Root Resorption in Orthodontics

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Abstract

Root resorption is a common iatrogenic consequence of orthodontic treatment, although it can also be seen in the absence of orthodontic treatment. It may occur at any time during orthodontic treatment and compromise prognosis of the tooth involved and also the stability of treatment results. Orthodontics is the only branch which actually uses the inflammatory process as a tool for solving esthetic and functional problems. Therefore, every orthodontist should know the risk factors of root resorption involved in the process and plan treatment with an aim to reduce its possibility. The severity and degree of root resorption related with orthodontic treatment are multifactorial, involving environmental factors and host factors. A proper medical history, an assessment of predisposing factors, radiographic evaluation of alterations in root morphology and careful planning and execution of orthodontic mechanics may reduce the incidence of root resorption. The objective of this review is to analyze the literature on the epidemiology, etiology, diagnosis, manifestations and treatment of different kinds of root resorption, as well as its relationship with orthodontics and endodontics.

Keywords: External root resorption, internal inflammatory resorption, orthodontic treatment, endodontic treatment

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Introduction

Root resorption (RP) is defined as destructive process of the tooth structures; cementum and/or dentine layers of the root caused by activity of the clastic cell that result in a subsequent resorption and lossin root structure, Root resorption may be physiological or pathological process. During transition to the permanent dentition, the Physiological root resorption described as naturally occurring process in deciduous teeth when permanent teeth start eruption process. It also may occur to a limited amount in the permanent teeth associated with physiological tooth movement . [1,2]

Orthodontically induced inflammatory root resorption (OIIRR) is term to describe the type of root resorption that occurs during orthodontic treatment process.

Pathological root resorption may occur in association with orthodontic tooth movement, many pathological condition trauma, and when adjacent teeth undergo ectopic eruption.[1]

Root resorption was first known in **1856**, when **Bates** first discussed the Absorption' phenomena of permanent teeth. Using radiographic method in **1927**, **Ketcham** first demonstrated the distinctions between root shape pre and Post OT. Soon after, an assortment of histologic, clinical, physiologic and biological research on root resorption during OT, were published, all of which were well- received by the orthodontic field.[1-3]

Andreasen, put forward a widely-acknowledged classification system in **1970**, in which the condition is classified by location, type and etiological features.
A multitude of classification systems and terminologies have been Proposed since then, with various researchers trying to discover clinically- related ones to ameliorate communication among clinicians and researchers in addition to assisting diagnosis and treatment plans of this pathological state.[1-7]

Later, OIIRR is classified as Progressive External Inflammatory Root Resorption by **,** who then sorted it into three groups according to severity:

1) Cemental surface resorption with remodelling: resorption of outer cemental layers only, which later on completely regenerated or

remodelled, that similar to remodelling of trabecular bone **(Figure 1)**.

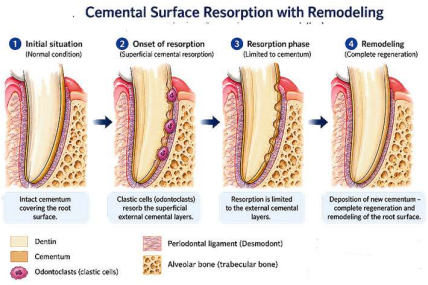


Figure 1: *Cemental Surface Resorption with Remodeling.*

Schematic illustration of the development and healing of cemental surface resorption. (1) Intact root surface covered by a continuous cementum layer. (2) Initial resorption phase characterized by superficial resorption lacunae produced by odontoclastic activity affecting only the outer cementum layer. (3) Resorption remains confined to the external cementum without involvement of the underlying dentin. (4) Reparative phase with deposition of new cementum and complete remodeling of the root surface. This type of resorption is generally reversible and does not result in permanent root shortening or significant alterations in root morphology. The process resembles physiological bone remodeling and represents the mildest form of orthodontically induced inflammatory root resorption.

2) Dentinal deep resorption with repair: where the outer layers of the dentin as well as the cementum itself are resorbed and repaired with cement material. The final shape of the root could or could not look like the original form after this resorption and formation process **(Figure 2)**.

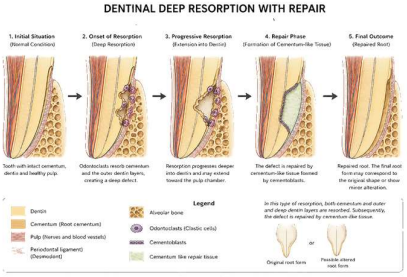


Figure 2: Dentinal Deep Resorption with Repair.

*Schematic illustration of deep external root resorption and subsequent repair. (1) Intact root structure. (2) Odontoclastic resorption affects the cementum and outer dentin layers. (3) The resorptive process extends into deeper dentin. (4) The defect is repaired by deposition of cementum-like tissue. (5) The final root morphology may either resemble the original contour or show minor permanent alterations. Tooth vitality is generally maintained throughout the process***.**

3) Circumferential apical root resorption: where the hard tissue constitutes of the root apex are completely resorbed, and reduced root length is thus clear. It is certainly possible there are different degrees of apical root shortening **(Figure 3)**.

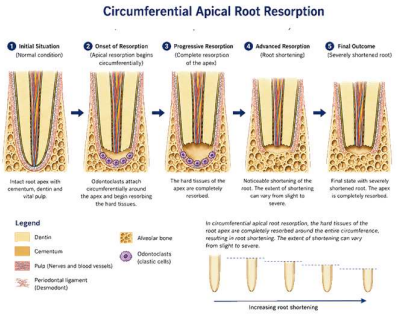
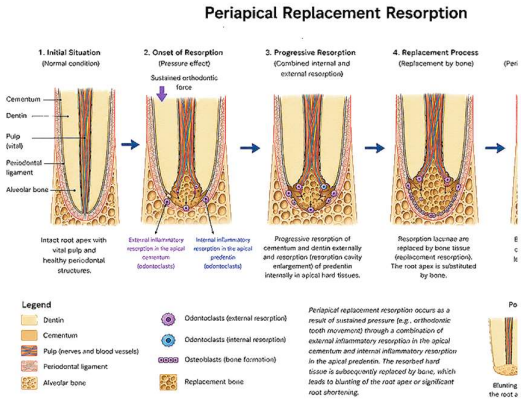


Figure 3: Circumferential Apical Root Resorption.

Schematic illustration of the progression of circumferential apical root resorption. (1) Intact root apex. (2) Odontoclastic cells initiate circumferential resorption of the apical hard tissues. (3) Progressive resorption of cementum and dentin around the entire root apex. (4) Noticeable root shortening due to loss of apical structures. (5) Final stage characterized by varying degrees of apical blunting and root length reduction. The severity of root shortening depends on the duration and intensity of the

4) The OIIRR can also be called 'Periapical Replacement resorption which develops when there is persisting pressure. This causes more marked a blunting of the apex or even extreme root

length loss in the more difficult cases , which could be caused by the combination of external inflammatory resorption around apical cementum and internal inflammatory resorption of apical pre-dentine, ensuing in periapical replacement resorption **(Figure 4)**.



.***Figure 4: Periapical Replacement Resorption.***

Schematic illustration of the progression of periapical replacement resorption. (1) Intact root apex with vital pulp and healthy periodontium. (2) Sustained pressure induces external and internal inflammatory resorption in the apical region. (3) Progressive resorption of apical cementum and dentin. (4) Resorption lacunae are replaced by newly formed bone tissue. (5) Final stage characterized by apical blunting and varying degrees of root shortening due to osseous replacement of the resorbed root structures.

Mostly detected OIIRR is ranged to be minor to moderate in orthodontic patients according to graded scales assessment of severity (using either periapical or panoramic radiographs).

Incidence statistics for prevalence of orthodontically induced root resorption vary from 1.1% to 100% . This variation depends on: the examination methods ; the choice of the criteria of root resorption ; the type of appliance and forces used; the extent of the tooth movement; the group of teeth examined; the duration of the treatment; and the dental age . However, in most studies, only a small percentage of severe and/or moderate resorption is reported and even for lingual orthodontics .Even if orthodontic treatment is considered to be aggressive from dental professionals concerning the attitude towards root resorption effect, root resorption tends to be an expected side effect of the orthodontic procedure (Lee et al. 2003). The prevalence of more severe root resorption in the literature varies less and ranges from 2-15% .Previous studies have also shown that a reverse relation between incidence values and OIIRR severity. Recent systematic reviews and meta- analysis were conducted to qualify and identify the incidence and severity of OIIRR pre- and post -comprehensive OT in the studies using CBCT, and the results showed that the anterior maxilla was showing the greatest amount of OIIRR followed by the anterior, posterior, mandible, and finally the posterior maxilla.

Orthodontic tooth movement relies on bone resorbing and root cementum remaining intact. The anti-angiogenic properties of cementum have been proposed as a mechanism by which osteoclastic resorption of cementum is inhibited, as the osteoclasts cannot gain access to the root surface area. The increased mineral content of cementum in comparison to bone probably also contributes to the relative resistance of cementum to osteoclastic activity, as well as the periodontal ligament fibres being more densely inserted into cementum than alveolar bone. Nevertheless, some element of root resorption during orthodontic treatment is likely to be almost universal, with 2 mm of root resorption often quoted as a normal sideeffect. Being able to predict those patients at risk of severe root resorption would be extremely useful, but as yet not possible.

Research in the early 1990s described treatment-related risk indicators for root resorption to include root torque, maxillary surgery and approximation of maxillary incisor roots against the lingual cortical plate .[16]

An overview of systematic reviews was published in 2021 by Yassir *et al.*, which described the risk of orthodontic-induced inflammatory root resorption being higher for fixed appliance treatment using heavy and continuous forces, intrusive forces (especially in conjunction with anterior temporary anchorage devices), maxillary incisor torque and retraction, mechanically complex treatment of severe malocclusions, treatment of long duration and tooth-anchored expansion. There was insufficient evidence to confirm the effect of other treatment- and patient-related factors, including age and gender, unusual root morphology, history of trauma and systemic medication.[16]

Changes in pulpal blood flow have been investigated in response to orthodontic forces. In a rat model, blood flow was shown to increase following orthodontic tooth movement.[17]

Another study using a radiospirometric method examined the respiration rate in human teeth which had been subjected to an orthodontic force for 72 hours and then a subsequent rest period of 1 week. The pulpal respiration rate remained depressed after orthodontic tooth movement, with the age of patients negatively correlated with the respiration rate and the size of the apical opening of the tooth positively correlated with the respiration rate.[18]
Other work has shown that following an initial decrease in blood flow after orthodontic force application, there is an increase in functional pulpal blood vessels, as a result of an increase in angiogenic growth factor.[19] A systematic review published in 2021 found that orthodontic tooth movement does not induce loss of pulpal vitality, although with low certainty of evidence.[20]

The objective of this review is to analyze the literature on the epidemiology, etiology, diagnosis, manifestations and treatment of different kinds of root resorption, as well as its relationship with orthodontics and endodontics.

Etiology

As a general concept, RR is a pathological process of multifactorial origin related to permanent loss of dental structure in response to mechanical, inflammatory, autoimmune or infectious stimuli [17]. External RR can be determined by a variety of factors such as periapical pathological processes, dental eruption and periodontal pathological processes ([8]. Genetic predisposition has also been described as an etiological factor of external RR, along with mechanical factors derived from orthodontic treatment, and in turn, the reaction to orthodontic force may differ depending on the genetic origin of the individual [19, 20]. The most associated genetic factors were IL-6 SNP rs1800796 GC and the presence of specific genotypes for P2RX7 SNP rs208294 [20, 21]. It is very likely that several of the molecular pathways and the aforementioned factors interact in effector cells for resorption at the level of fusion, activation, and cell adhesion [22]. On the other hand, most cases of internal resorption are idiopathic [23]. However, like external resorption, it is usually related to dental trauma, as this can impact hard dental tissues, as well as damage the pulp and the periodontium and adjacent alveolar bone [24]. Consequently, it also becomes related to the stimulation of pulp tissue, which, when starting an inflammatory process, leads to undifferentiated pulp cells to become osteoclasts or macrophages, which results in dentin resorption [11] **(Figure 5)**.

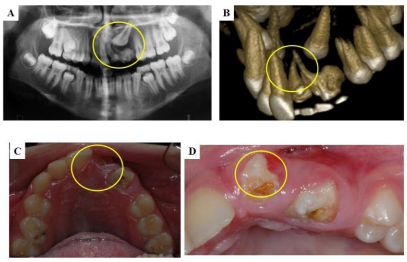


Figure 5: *Traumatic dilaceration, displacement, and root resorption of the maxillary anterior teeth. (A) Panoramic radiograph showing post-traumatic developmental disturbances, including dilaceration of teeth 21 and 22 and displacement of tooth 23. (B) Three-dimensional CBCT reconstruction confirming the abnormal position and morphology of the affected teeth. (C) Intraoral occlusal view of the impacted and displaced teeth. (D) Magnified intraoral view showing malformed crown morphology, eruption disturbance, and external root resorption of tooth 21. Circled areas indicate trauma-related changes*.

The role of osteoclasts and odontoclasts is related to physiological and pathological clinical scenarios, including RR. Understanding the mechanism that controls its development and activation would provide information for its early detection and clinical management [25]. Other studies mention relationships with the presence of rheumatoid arthritis, and talk about the Herpes zoster virus, as a possible viral etiology [26, 27]. Further studies have suggested possible associations between root resorption and systemic diseases. For example, links with rheumatoid arthritis have been reported. In this chronic inflammatory autoimmune disease, increased release of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-1 (IL-1), and interleukin-6 (IL-6) occurs. These cytokines are well known to promote osteoclastogenesis and may therefore also influence resorptive processes affecting dental hard tissues. Furthermore, it has been suggested that systemic inflammatory reactions may modulate local tissue responses within the periodontium and dental pulp, thereby facilitating the initiation or progression of root resorption [26].

In addition to autoimmune disorders, viral infections have also been investigated as

potential etiological factors. In particular, the Herpes zoster virus has been described in the literature as a possible trigger or contributing factor. It is assumed that viral infections may initiate processes leading to the activation of odontoclasts and osteoclasts through direct tissue damage, neurogenic inflammatory reactions, or alterations in the local immune response. Although the current evidence remains limited, these observations highlight the potential role of systemic and infectious influences in the development of root resorption [27].

The complex etiology of root resorption can be understood as the result of interactions between various local and systemic factors. Mechanical stimuli, genetic predisposition, inflammatory processes, trauma, and systemic diseases may act individually or synergistically to activate resorptive cells. The resulting activation of osteoclasts and odontoclasts ultimately leads to the resorption of dentin, cementum, and, in some cases, adjacent bone tissue.

A simplified schematic representation of the major etiological factors is shown in **Figure 6**.

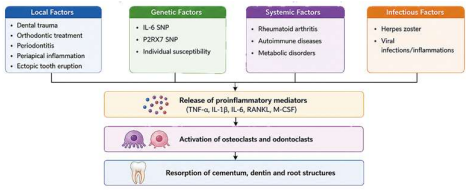


Figure 6: *Schematic representation of the multifactorial etiology of root resorption.*

Local Factors

Although the exact etiology of root resorption has not yet been fully elucidated, several causative patterns have been identified that may serve as a basis for understanding these pathological processes. In external root resorption, both biological and mechanical factors appear to play significant roles. In contrast, internal root resorption is thought to be primarily associated with damage to the pulpal tissues resulting from traumatic injury or inflammatory processes. Nevertheless, it is likely that complex interactions among local tissue responses, immunological mechanisms, and individual genetic predispositions also contribute to its development.

Continued investigation of the underlying molecular mechanisms is of considerable importance, as a more comprehensive understanding of the pathogenesis may not only facilitate the identification of patients at increased risk but also provide new opportunities for prevention, early diagnosis, and targeted therapeutic interventions. Therefore, further research into the relationships between root resorption, systemic diseases, and other potential risk factors is of substantial medical and clinical relevance.

.Diagnosis

For the correct diagnosis, the use of radiographs and anamnesis is of vital importance, since only through them will it be possible to identify the different factors that could cause root resorption [1]. As a differential diagnosis, it can be identified that external RR is always accompanied by bone resorption, therefore, radiolucent areas can usually be seen both in the root and in the adjacent bone, while internal reabsorption is limited to affecting the root [28]. According to research, internal resorption lesions may perforate the external surfaces of the root, which may not be detectable in conventional radiographic images [29], and at the same time it is concluded that panoramic radiography is not appropriate for diagnosis of external RR [30]. The CBCT is a new technology that uses a cone-shaped beam, which rotates in 360 degrees and acquires the projected data in a single rotation, which facilitates the perception of 3D for the dentist [31,55-61]. Their arrival has greatly improved the physician's ability to diagnose internal root resorption [32-36] and can also be reliable in detecting the presence of external RR in clinical practice [33]. Although conventional periapical radiographs can provide acceptable diagnostic accuracy [34-41], CBCT is superior in the diagnosis of external and internal inflammatory RR after dental trauma and can be considered in the differential diagnosis in resorption lesions in teeth with endodontic treatment [35]. Due to its superior diagnostic accuracy, it also resulted in a greater probability of correct management of resorption lesions [36]. However, a disadvantage is that the radiation dose of a CBCT study is higher than most conventional imaging techniques [37]. Achieving an adequate diagnosis and differentiation of an external RR from an internal RR is essential, since as we both know they have different etiologies and their management must also be specific. CBCT is the most accurate diagnostic method, however, it should be used sparingly for the dose of radiation involved in its use, for this reason the use of conventional periapical radiographs should not be ruled out at least in the case of external RR.

Manifestations

Radiographs highlight that some forms of external RR are accompanied by radiolucency of the bone adjacent to the resorption lesion or may present changes in the shape of the root, in which the missing part of the root is replaced by bone tissue, without radiolucency [18-33]. External RR associated with orthodontic treatment causes a permanent shortening of the root, which translates into a loss of dental support [38]. Also, it is accompanied by mobility of the affected teeth [39]. On the other hand, internal RR can manifest itself in a purely destructive way (internal inflammatory reabsorption), and on the other, as resorption by internal replacement, which is in conjunction with the deposition of metaplastic bone / cement tissue adjacent to the sites of resorption [36]. It is usually asymptomatic, so an early diagnosis is necessary before the process compromises the remaining mineralized structures of the tooth [40, 41]. If a perforation of the crown and the metaplastic tissue is exteriorized, a pink coloration appears on the vestibular surface, causing pain [42]. Traditionally the pink spot was considered in the crown as a pathognomonic sign of internal resorption, but also usually indicates the presence of an invasive cervical resorption [40]. Because the process of external and internal resorption takes place in the root portion of the teeth, the manifestations of these are mostly subclinical. Thus, at the time of making radiographic diagnoses it is very important to always examine every detail to realize this type of pathologies (***Figure 7, Figure 8)***.

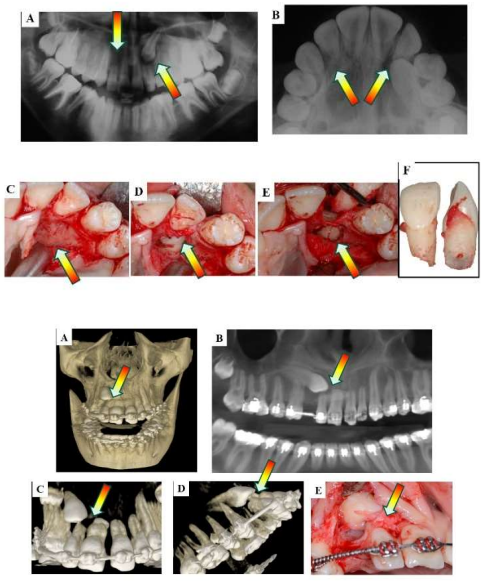


Figure 7

Figure 8

Figure 7: *Severe external root resorption caused by an impacted maxillary canine. (A, B) Radiographic findings showing an ectopically displaced maxillary canine (tooth 23) associated with root resorption of the adjacent lateral incisors. An unexplained root resorption is present on tooth 12, whereas severe root resorption of tooth 22 is caused by direct contact with the impacted canine. (C–E) Surgical exposure of tooth 23 demonstrating its close proximity to the root of tooth 22. (F) Extracted tooth 22 exhibiting extensive external root resorption and substantial loss of root structure.*

Figure 8: *CBCT evaluation of an impacted maxillary canine associated with root resorption of the lateral incisor. (A–D) Three-dimensional CBCT reconstructions showing the position of the impacted maxillary canine (tooth 13) and external root resorption of the adjacent lateral incisor (tooth 12). (E) Surgical exposure of the impacted canine. Arrows indicate the impacted tooth and the resorptive defect*

Treatment ;

Treatment alternatives depend on the case and are intended to address the cause of resorption and help regeneration of the resorption lesion .[43-48] Timely management of the affected tooth can delay the resorption lesion and increase the prognosis of the tooth survival ,[31-43] Internal resorption requires the presence of vital tissue to advance, therefore, endodontic treatment stops the process [40-50]. The technique of choice to carry it out is thermoplastic injection of gutta-percha. In case the resorption is in an advanced stage and has produced a communication of the root interior with the periodontium, the filling material must be MTA.[33-40] It is not possible, through the pulp, to control the resorption process that is taking place in the external part, after all, the causes are acting in the periodontal ligament.[41-45]External RR for orthodontics does not require endodontic treatment, as occurs with the forces applied on the tooth, it should be treated by eliminating these forces ..[46-57] Some studies talk about the clinical efficacy of MTA to limit the process of inflammatory resorption and promote the apexification and regeneration of the periradicular tissue .[51-61`]

The mechanisms underlying orthodontic tooth movement continue to provoke interest and investigation.

A recent in-vitro study by Chachartchi et al (2023) has investigated the similarities in the inflammatory processes common to both periodontal disease and orthodontic tooth movement.[25)]The authors found that periodontal inflammation and mechanical forces associated with orthodontic tooth movement resulted in bony breakdown by effects on different cell types, with distinct mechanisms for periodontal bone breakdown and orthodontic bone remodelling.[21,25]

Another area of recent research is developing the ability to predict those individuals who might be more prone to orthodontic-induced inflammatory root resorption by detecting possible biomarkers in either the blood or the saliva. In a small retrospective study, there was a significant increase in salivary cytokines including IL(interleukin)-7, IL-10, IL-12p70 and IFN(interferon)-gamma and a significant decrease in IL-4 for patients with moderate/severe root resorption.[26] Gingival crevicular fluid has also been used in a more recent study by Huang et al (2021) to identify tissue-specific markers which may allow early detection of root resorption during orthodontic tooth movement.[27] In PubMed, Science Direct, Google Schoolar searched for information with combinations of the keywords: external RR, internal RR, orthodontic treatment, endodontic treatment, epidemiology, etiology, diagnosis, manifestations and treatment.

Both external and internal resorption present preference to the upper central incisor teeth. In the external reabsorption both biological and mechanical factors intervene and in the internal reabsorption the mechanical factor prevails. Cone Beam Computed Tomography (CBCT) is the most accurate diagnostic method. The treatment of external RR will depend on its etiology and the dentist's diagnostic criteria, while stopping the internal resorption process ultimately requires endodontic treatment.

Conclusions

External and internal resorption have a multifactorial etiology. A correct diagnosis is essential to select the appropriate treatment plan to stop the resorption process. Because its manifestations are subclinical, CBCT is the diagnostic tool of choice for its proven efficacy. Calcium-enriched mixture cement represents a good treatment option for root perforations. New questions remain open, such as its relationship with systemic diseases, demographic aspects and the development of alternative materials for the treatment of these pathologies, for future update studies.

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