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**Research Article**

# ROOT RESORPTION IN ORTHODONTICS – A LITERATURE REVIEW

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**Abstract**

Root resorption, primarily seen as External Apical Root Resorption (EARR), is a notable issue in orthodontics. Several factors contribute to this condition, including the magnitude and type of orthodontic forces, the patient's age, genetic predispositions, and the kind of orthodontic appliances used. Both fixed orthodontic treatments (FOT) and clear aligner treatments (CAT) can lead to varying degrees of root resorption, with CAT potentially causing milder root shortening due to more controlled force application. Early detection of root resorption is vital for preventing further damage, making regular radiographic monitoring and informed consent essential. Despite advancements in orthodontic techniques, determining the optimal force to move teeth without causing root resorption remains unresolved, highlighting the need for further research to improve patient outcomes.

**Keywords:** Autistic children, Family caregivers, Puberty.

## INTRODUCTION

Root resorption is a common adverse effect following orthodontic treatment, with external apical root resorption being the most prevalent type. Bates first described root resorption of permanent teeth in 1856, and in 1914, Ottolengui linked it to orthodontic treatment. Ketcham's 1932 study demonstrated the impact of orthodontic treatment on root length and shape by comparing radiographs before and after treatment, sparking further research into histological, clinical, and physiological root resorption. Localized root resorption occurs as a normal response to oral microtrauma when excessive pressure on the tooth exceeds the reparative capacity of the periodontal ligament and cementum. This exposes dentin, leading to multinucleated clasts cells triggering the dissolution of the root structure. The process is complex, and many aspects remain unclear. Recently, due to medico-legal concerns, interest in root resorption following orthodontic treatment has surged, with new information continuously emerging. The current review aims to provide comprehensive knowledge of root resorption due to orthodontic treatment, raising awareness of the factors leading to resorption and enhancing understanding of how to minimize it.

**Normal Structures surrounding the teeth**

Each tooth has a crown and root portion, joining at the Cemento-enamel junction. The root portion or the radicular portion is composed of Cementum, dentin and pulp, encased by periodontal ligament, which firmly holds the tooth in the alveolar process of the jaw, so that each tooth is held in its position related to the others in the dental arch.

**Response to Normal function**

During mastication, teeth and periodontal structures endure heavy, intermittent forces, with contact lasting under a second and pressures ranging from 1-2 kg for soft foods to 50 kg for harder objects. The periodontal ligament (PDL) and its gingival fluid prevent rapid tooth displacement by transmitting forces to the alveolar bone, which bends in response. This bending, often overlooked, generates piezoelectric currents that stimulate bone regeneration and adaptation to functional demands. The PDL is suited for short-duration forces but loses its adaptive ability when gingival fluids are squeezed out. Prolonged force, even mild, leads to bone remodeling, facilitating orthodontic tooth movement. Similarly, light, prolonged forces from lips, cheeks, or tongue can also cause teeth to shift location.

**Effects of force magnitude:**

Heavier sustained pressure on the periodontal ligament (PDL) reduces blood flow until vessels collapse entirely. Prolonged light force decreases blood flow through the compressed PDL, causing the tooth to move in its socket quickly. Within hours, the chemical environment changes, altering cellular activity. Orthodontic effects begin if removable appliances are worn for more than 4-6 hours daily. Research indicates increased levels of prostaglandin and interleukin-1 beta in the PDL shortly after pressure application, with prostaglandin E being a key mediator (1). Osteoclasts and osteoblasts, essential for bone remodeling during tooth movement, are stimulated by prostaglandin E.

If the sustained force is strong enough to completely occlude blood vessels and cut off the blood supply within the PDL, sterile necrosis occurs in the compressed area instead of stimulating osteoclast development, delaying orthodontic tooth movement. In clinical orthodontics, it's challenging to avoid creating avascular areas in the PDL. Releasing pressure at intervals while maintaining it long enough to produce a biological response might help maintain tissue vitality, as supported by animal experiments. However, practical implementation is currently lacking. Future methods for activating and deactivating springs could make this approach useful.

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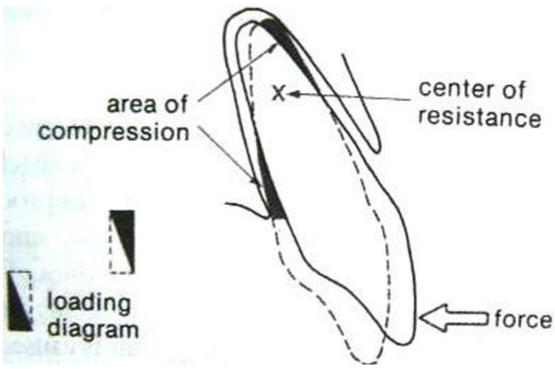
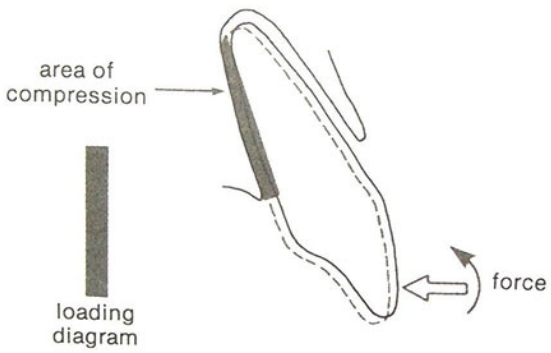
**Effect of force distribution and types of tooth movement**

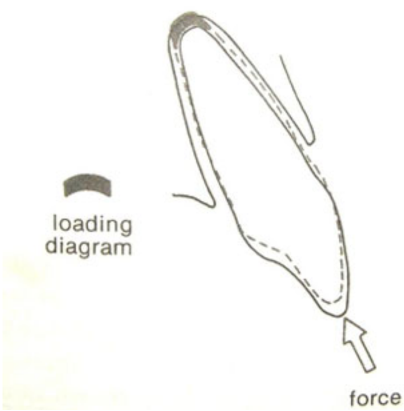
Orthodontic tooth movement is best achieved with forces that activate cellular processes without blocking blood flow in the PDL. The force and its distribution affect the biological response, which varies with the type of tooth movement. Tipping, a basic orthodontic movement, involves applying force to the tooth crown, causing it to pivot around its "center of resistance" located midway along the root. This action compresses the PDL near the root apex on the side of the applied force and near the alveolar crest on the opposite side, with pressure highest at thesepoints and decreasing toward the center of resistance.




When two forces are applied to the crown of a tooth, it can be moved bodily, meaning the root apex and crown move in the same direction and amount, uniformly loading the entire PDL area. This requires twice as much force as tipping to produce the same pressure and biological response. Forces needed for partial tipping and partial translation fall between those for pure tipping and bodily movement.




Extrusion movement ideally creates only tension within the PDL, with no compression areas. Intrusion movements require careful control of force magnitude, applying very light force to the teeth, as it concentrates in a small area at the tooth apex.




**Effects on root structures**

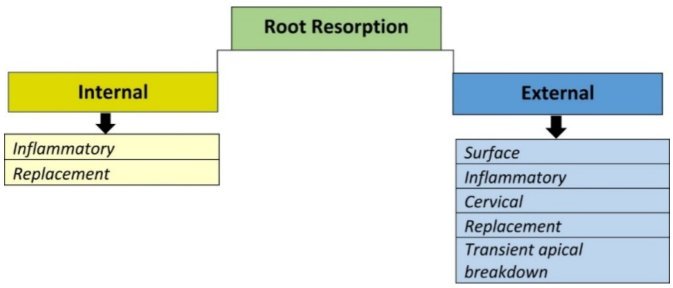
Orthodontic treatment involves bone resorption and apposition near the tooth root and PDL reorganization. Previously, it was believed that tooth roots weren't remodeled like bone. However, recent research shows that orthodontic forces typically impact the cementum of the root, similar to the adjacent bone, and cementum repair also takes place.

**Resorption**

Root resorption is a pathological and physiological process that results in the loss of the cementum and dentine (2). “Tooth resorption” rather than “root resorption” is a more appropriate term because resorption can involve the root and/or the crown of the tooth. There are various types of tooth resorption, each with specific causes and pathogenesis. A comprehensive understanding of the etiology and pathogenesis is crucial for diagnosis and management, or for monitoring until definitive treatment, such as root canal or extraction, becomes necessary.

**Classification of Root resorption**

The classification of root resorptions based on their location in the root and the subsequent subclassification based on the pathogenesis (3)




According to Proffit, shortening of roots after orthodontic treatment occurs in 3 distinct forms, that must be distinguished when the etiology of resorption is considered (4):

- Moderate Generalized Root resorption
- Severe generalized Root resorption
- Severe localized Root Resorption

FussZ et al, in their classification classified root resorption according to the stimulating factors, such as (5):

- Pulpal infection root resorption
- Periodontal infection root resorption
- Orthodontic pressure root resorption
- Impacted tooth or tumor pressure root resorption
- Ankylotic root resorption

**Grading of apical root resorption**

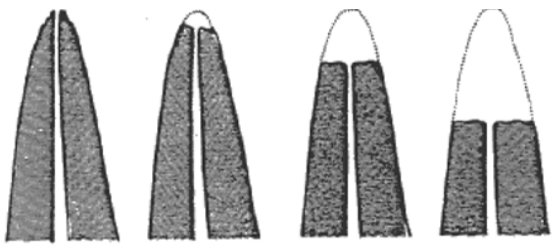
Robert W De Shields using intraoral radiographs described the following grading system for apical root resorption (6):

Grade 0: No resorption
Grade 1: Possible resorption
Grade 2: Definite resorption. The apical outline was definitely irregular but the root was not shortened or blunted.

Grade 3: Mild apical blunting. The reduction in root length was less than 3mm.
Grade 4: Moderate apical blunting. Resorption more than 3mm but less than 1/3rd the root length.
Grade 5: Severe blunting. More than 1/3rd of the original root length was lost.

Later in 1989, David N et al, described another grading system (7):

Grade-0: - Normal apical contour, same length as pretreatment.
Grade-1: - Apical irregularity, same length as pretreatment
Grade-2: - Apical root resorption of less than 2mm
Grade-3: - Apical root resorption more than 2mm, less than one third of original root length.
Grade-4: - Apical root resorption more than one third of original root length.



1 2 3 4

**Process of root resorption**

Root resorption of deciduous dentition is a normal, physiological process, necessary precursor for the eruption of the permanent succeedenous teeth. Whereas, root resorption in the permanent dentition is a pathological, irreversible process with a complex biologic process of which many aspects still remain unclear.

As stated by Thomas M. Graber, root resorption, unlike alveolar bone resorption, is unpredictable (8).

Shafer et al enumerated the various major factors causing root resorption of permanent teeth (9):

1. Physiologic tooth movement
2. Adjacent impacted tooth pressure
3. Periapical or periodontal inflammation
4. Tooth implantation or replantation
5. Continuous occlusal trauma
6. Tumors or cysts
7. Metabolic or systemic disturbances
8. Local functional or behavioral problems
9. Orthodontic treatment
10. Idiopathic factors.

Newman summarized following common features for various situations leading to root resorption (10):

1. Increase of pressure (tooth eruption, tumor)
2. Tissue damage in the periodontal membrane (mechanical, chemical, thermal).
3. Increased blood supply (hyperemia connected with certain types of inflammation, hypertrophy, epulis)
4. Pulpal/periodontal infection.
5. Individual predisposition (systemic diseases, endocrine disturbances).
6. Proximity of the root apex to the palatal cortex has been associated with apical root resorption.

**Histopathology of root resorption**

In orthodontics, root resorption is known as induced inflammatory resorption, a type of pathological root resorption. Orthodontic forces applied to the teeth lead to the removal of hyalinized areas in the periodontal region, which also affects the cementum. The resorption process begins with dentinoclasts, and osteoclast-like cells called odontoclasts, which are typically pleomorphic and multinuclear, cause the resorption.

**Factors affecting Root Resorption**

In line with many studies on the etiology of root resorption, the possible reasons for root resorption can be classified as follows (11):

**Factors related to patient:**

- **Genetics:** The genetic link to osteoclast formation (resorption cells) is under investigation due to the variability in the resorption process among patients. Since this variability cannot be fully explained by orthodontic or environmental factors, researchers are exploring genetic predispositions that may contribute to resorption (12). Significant differences in root resorption among patients, even when treatment and clinician-related factors are standardized, highlight the importance of individual predisposition. Studies suggest that personal tendency towards root resorption may have a greater impact than the amount and duration of orthodontic force (13). Genetic differences in the interleukin-1ß (IL-1ß) gene, related to the inflammatory response from orthodontic treatment, may clarify the occurrence of certain external apical resorptions. The IL-1ß allele 1 increases the risk of external apical root resorption (EARR) by 5.6 times. The IL-1ß (13954) gene proposes a role for this cytokine in the development of EARR and the protective mechanism of cementum against root resorption.

- **Systemic Factors:** Studies suggest that Endocrine problems such as Hypothyroidism, Hypopituitarism, Hyperpituitarism etc are related to the process of root resorption. Decreased level of estrogens and hyperthyroidism may enhance orthodontic tooth movement, whereas, hypothyroidism might result in increased root resorption. Goldie & King in their study suggested that the parathyroid hormone plays a major role in bone metabolism, but low calcium levels are necessary for root resorption to occur (14). Chronic asthma and allergies increase the risk of inflammatory root resorption during orthodontic treatment (15)

- **Nutrition:** Becks has shown that root resorption occurred in the animals lacking calcium and vitamin D in their foods (16)

- **Chronological age& dental age:** All tissues involved in the root resorption process show changes with age. The periodontal membrane becomes less vascular, aplastic and narrow, the bone becomes denser, avascular, aplastic and cementum becomes wider. These changes are reflected by a higher susceptibility to root resorption seen in adults. Though certain studies consider Chronological age as a risk factor (16), some do not approve this correlation (17). During growth, tooth movement can impact root development, causing dilaceration, which decreases expected root length and root resorption. This may result from the deflection of Hertwig's sheath. Teeth with incomplete apices undergo less root resorption than those with complete roots, likely because the apices continue developing until full root length is achieved during orthodontic treatment (17).

- **Gender:** Gender is also considered a risk factor for tooth root resorption, with males being at a higher possibility of root resorption than females (18). However, some authors reported that gender is not associated with the root resorption of the neighboring impacted teeth (19).

- **Ethnic factors:** Some ethnic groups, namely Hispanics, are more prone to resorption than Asians (20).

- **Neighboring unerupted tooth:** Root resorption can begin due to a neighboring unerupted tooth. A common issue with unerupted canines is the resorption of the roots of adjacent lateral incisors or bicuspids. Eruptive process or migration of the unerupted canines during the root growth probably can increase the risk of root resorption.

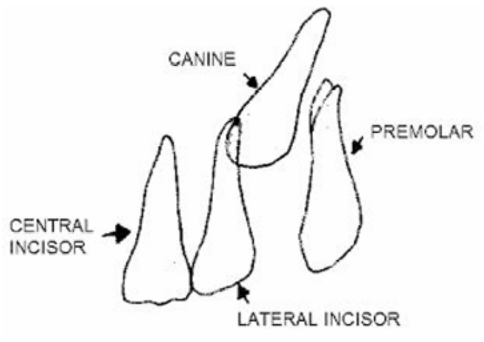



**Fig. 2.** Erupting canine teeth may induce root resorption of the lateral incisors and first premolars

The 3D evaluation of unerupted canines and root resorption of lateral incisors revealed no root resorption in 40.4% of cases, minor root resorption in 35.7%, 14.2% moderate and sever root resorption in 14.2% and 4.0% cases respectively (21). A key predictor for root resorption in incisors and first bicuspids is the close physical proximity, up to 1 mm, between unerupted canines and adjacent roots.

- **Presence of root resorption before Orthodontic treatment:** Root resorption that existed prior to orthodontic treatment increases risk for root resorption during orthodontic treatment (16). Goldesen L, Hensikson (1975) reported that in such cases incidence of root resorption increased from 4% to 77% after treatment.

- **Habits:** Deleterious habits such as Bruxism, nail biting, tongue thrusting associated with open bite and increased tongue pressure are related to increased root resorption (16).

- **Root shape & Tooth Specificity:** Root resorption often occurs in the apical part of the root due to concentrated forces at the root apex. Orthodontic tooth movement is never entirely translatory, with the fulcrum usually above the root apex. The apical third of the root is covered with cellular cementum, while the coronal third is covered with non-cellular cementum, and periodontal ligaments are oriented differently in the apical part of the tooth root. Pipette-shaped roots are the most susceptible root form to root resorption, then compared to blunt tooth roots (16). Thin and irregular apices, such as long or curved ones, are more prone to resorption due to their decreased resistance to mechanical stimuli. Root resorption is more common in hypofunctional teeth with atypical root shapes than in functional teeth. This likely occurs because the absence of occlusal contacts in hypofunctional teeth prevents physiological root transformation after eruption, leading to root resorption (22). Regarding tooth specificity, teeth of the maxillary teeth are more sensitive to root resorption than the mandibular teeth (16), especially upper and lower incisors appear to be more susceptible to Root resorption (23). There are controversial data about initial length of the tooth root and the amount of tooth root resorption. There is an opinion that longer roots are more likely to be re sorbed than shorter ones because longer roots are displaced farther for equal torque (24).

- **Alveolar Bone Density:** The role of alveolar bone density in root resorption is controversial. A part of the studies has established that the denser is alveolar bone, the more root resorption occur during the orthodontic treatment. According to Reitan, strong continuous force affecting alveolar bone of less density causes the same root resorption as a mild continuous force affecting alveolar bone of higher density. It is more difficult to resorb with orthodontic pressure than bundle bone.

- **Previously traumatized tooth:** Dental trauma may cause root resorption to the teeth without orthodontic treatment. Orthodontically moved traumatized teeth with previous root resorption are more sensitive to further loss of root material (16). The teeth can be treated orthodontically three months after the tooth transplantation or replantation.

- **Endodontically treated teeth:** For endodontically treated teeth increased and more often root resorption is characteristic during the orthodontic treatment. The hypothesis was raised that endodontically treated teeth are more resistant to root resorption because of increased hardness and density of dentin (16). Qualitative endodontic treatment of teeth is very important. When the root canal filling reaches the root apex, resorption doesn’t start however in case of a shorter filling a part without the filling resorbs (25).

- **Classification of Malocclusion:** Correlation between malocclusion and tooth root resorption has been assessd by various authors. Some studies concluded that there is no relation between root resorption and malocclusion, whereas certain stated that dental and skeletal malocclusion induce occurrence of root resorption (26). Upon studying tooth root resorption occurring during treatment of Angle II class orthodontic malocclusion, it was established severe ($^3$2 mm) maxillary incisor root resorption in 12,4% of children (27). Relationship between the change in overjet and severity of root resorption is also been evaluated by several studies. The greater the overjet during the orthodontic treatment, the greater the root resorption for maxillary anterior teeth, because greater tooth movement is necessary in or der to decrease overjet (24). It was established that the deeper is overbite, the greater is root resorption of a maxillary permanent first molar distal root and maxillary incisor (28).

**Treatment related factors**

- **Treatment duration:** It has been noted in many clinical studies that prolonged orthodontic treatments (over 3 years) are positive correlated with severe root resorption (22,29). One month of additional treatment causes extra root resorption of 0.1 and 0.2 m*m* of the most severely resorbed central and lateral incisor, respectively. In a systematic review, it was stated that root resorption after 6 to 9 months of orthodontic treatment was detected in 34% of teeth, meanwhile in the end of orthodontic treatment that lasted 19 months, root resorption increased up to 56% (16). The review also reported that the amount of root resorption during orthodontic treatment is 0.9mm per year (16)

- **Magnitude of orthodontic force and Direction of tooth movement:** Applying force in orthodontic treatment is a primary cause of EARR, as it triggers the inflammation needed for tooth movement and root resorption. There's debate about whether orthodontic force alone causes root resorption and if small forces can contribute. Some authors recommend using forces of 7 to 26 g/cm², with intermittent forces causing less damage. In more detail, light orthodontic forces usually tend to result in mild root resorption, while archwire sequencing, bracket prescription and self-ligation appear to do not affect the root length (30). During tipping movement, the apex absorbs all the compressive stress, resulting in increased stress per unit surface area (31,32), where as translation movement generates compressive stress to the entire root surface, which causes cementum resorption at the sides of periodontal ligament compression. Though, extrusive movements happen effortlessly, they can also cause orthodontically induced root resorption at the cervical third of the root. During intrusive tooth movement, almost all the stress is concentrated in the apex; thus, again in this situation the risk of EARR rises significantly (33). Intrusion movements generate about 4 times more root resorption than during extrusion movements (34).

- **Continuous Vs Intermittent force:** Although continuous force has been proven to produce quicker tooth movement than intermittent force, it is associated with a greater risk of root resorption. Intermittent force is applied to avoid more significant root resorption, which allows the reparative mechanism to be initiated. The application of intermittent force was obtained with a 4-day force application period followed by a 3-day resting period, and considerably less overall root resorption was found. This eventually has led to using light continuous forces for carrying out all types of tooth movements (35)

- **Type of Orthodontic technique& appliance:** Root resorption is an inevitable drawback of all orthodontic techniques. The misalignment of brackets and mismatch between preadjusted brackets and tooth shapes prolong Fixed Orthodontic Treatment (FOT) to several months. Consequently, teeth often experience back-and-forth movement, significantly shortening root length. Therefore, this treatment method is considered a high-risk factor for External Apical Root Resorption (EARR) (36). Clear Aligners Treatment (CAT) typically results in mild root shortening, as they can be preprogrammed to control the force applied on teeth and manage apical stress to minimize orthodontically-induced root resorptions. The treatment time for CAT is comparable to Fixed Orthodontic Treatment (FOT), despite CAT having a slower tooth movement velocity, particularly in non-extraction cases (37). Gay et al. noted that root resorption from clear aligners is similar to that from light forces, affecting approximately 10% of the initial root length (38), conversely, another study found a similar predisposition for apical root resorption with both removable aligners and fixed appliances (39). While the evidence is limited, studies indicate that Orthodontically Induced Inflammatory Root Resorption (OIIRR) is not significantly impacted by the type of bracket ligation method (conventional/self-ligating), bracket prescription, or the use of straight wire versus standard edgewise brackets (40,41).

- **Extraction Vs Non-Extraction cases:** Extraction cases have 2,72 times more chances of developing severe EARR40; since, the retraction mechanics used for the anterior teeth increase the apical movements and the treatment duration (42,43). Root resorption develops more often after extraction of four first premolars if compared to the patients with non-extracted teeth or with extracted of just maxillary first premolars (16).

- **Root resorption detected radiologically during orthodontic treatment:** Detecting minor root resorption or irregular root contour 6-9 months into orthodontic treatment indicates a high risk of further resorption. Conversely, if no root resorption occurs within this period, severe root resorption is unlikely by the end of the treatment (16).

- **Root resorption after removal of appliances:** Root resorption due to orthodontic treatment ceases after active treatment ends. Active root resorption lasts about a week after removing the orthodontic appliance, followed by cementum repair lasting 5-6 weeks. Post-removal root resorption is mainly caused by occlusal trauma, active retainers, or other factors (16).

- **Relapse:** Reitan (1964) claimed that the forces of relapse are strong enough to cause root resorption. Sharpe et al12 (1987) found a higher frequency of root resorption in patients demonstrating relapse.

**Other considerations:**

- **Tooth Vitality:** Studies show that teeth vitality & color do not change even in cases of extensive root resorption. Orthodontic movement may cause pulp blood flow disturbances, vacuolization and, in rare cases, pulp necrosis, however it doesn’t relate to root resorption (16).

**Repair Process:**

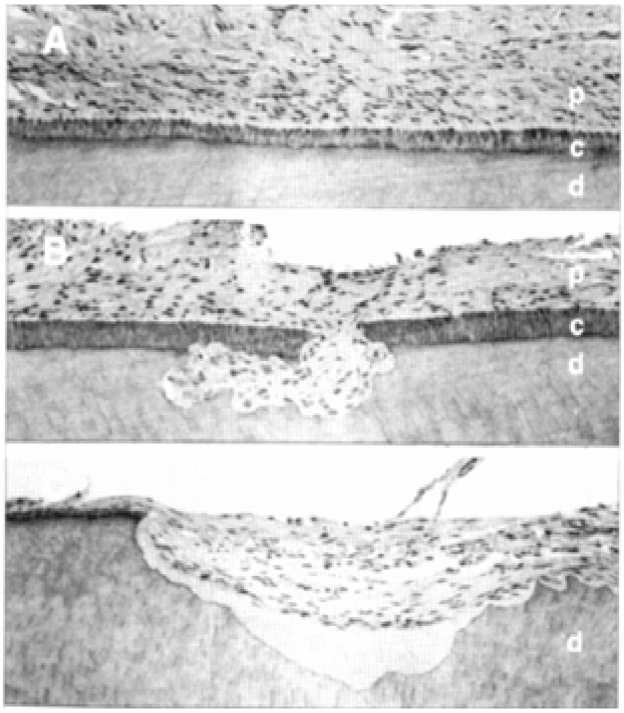
This can occur in 2 ways: Repair of root resorption starts immediately after the discontinuation of the orthodontic force or the decrease under a certain level. Following the detachment of cementoclasts/odontoclasts, root repair starts around the resorption lacunae. Later on fibroblast-like cementoblastic cells produce non-collagenous matrix proteins and collagen fibrils in order to cover the lacunae with the new cementum and new periodontal ligament (44, 45). The amount of root repair is influenced by several factors, including the magnitude of applied force, the type of orthodontic appliance, and patient-related aspects. Notably, cementum repair is enhanced when interrupted or intermittent orthodontic forces are applied.

1. Non – Functional Retarded Repair Cementum: Also known as arrested resorption, this type of repair is more common in severe external root resorption lesions with significant pulp canal exposure, and is also observed in some moderate lesions.

2. Functional Rapid Repair Cementum: This type of repair occurs in superficial external root resorption lesions and moderate apical external root resorption sites.

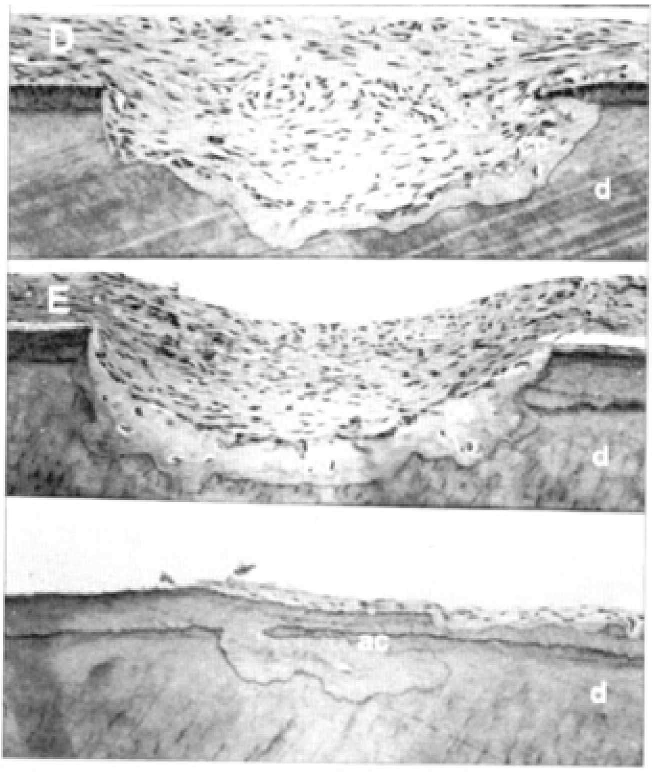
In their study, Owman-Moll et al reported the histological degrees of root repair as follows (46):

- Partial Repair: The cervical part of the root is repaired with cellular or acellular cementum
- Functional Repair: The apical part is repaired with cellular cementum
- Anatomic Repair: The middle part of the root is repaired with acellular cementum




A – Normal root surface; B – Undermined root resorption in the cervical third of the root

C – Partial repair with acellular cementum in the cervical third of the root; D – Partial repair with cellular cementum in the apical third of root; E -Functional repair with cellular cementum in the apical third of root; F- Anatomic repair with acellular cementum in the middle third of the root (images obtained by study of Owman-Moll et al (46))

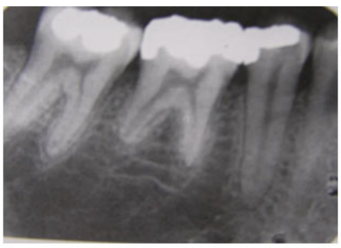



**Diagnosis & Investigations**

According to Naphtali Brezniak and Atalia Wasserstein49 (1993), radiographs are commonly used as a diagnostic aid for root resorption (47). Various radiographic techniques used as diagnostic aids for assessing root resorption are:

- Periapical bisecting angle
- Periapical paralleling
- Orthopantomogram
- Cephalogram
- Laminogram
- Computed tomography
- Cone beam computed tomography

Detecting apical root shortening via radiographs requires a certain degree of resorption, making it challenging to standardize techniques for comparing the same teeth over time. Tooth movement complicates assessing exact root loss, especially with torquing or tipping. Radiographs primarily detect root shortening, and surface resorption is only visible if mesio-distally oriented or advanced. Common radiographs are ineffective for assessing buccal and lingual root resorption.



Despite its limitations, the periapical paralleling technique is the best for detecting and evaluating apical root material loss. It offers the most accurate information with minimal patient irradiation, especially for teeth prone to root blunting, like maxillary and mandibular incisors. Compared to orthopantomogram or lateral cephalograms, this technique results in less distortion and fewer superimposition errors. However, regular radiographic techniques might obscure major defects on the root surface, thus modern imaging techniques such as CT or CBCT are currently used.

**Conclusion**

After orthodontic treatment, all permanent teeth may show microscopic root resorption that is clinically insignificant and radiographically undetected. This resorption is a probable consequence of orthodontic force and active tooth movement, with varying incidence among investigators. Most studies agree that root resorption ceases once active treatment ends.
Root resorption of deciduous teeth is normal and essential, while permanent teeth can undergo significant external resorption due to various stimuli. The resorptive potential varies among individuals and different teeth in the same person, questioning the role of systemic factors as primary causes. Variations are explained by tooth and alveolar bone structure, as well as movement types. Treatment duration and mechanical factors significantly influence root resorption. Comparing results across studies is challenging due to differing factors and methods, highlighting the need for further research. The question of an optimal force for tooth movement without causing root resorption, and the predictability of root resorption, remains unanswered.

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