. Os resultados demonstram que a Tomografia Computadorizada de Feixe Cônico apresenta maior sensibilidade e especificidade quando comparada às radiografias convencionais, possibilitando visualização tridimensional detalhada, melhor diferenciação entre os tipos de reabsorção e análise volumétrica das perdas radiculares. Conclui-se que a TCFC constitui ferramenta fundamental no diagnóstico e monitoramento das reabsorções radiculares, especialmente em casos complexos que envolve recuperação e movimentação ortodôntica.

Palavras-chave: Reabsorção da Raiz do Dente. Reabsorção Radicular Interna. Tomografia Computadorizada de Feixe Cônico. Radiografia Dentária.

RESUMEN

La reabsorción radicular corresponde a la pérdida progresiva de los tejidos dentarios mineralizados y puede ocurrir de forma fisiológica, patológica o idiopática. Esta reabsorción puede afectar tanto la superficie interna como la externa del diente,

presentando diferentes mecanismos etiológicos, patrones radiográficos e implicaciones terapéuticas. El diagnóstico precoz es determinante para el pronóstico del elemento dental y para la definición de la conducta clínica más adecuada; sin embargo, el diagnóstico suele ocurrir de manera esporádica durante un examen clínico y radiográfico de rutina, lo que dificulta un pronóstico favorable. Las radiografías convencionales, como las periapicales y panorámicas, son ampliamente utilizadas como métodos iniciales de evaluación; no obstante, al tratarse de exámenes bidimensionales, presentan limitaciones importantes, incluyendo la superposición de estructuras, distorsiones y baja sensibilidad para lesiones iniciales, siendo la tomografía computarizada el examen más satisfactorio para el diagnóstico de esta lesión. Este estudio se caracteriza como una revisión bibliográfica narrativa, realizada mediante un levantamiento sistematizado de la literatura científica en las bases de datos PubMed, Scopus y Web of Science, utilizando los descriptores “Tooth Resorption”, “Root Resorption”, “Radiography” y “Diagnosis”, combinados mediante operadores booleanos; se incluyeron artículos publicados en los últimos cinco años, disponibles en texto completo y que abordaran directamente el uso de métodos radiográficos en el diagnóstico de las reabsorciones radiculares internas y externas, y se excluyeron estudios duplicados, reportes de casos aislados y publicaciones sin rigor metodológico. La selección se realizó por etapas, contemplando la lectura de títulos y resúmenes y el análisis crítico de los textos completos. Los resultados demuestran que la Tomografía Computarizada de Haz Cónico presenta mayor sensibilidad y especificidad en comparación con las radiografías convencionales, permitiendo una visualización tridimensional detallada, una mejor diferenciación entre los tipos de reabsorción y un análisis volumétrico de las pérdidas radiculares, concluyéndose que la TCHC constituye una herramienta fundamental en el diagnóstico y monitoreo de las reabsorciones radiculares, especialmente en casos complejos que involucran recuperación y movimiento ortodóncico.

Palabras clave: Reabsorción de la Raíz Dentaria. Reabsorción Radicular Interna. Tomografía Computarizada de Haz Cónico. Radiografía Dental.

1 INTRODUCTION

Root resorption is a complex pathological or physiological process resulting in the loss of dental hard tissues, mediated by osteoclastic activity (Heboyan et al., 2022). Although it has different clinical manifestations and etiologies, it is a condition of great relevance in Dentistry, since it can compromise the structural integrity of the dental element and, in more severe cases, lead to its early loss (Heboyan et al., 2022).

These resorptions can be classified, according to their cause, location and complexity, into external and internal resorptions. In addition, they can be located at different points of the root (cervical, middle, or apical third) and, according to their extension, they become communicant, connecting the pulp cavity to the periodontium (Souza et al., 2023)

From an etiopathogenic point of view, root resorptions are associated with multiple factors, including pulp inflammation, dental trauma, periapical infections, and prolonged mechanical stimuli. Among these, orthodontic movement stands out, considered one of the main triggering factors of external root resorption, especially when excessive or long-lasting forces are applied to the teeth. Internal root resorption, in turn, although less prevalent, is silent and progressive, and is often diagnosed only in routine imaging tests. (Savoldi et al., 2022; Withayanukonkij et al., 2024).

Orthodontic Treatment-Induced Root Resorption (OIRR) is a sterile inflammatory process that results from the mechanical forces applied during orthodontic treatment. Statistically, its prevalence is high: it is estimated that between 40% and 60% of orthodontic patients develop mild to moderate root resorption, while more severe cases, which can compromise tooth function, occur in 1% to 5% of patients (Lin et al.). Since most changes in root length are irreversible, the ability to predict risk and detect the process early is critical to minimizing permanent damage and ensuring tooth stability (Butsabul et al.).

Clinically, this condition can be classified into two main types: internal root resorption (IRR) and external root resorption (ERR), depending on the site of origin of the aggression (Heboyan et al., 2022). IRR originates in the root canal system and is often linked to chronic pulp inflammation, and can be transient or progressive. RRE represents the most common type of resorption and can begin at any point on the root surface in completely erupted teeth; starting at the periodontal ligament; it can be triggered by trauma, orthodontic pressure, or infectious processes (Heboyan et al., 2022).

Radiographically, the RRE appears as a nebulous radiolucent lesion at the root, with poorly defined borders; Its expansion is predominantly lateral, generating large and extensive affected areas on the root surface, but shallow especially in the early stages. IRR is discovered on routine radiographic examinations; presenting a symmetrical radiolucent area, with sharp, regular and defined borders; the root canal loses its original shape, being observed in oval and asymmetrical shapes (MOREIRA-SOUZA et al., 2022).

Accurate diagnosis is essential for the preservation of the dental element, since early detection directly influences the prognosis and the choice of therapeutic intervention. Historically, panoramic and periapical radiography have been the most widely used screening methods; however, limitations inherent to two-dimensional imaging, such as distortions, anatomical overlaps, and low sensitivity for incipient lesions, pose significant challenges (Moreira-Souza et al., 2022; Lin et al., 2025). In addition, the complexity of the diagnosis is aggravated by the often asymptomatic nature of these lesions in their early stages, which makes imaging tests decisive for the differential diagnosis and, consequently, an appropriate treatment plan for each type of resorption.

Recent reviews indicate that the exclusive dependence on two-dimensional radiographic methods may lead to underestimation of the severity of tissue loss, especially in cases of invasive cervical resorption and orthodontically induced inflammatory resorption (OIIRR); since bone overlap can hide critical defects located, mainly, on the buccal and/or lingual surface (Yazid et al., 2020; Souza et al., 2023). Thus, in order to obtain a more accurate diagnosis, it is necessary to use tools that overcome the anatomical barriers of conventional tests.

With the advent of Cone Beam Computed Tomography (CBCT), there has been a paradigm shift, allowing a detailed three-dimensional visualization of tissue losses and spatial lesion relationships (Peralta-Mamani et al., 2024). This study aims to review the diagnostic protocols and the efficacy of the different radiographic modalities in the identification of these resorptions.

The Need for Diagnostic Accuracy Historically, the evaluation of root resorption has been performed with two-dimensional (2D) radiographs, such as panoramic and periapical radiographs. However, these methods have significant limitations, including geometric distortion and superposition of structures, which can lead to an underestimation or overestimation of actual root loss (Butsabul et al.; Moreira-Souza et

al.). Cone Beam Computed Tomography (CBCT) has emerged as an indispensable and more accurate tool, allowing a detailed and quantitative three-dimensional (3D) volumetric evaluation of the root structure, free from the distortions inherent to 2D images (Heboyan et al.; Leonardi et al.). (MARIA GABRIELLY)

2 METHODOLOGY

The present study is characterized as a narrative literature review, developed with the objective of synthesizing and analyzing the most recent scientific evidence related to the radiographic diagnosis of internal and external root resorption. The research was consolidated from selected scientific articles, using the descriptors "Tooth Resorption", "Root Resorption", "Radiography" and "Diagnosis", combined according to the technical terminology of the area. Articles published in the last five years, available in full, that directly addressed imaging modalities for resorption detection were included. Studies that did not have a direct relationship with the diagnostic theme or that used methodologies of low scientific rigor were excluded. The selection of studies was conducted in stages of screening titles, abstracts and detailed evaluation of full texts to ensure the relevance of the extracted data, which were organized in a descriptive and comparative way.

3 RESULTS AND DISCUSSION

The process of root resorption involves a complex biological response, in which multinucleated cells similar to osteoclasts promote the degradation of mineralized tissues. In the case of internal resorption, chronic pulp inflammation plays a central role in the activation of these cells, resulting in a progressive loss of dentin from the inner wall of the root canal (Heboyan et al., 2022).

The differentiation between internal and external tooth resorption is one of the main diagnostic challenges in clinical practice, since both can present similar radiographic signs in two-dimensional examinations. Classically, internal resorption manifests as a uniform and well-defined expansion of the root canal space, while external resorption has irregular margins, which may result in apical shortening or cavities on the lateral root surfaces (Heboyan et al., 2022). However, the literature demonstrates that these features are not always clearly identifiable on conventional radiographs, especially in the early stages of the lesion (Alassiry et al., 2022; Pour et al., 2022; Pereira et al., 2022).

There is a consensus in the literature regarding the superiority of cone beam computed tomography (CBCT) over periapical and panoramic radiographs in the detection, characterization, and differentiation of internal and external tooth resorptions. Experimental, clinical, and observational studies have reported that CBCT has high values of accuracy, sensitivity, and specificity, often higher than 90–95%, allowing early identification of lesions, accurate differential diagnosis, and detailed three-dimensional assessment of the extent, depth, and location of resorptions (Alassiry 2022; Habibi Kia et al., 2022; Pour et al., 2022; Yazid et al., 2020; Souza et al., 2023; Lin et al., 2022; Moreira-Souza et al., 2021; Peralta-Mamani et al., 2024).

On the other hand, two-dimensional radiographic methods showed inferior and variable diagnostic performance, especially in early, cervical or localized lesions on the buccal and lingual surfaces of the roots, in addition to relevant limitations resulting from the overlapping of anatomical structures and the two-dimensional representation of three-dimensional structures (Pereira et al., 2022; Heboyan et al., 2022; Pour et al., 2022; Yazid et al., 2020). Specific studies have shown that panoramic radiography, while useful for an overall assessment, often underestimates the presence and severity of external root resorptions, especially in teeth adjacent to impacted third molars and canines (Moreira-Souza et al., 2022).

In addition to qualitative diagnostic superiority, recent advances in three-dimensional image analysis have expanded the potential of CBCT, allowing accurate quantitative assessments. Automated tooth segmentation techniques make it possible to measure root volumetric losses associated with orthodontically induced inflammatory resorption in an efficient and reproducible way, overcoming the limitations of traditional linear analyses (Lin et al., 2025). In addition, technical adjustments and image processing, such as the modification of gamma parameters, have been shown to further increase the diagnostic sensitivity of CBCT in the detection of internal resorptions (Habibi Kia et al., 2022).

In the orthodontic context, external apical root resorption is recognized as a relatively common sequela. Comparative studies have indicated that different therapeutic modalities have distinct impacts on root integrity, with evidence that the use of aligners may result in lower levels of apical resorption when compared to conventional fixed appliances in molar intrusion procedures (Withayanukonkij et al., 2024). Additionally, local anatomical factors, such as the presence of dense bone islands (idiopathic

osteosclerosis), have not shown a significant association with increased risk of resorption, as long as cases are properly monitored by appropriate imaging tests (Savoldi et al., 2022).

In treatments of rapid maxillary expansion, studies also reinforce the central role of CBCT in monitoring the integrity of the roots of the supporting teeth. Three-dimensional analysis allows the identification of root volumetric losses and subtle morphological changes that would not be detectable on conventional radiographs, contributing to a safer and more accurate follow-up of the adverse effects of treatment (Leonardi et al., 2023; Butsabul et al., 2024).

Despite the widely documented diagnostic advantages, the authors highlight that the indication for CBCT should be judicious, considering the higher cost and higher dose of radiation compared to two-dimensional methods, in accordance with the ALARA principle (Pour et al., 2022; Souza et al., 2023). Thus, contemporary diagnostic protocols recommend a staggered approach, in which periapical and panoramic radiographs remain as initial screening tests, while CBCT should be used as a complementary method in situations of persistent clinical suspicion, incongruence between clinical and radiographic findings, or the need for detailed therapeutic planning, ensuring greater diagnostic accuracy and better clinical prognosis (Habibi Kia et al., 2022; Lin et al., 2022; Peralta-Mamani et al., 2024).

3.1 ETIOPATHOGENESIS OF ROOT RESORPTION

Root resorption is defined as the pathological loss of hard dental tissues, such as cementum and dentin, or of adjacent alveolar bone (Heboyan et al.). Root surfaces are naturally protected by anti-resorptive barriers, formed by pre-cementum on the outer surface and pre-dentin on the inner surface. The resorption process is initiated when multiple factors, whether mechanical, chemical or thermal, damage these protective barriers. Specifically, OIRR is a non-infectious inflammatory process. The applied orthodontic force, essential for tooth movement, inevitably triggers an inflammatory response in the periodontal ligament. This inflammation, although necessary for bone remodeling that allows tooth movement, is also the main cause of root resorption associated with the treatment (Heboyan et al.).

3.2 RISK FACTOR ANALYSIS

The literature describes the etiology of OIRR as multifactorial, and it is useful to categorize risk factors into two major groups: endogenous (patient-related) and exogenous (treatment-related).

3.3 ENDOGENOUS FACTORS (PATIENT-RELATED)

These are factors intrinsic to the patient that can modulate their susceptibility to root resorption.

• **Genetic Predisposition:** Genetic differences, particularly in the interleukin-1ß (IL-1ß) gene, an inflammatory mediator, may explain why some patients develop more severe resorptions. Specifically, it has been shown that the presence of allele 1 of the IL-1ß gene is associated with a 5.6-fold increased risk of developing External Apical Root Resorption (RRAE) (Heboyan et al.).

- **Age:** The age of the patient at the start of treatment has a significant impact. Younger patients (minors) tend to have less root resorption. In addition, patients with teeth that are still developing (immature) have a much lower risk of RAAR (Lin et al.; Heboyan et al.).
- **Gender:** Studies indicate that the female gender has a significant impact on the resorption rates of upper central and lateral incisors, upper and lower canines, with higher rates observed in women (Lin et al.).
- **Root Morphology:** Atypical root shapes, such as blunt (flattened) or pipette-shaped (tapered) roots, demonstrate a greater susceptibility to resorption when compared to roots with regular morphology (Heboyan et al.).
- **Malocclusion:** Certain types of malocclusion are associated with a higher risk of resorption in specific teeth. Anterior open bite has been shown to have a significant impact on maxillary incisor resorption, while deep overbite was associated with maxillary molar resorption (Lin et al.).

3.4 EXOGENOUS FACTORS (TREATMENT-RELATED)

These factors are directly linked to clinical decisions and the mechanics employed during orthodontic treatment.

- **Duration of Treatment:** The duration of treatment is a well-established causal factor. Treatments that extend for more than 30 months considerably increase the

risk of severe resorption. In contrast, treatments lasting less than 1.5 years generally do not have clinically significant resorption (Heboyan et al.).

- **Type of Tooth Movement:** Vertical movements, especially intrusion (movement of the tooth toward the bone), and incisor proclination are considered critical indicators for the development of RAAR (Heboyan et al.; Butsabul et al.). One study demonstrated that the amount of root resorption was approximately one-third of the applied intrusion distance (Withayanukonkij et al.).
- **Magnitude and Type of Force:** The force applied is a key factor. Comparison between different appliance systems shows that tooth-supported appliances (TB-RME) cause a significantly higher amount of resorption than bone-supported appliances (BB-RME) (Leonardi et al.). Additionally, for molar intrusion, fixed appliances with mini-implants (FM) resulted in more resorption than clear aligners (CA) (Withayanukonkij et al.).

3.5 DIAGNOSIS AND MEASUREMENT METHODS

Critical evaluation of diagnostic methods is fundamental for OIRR research. Panoramic radiography (PAN) has been the most widely used method in clinical practice, but its efficacy for quantifying resorption is limited. A systematic review demonstrated that PAN significantly underestimates the prevalence of RAAR. The studies analyzed showed a prevalence detected by PAN between 5.3% and 19.5%, while the prevalence detected by CBCT in the same groups of patients ranged from 22.8% to 62.0% (Moreira-Souza et al.).

Cone Beam Computed Tomography (CBCT) is therefore the method of choice for accurate evaluation. It is considered indispensable for the analysis of three-dimensional volumetric changes, eliminating the overlaps and distortions of 2D radiographs and providing a much more accurate quantification of root structure loss (Heboyan et al.; Butsabul et al.).

4 CONCLUSION

The analysis of the scientific evidence compiled in this review allows us to conclude that the accurate diagnosis of root resorptions is a critical pillar for the clinical longevity of the dental element. The differentiation between internal and external processes, although

challenging, is fundamental, given that each condition requires different therapeutic protocols and has varied prognosis.

It has been established that **conventional (2D) radiographs**, such as periapical and panoramic radiographs, although useful as initial screening, have significant intrinsic limitations. They often underestimate the extent of lesions and fail to detect resorptions at early stages or localized on the buccal and lingual surfaces, due to overlapping anatomical structures.

On the other hand, **Cone Beam Computed Tomography (CBCT)** has established itself as the gold standard for the diagnosis and monitoring of resorptions. Its ability to provide a three-dimensional, distortion-free view with high sensitivity (greater than 90%), allows you to:

- The exact location and volumetric measurement of tissue loss.
- The clear differentiation between internal (canal-centered) and external (periodontium-initiated) resorption.
- Close monitoring in cases of orthodontic movement (OIRR) and maxillary expansion.

It is concluded that, despite the higher cost and dose of radiation, CBCT should be the preferred choice in cases of clinical suspicion not confirmed by 2D examinations or when the therapeutic planning requires millimetric precision. The adoption of evidence-based protocols, which integrate the sovereign clinic with advanced imaging technologies, is indispensable to minimize avoidable tooth loss and optimize outcomes in modern dental practice.

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