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Review article

Root Resorption in Orthodontics: Clinical Implications and Preventive Strategies

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Abstract
Root resorption is a significant complication of orthodontic treatment, characterized by the progressive loss of root structure due to mechanical forces applied during tooth movement. Although often subclinical, moderate to severe cases can compromise tooth stability, leading to mobility, sensitivity, and even tooth loss. The incidence and severity of resorption vary according to treatment duration, appliance type, and patient-specific factors. Fixed multi-bracket appliances are well documented to induce higher resorption rates compared to clear aligners, though evidence regarding aligner-associated risks remains limited. Root resorption may present externally, cervically, or internally, each with distinct pathophysiological mechanisms, diagnostic challenges, and therapeutic approaches. Cone-beam computed tomography (CBCT) has emerged as the most reliable imaging modality, offering superior diagnostic accuracy compared to conventional radiographs. Preventive strategies emphasize the use of light, intermittent forces, careful monitoring of maxillary anterior teeth, and early intervention with root canal therapy when indicated. Management protocols include calcium hydroxide dressings, bioactive materials such as mineral trioxide aggregate (MTA), and enhanced irrigation techniques for internal lesions. Understanding the multifactorial etiology of root resorption—including trauma, pulpal infection, systemic predisposition, and excessive orthodontic forces—is essential for risk mitigation. This review highlights current evidence on the types, causes, diagnostic methods, and management strategies of orthodontic root resorption, underscoring the need for individualized treatment planning and continued research to optimize patient outcomes.
Keywords: Tooth Structure, Orthodontic Treatment, Orthodontic Forces, Apical Root.

Introduction

Orthodontic treatment, among other dental interventions, can lead to root resorption, a destructive process causing root structure loss. This occurs due to pressure exerted on teeth during orthodontic treatment, impacting the periodontal ligament and surrounding tissues, and ultimately destroying root tissues. Understanding root resorption is crucial in orthodontics because it significantly affects treatment results and long-term dental health.

Root resorption during orthodontic treatment varies, with moderate to severe cases occurring in approximately 2.9% of patients. Although rare, this condition can lead to mobility of the tooth, sensitivity, in severe instances, loss of tooth structure. Treatment time, appliance design, and patient factors may influence root resorption incidence.(1) Orthodontists should be familiar with various types of root resorption to limit associated risks. Knowledge of root resorption diversity helps dentists predict risks and plan appropriate treatment. Understanding the factors and mechanisms characteristic of root resorption facilitates better management options in orthodontics (1).

Numerous studies document post-treatment root resorption incidence and severity with fixed multi-bracket appliances. Despite the increasing use of clear aligners, knowledge regarding root resorption risk and aligner-based orthodontic treatment remains limited. The extent of root resorption caused by aligners is unclear, despite documented negative consequences with fixed appliances. A progressive inflammatory response (2). Root resorption is greater in areas experiencing higher stress. Cementum areas near the center of rotation, where stress is low, exhibit fewer cells and reduced remodeling activity (3). Orthodontic interventions differ in their potential to cause root resorption, with fixed braces potentially causing more than clear aligners. Force application and duration significantly influence the degree of root destruction. Tailored orthodontic treatment is necessary for achieving healthy outcomes (4). Orthodontic treatment-induced root resorption, a well-documented complication, raises concerns regarding potential negligence in diagnosis, force system application, force monitoring, or provision of comprehensive treatment information. The central challenge lies in identifying pre-treatment predisposition to root resorption(5)

Root resorption (types)

Root resorption involves the body dissolving and reabsorbing tooth roots. This can occur in various situations, including orthodontic treatment involving force application. Understanding root resorption is crucial for orthodontists and patients, as it can impact treatment outcomes and dental health.

Orthodontic treatment necessitates vigilant monitoring for root resorption, which can cause tooth mobility and even tooth loss. Root resorption frequently occurs in orthodontic patients, with incidence varying based on treatment methods, individual differences, and genetic factors. Some patients may exhibit excessive resorption, underscoring the importance of careful evaluation and personalized treatment planning (6)

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Lip/tongue dysfunction, potentially stemming from prolonged finger-sucking, can contribute to and result from increased overjet. Apical root resorption may be indirectly affected by lip/tongue dysfunction through its impact on overjet maintenance or aggravation, and directly through its influence on orthodontic tooth movement. (7)
Loss of tooth structure (RR) is pathological (uncontrolled)in permanent teeth but physiological in deciduous teeth. While the exact mechanisms remain unclear, trauma to the teeth is a main influencing factor. Some potential causes include orthodontic treatment, necrotic pulpal tissue, inner whitening, surgery procedure at the junction between cementum and enamel, and general factors (systemic) (8)

Root resorption (External)
Orthodontic forces influence bone, periodontal ligament, pulp, and cementum. Loss of tooth structure (RR) on the surface area is of natural importance for the movement of the tooth during treatment. Dentin is protected from osteoclasts until cementum repair occurs, controlling the resorption process. External root resorption (ERR) is a relatively common phenomenon (Fig 1).

Figure 1. External root resorption

External Cervical Resorption (ECR) / Invasive Cervical Resorption (ICR)
Lesion Exposure and Debridement: A minor surgical flap is typically raised to access the defect. The resorptive tissue is then meticulously removed using ultrasonic instrumentation or chemical agents.
Topical Agents: To ensure the elimination of any residual resorptive cells, many clinicians apply 90% trichloroacetic acid (TCA) or utilize antimicrobial photodynamic therapy.
Defect Restoration: Once cleaned, the cavity is sealed with a highly biocompatible material, such as Mineral Trioxide Aggregate (MTA) or Biodentine, and finished with a standard resin composite restoration.
Endodontic Considerations: If the resorption has caused a perforation or is in close proximity to the pulp chamber, root canal treatment is performed either prior to or during the repair process.
This resorption type is radiographically undetectable. Resorption becomes radiographically visible and irreversible when dentin loses its pre-cementum and cementum protective layers. Levander and Malmgren classified apical external resorption by severity (9).
For the diagnosis and assessment of external root resorption, utilize CBCT imaging and periapical radiographs. Therapeutic management for inflammatory resorption focuses on eliminating bacteria from the root canal by employing calcium hydroxide as a long-term intracanal medicament, followed by the use of bioactive materials such as mineral trioxide aggregate (MTA) or Biodentine (10).

Root resorption (Cervical)
(RR) in cervical area of the tooth is a form of external (outer) inflammatory resorption linked to orthodontic treatment. Patients diagnosed with cervical resorption show a higher incidence among those who have undergone orthodontic treatment. Orthodontic treatment has become a dominant risk factor for this resorption over the last twenty years, increasing from 28.4% to 45.7%.
Cervical resorption incidence may be increasing due to improved scientific evidence, more accurate diagnostics, and greater orthodontic treatment uptake, as indicated by insurance data from some countries. Diagnosis typically occurs after the active treatment phase (9).
The treatment of cervical root resorption relies significantly on the defect's location and severity. The primary objectives are to halt clastic activity, excise resorptive tissue, and structurally restore the tooth. Standard clinical approaches include surgical repair, root canal therapy, and the application of topical medication.

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Root resorption (Internal)

Resorption of the root of the inner area in permanent teeth is a clinical encounter that can cause significant tooth structure loss, leading to localized widening of the pulp cavity at the lesion site. The disorder (inner RR) often has no signs and can be detected during repetitive dental X-ray investigations. Until the progressive stage, the root resorption can be detected, appearing as a 'pink tooth'. The pink color stems from granulation tissue accumulating in the upper area of dentin, which weakens the crown. Nevertheless, of course, the aesthetic change notices the patient.

Internal resorption is associated with infection, pulp trauma, and orthodontic treatment. Radiographic indicators of radiolucency's disorderly the root canal around pulp chambers. Histological analysis reveals pulpal granulation tissue that has multinucleated giant cells from near the inner root canal walls. Root canal treatment is typically the preferred intervention due to the inflammatory nature of internal resorption (11). Internal root resorption is an uncommon dental condition where the inner structure of a tooth's root begins to break down. Unlike external root resorption, which affects the outer surface (Figure 2).

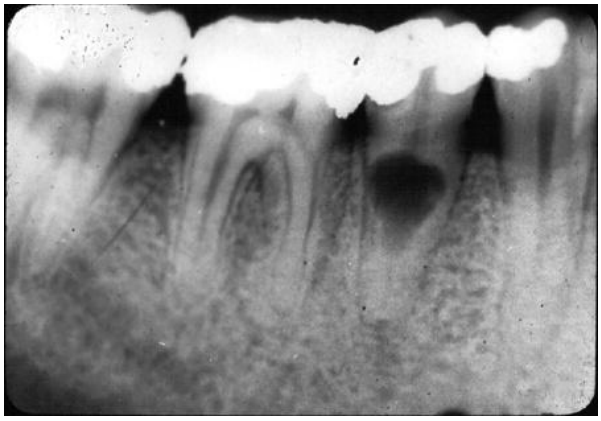

Figure 2. Internal root resorption

In internal root resorption, use a diagnostic protocol (diagnostic imaging), CBCT is the cornerstone of diagnosis. Due to the irregular morphology of the root canal system, studies indicate that endodontic files contact only 40% to 60% of the cavity walls. Consequently, contemporary protocols rely heavily on irrigation activation techniques; passive ultrasonic irrigation is used to enhance irrigant penetration and effectiveness, alongside the application of 17% EDTA to remove the smear layer and facilitate the action of disinfecting agents (12).

Causes which effect on the treatment and lead to root resorption

Pre-cementum defends the external (outer) walls of tooth roots, while pre-dentin and odontoblasts defend the inner walls. Resorption, resulting in dentin, cement, or bone tissue loss, is related to both physiological and pathological factors. Resorptive cells cannot take possession of nonmineralized surfaces. Mechanical, chemical, and thermal influences can inspire defensive barrier mineralization and initiate root resorption (13). In external(outer) inflammatory resorption (EIR), periodontal ligament (PDL) lacerations and necrotic variations in the root canal of the canal initiate the process because showing dentinal tubules accumulate bacteria, and destroyed tissue remnants perpetuate inflammation. (14).

One of the most cause in root resorption of tooth structures is trauma in the dental area, pulpal contamination and inflammation, systemic and hereditary factors, periodontal disease, high orthodontic forces, and biological resorption of deciduous teeth. Root resorption, if not treated quickly and do not make necessary X-ray investigations, can threaten tooth structure, purpose, esthetics, and lifespan (15). Loss of tooth structure, root resorption (RR) needs two stages: injury and stimulation. Injury involves non-mineralized tissues layering the external root surface (pre-cementum) or the internal root canal surface. Chemical irritation, such as from whitening teeth procedures using 30% hydrogen peroxide or other irritating agents, can also cause injury to the teeth (16).

The maxillary incisors are mainly affected by orthodontic forces, especially the apical part of the roots when high force. More studies showed external apical root resorption (EARR) is greatest in maxillary incisors compared to other teeth. Maxillary lateral incisors usually display more resorption than maxillary central incisors (17,18). This demonstrated a positive correlation between heavy forces and an increased risk of root resorption. The paper recommends using light, continuous forces to minimize tissue damage.

The study confirmed by (19) that conventional periapical radiographs often fail to detect early-stage resorption. In contrast, CBCT provides high diagnostic accuracy in determining the size and location of resorptive lesions, thereby facilitating early adjustments to treatment plans.

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How to diagnose root resorption

Radiographic investigations assist in identifying dental structures. Cephalometric and panoramic film assessment is a routine pretreatment procedure in many dental protocols. Most educational programs recommend these preapical, cephalometric, and panoramic dental radiographs (Fig 3) (20). More research is needed, according to European rules, regarding cone beam computed tomography (CBCT's) use in dental trauma and its diagnostic efficacy, specifically its impact on treatment planning and patient outcomes.(21)

Figure 3. Dental panoramic tomograph

CBCT (Figure 4) effectively diagnoses orthodontic root resorption due to its 1:1 reconstruction ratio, eliminating amplification error. It clearly visualizes root structure, facilitating additional precise qualitative valuations of loss of tooth structure (RR). Furthermore, its 3D reconstruction allows for multi-angled observation, enhancing cross-sectional research. Cone-beam computed tomography (CBCT) suggestions better-quality, accuracy, and understanding in root resorption (RR) studies compared to 2D (panoramic x-ray) imaging. CBCT data delivers equal image data of the right and left sides, removing image overlay interference. CBCT precisely measures tooth and root resorption volumes, finding it to be a more reliable 3D method for investigating external apical root resorption (EARR). CBCT also offers the significant advantage of in vivo application in root resorption studies, unlike micro-CT (22). Lumes found it to be a more reliable 3D method for investigating external apical root resorption (EARR). CBCT also offers the significant advantage of in vivo application in root resorption studies, unlike micro-CT (22).

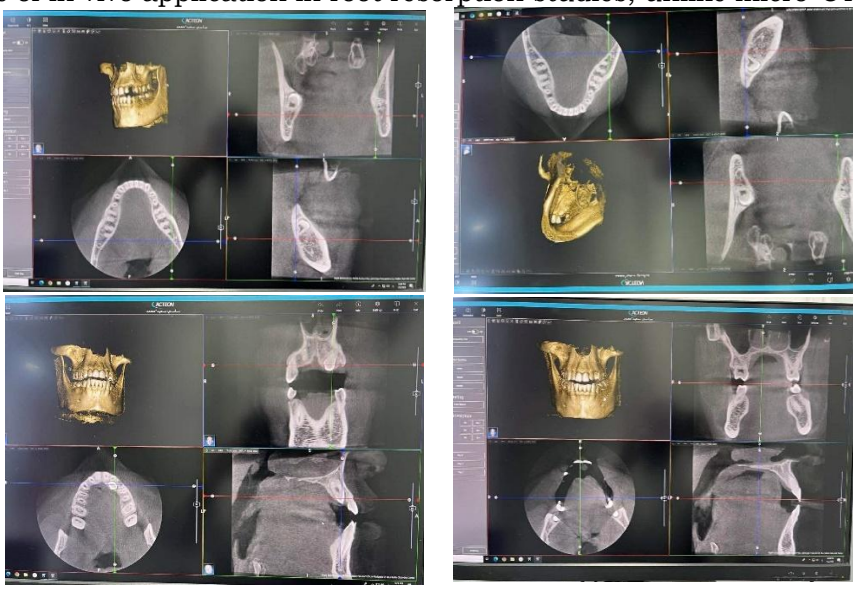

Figure 4. Cone beam computed tomography

Acted teeth were similar to those of biological teeth when erupted, with an alteration of 0.2 mm. Though impacted teeth showed significantly more root resorption overall, this difference was never clinically significant. Loss of tooth structure in the external part of the root, especially in the apical area, is multifactorial; consequently, routine X-ray regulation is recommended, especially in orthodontic patients undergoing treatment longer than six months (23).

Root Resorption (Implications)

Root resorption weakens tooth stability, jeopardizing orthodontic treatment success. Weakened roots increase tooth mobility and reduce secure positioning, leading to unintended tooth movement and counteracting orthodontic objectives. Patients may experience post-treatment tooth shifting, causing concerns about the durability and overall dental health (24).

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Management and Preventive Measures

Lighter forces are employed to move teeth gradually, allowing bone and tissue to adapt without harm. Consistent monitoring throughout treatment is crucial for early issue identification and timely plan adjustments. Etiological factor documentation helps in the proper treatment of root resorption through its removal. This paper remembers stimulation factors for root resorption types, diagnosis by radiographic x-ray, assisting clinicians in diagnosis and treatment (16).

Conclusion

Root resorption in orthodontics poses a threat to the stability and longevity of results. Understanding contributing factors, such as mechanical forces and patient-specific characteristics, is crucial for clinical practice. Acknowledging these aspects allows orthodontists to mitigate risks during treatment and improve patient outcomes. Continued research is necessary.

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Declaration of Generative AI and AI-assisted technologies in the writing process.

During the preparation of this work, the authors declare that this research paper is entirely their own original work. No generative artificial intelligence (AI)tools or AI-assisted technologies were used in data analysis or the writing process of this manuscript.

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