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Review Article

External Apical Root Resorption in Orthodontic Patients- Local Cause or Genetic Predisposition

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Abstract

External apical root resorption (EARR) is an unwanted sequel of orthodontic treatment that results in loss of dental structure of root apex. Many studies have aimed to elucidate the causal relationship between orthodontic tooth movement and root resorption, but to date this issue is poorly understood.

Etiology of EARR is thought to be complex and it is caused by amalgamation of poorly understood environmental and host factors. Biomechanical or treatment related risk factors include treatment duration, type of orthodontic appliance, tooth extraction, type of movement, root torque, extensive tooth movement and force magnitude, which account for approximately $1/10^{th}$ to $1/3^{rd}$ of total variation in EARR. While the severity of EARR cannot be fully explained by treatment related factors, the association of genetic factors with variation in EARR among individuals has been investigated. 50 - 66% of variation in EARR concurrent with orthodontic treatment is found to be associated with genetic etiology.

Aim of this review is give an insight into the etiology of EARR for a better understanding of the risk factors of EARR. By understanding how a combination of genetic and treatment related factors may place a patient at higher risk of EARR, clinicians would be better equipped to explain the risk and minimize the treatment related occurrence of EARR.

Keywords: External Apical Root Resorption; Risk Factors; Orthodontic Patients

Introduction

External Apical Root Resorption (EARR) is specific type of root resorption characterized by shortening of the apical third of the root that can be seen on dental radiographs. It occurs as a side-effect during orthodontic treatment. It may also be reported without application of orthodontic forces. EARR usually has asymptomatic course. Thus early detection is possible only during radiological examination.

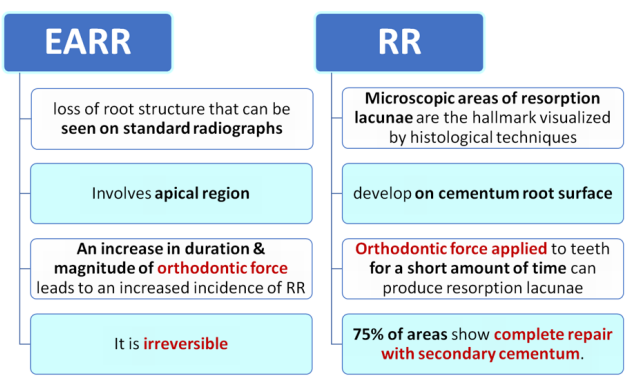
EARR may occur in 0 to 100% of the orthodontic patients. One- third of patients undergoing orthodontic treatment exhibit moderate degree (>3mm) of root resorption. 2-5% of the cases show severe root resorption (> 5mm) [1,2]. 7 to 13% of individuals who did not have orthodontic treatment also showed root resorption [3].

Root resorption has been classified by Levander-Malmgren [4]. (Table 1).

EARR is different from root resorption as shown in flowchart 1. When root resorption surpasses the reparative capacity of cementum, EARR is seen.

	Grade
0	No evidence for resorption
1	Irregular root contour
2	Apical root resorption less than 2 mm
3	Apical root resoption > 2mm and < 1/3 of original root length
4	Root resorption exceeding 1/3 of original root length

Table 1: Levander-Malmgren classification for root resorption.



Flowchart 1: EARR versus Root resorption.

EARR occurs in apical region due to several factors [5]. First, all the forces are focused at the root apex. Second, increased stress in the apical region may be due to different orientation of periodontal fibers in the region. And lastly, cellular cementum is present in apical region which depends on a patent vasculature. Hence, periapical cementum gets easily injured in the case of trauma and vascular stasis.

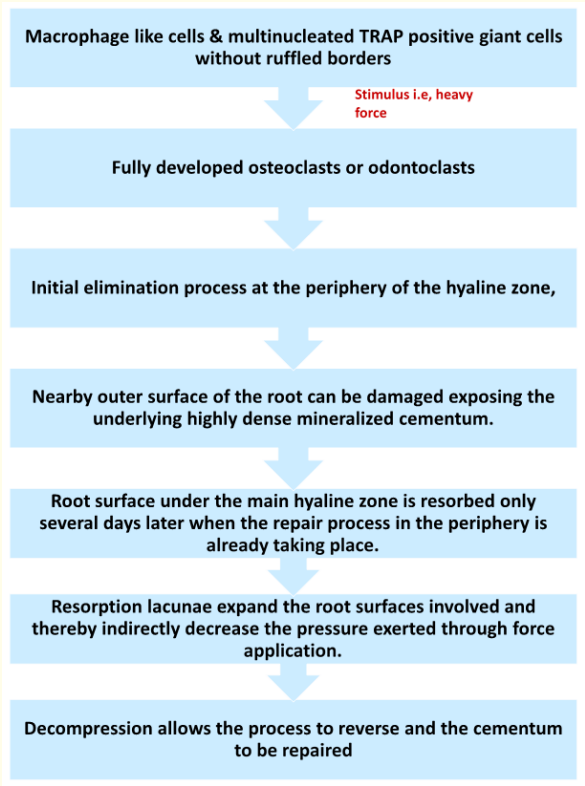
Diagnosis of EARR

OPG and Periapical views are most widely used diagnostic technique. A two dimensional image underrates the actual amount of root resorption as compared to computerized tomography. Despite limitations, periapical paralleling technique is the most preferred technique because it has most favorable benefit to risk ratio in detecting the degree of apical root material loss. It provides the most appropriate information with the least irradiation when used for teeth that are most likely to exhibit blunting of roots: maxillary and mandibular incisors. Also, distortion and superimposition errors are less as compared to the OPG or the lateral headfilm.

Dudic and colleagues assessed the effectiveness of CBCT compared to panaromic radiographs in 22 patients near the end of their orthodontic treatment and demonstrated that detection of root resorption was significantly higher in CBCT compared to panaromic radiographs (69.0% vs. 43.5%, respectively) [6]. CBCT as diagnostic tool is a sensitive imaging modality for assessment of EARR. Several studies have shown that orthodontically induced root resorption occurs in up to 91% of teeth but it is not used routinely due to cost effectiveness factor and radiographic exposure [7]. However, CBCT should be done for high risk patient for EARR or when decision has to be taken to alter or end the treatment.

Mechanism of EARR

Mechanism of root resorption is not completely understood. Inflammatory root resorption induced by orthodontic treatment is a part of process of elimination of hyaline zone. An imbalance between bone resorption and deposition may contribute to root resorption by the cementoclasts/osteoclasts (Flowchart 2).



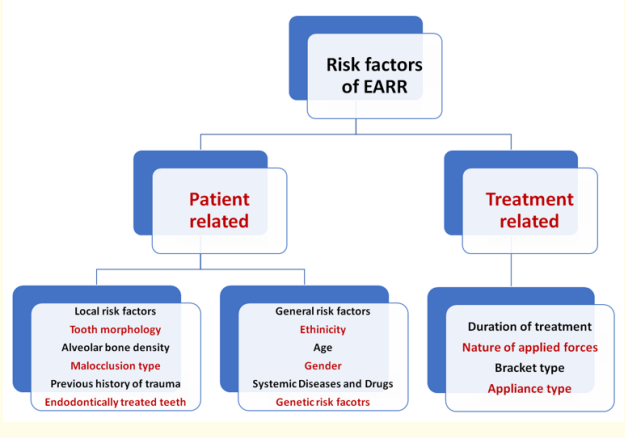
Flowchart 2: Flow chart to explain mechanism of EARR.

Odontoclasts are multinucleated cells responsible for the resorption of dental hard tissues. These cells are morphologically and functionally similar to osteoclasts. Both odontoclasts and osteoclasts are of hemopoietic origin [8,9]. The OPG/RANKL/RANK system has a key role in osteoclastogenesis/odontoclastogenesis. Osteoclastogenesis is moderated by osteoprotegerin (OPG), a member of the TNF receptor superfamily that inhibits osteoclastogenesis by preventing RANKL from binding to its receptor RANK at the osteoclast membrane [10,11]. Activated odontoclasts exhibit OPG, RANKL and RANK during resorption [12].

Together M-CSF (Macrophage-colony stimulating factor) and RANKL (Receptor activator nuclear factor kappa B ligand) are required to induce the expression of genes that are essential to the commitment of the progenitors to the osteoclast lineage and their differentiation [13]. TGF-α, IL-1β and IL-6 are capable of increasing RANKL activity which upregulates osteoclastogenesis. TNF- α, IL-1 and IL-6 directly acting on osteoclasts and hence, directly also regulate osteoclastogenesis [13-15].

Risk factors of EARR

According to Graber and Vanarsdall, EARR is a complex phenomenon caused by a combination of poorly understood environmental and host factors (Flowchart 3).



Flowchart 3: Flow chart of Classification of risk factors of EARR.

Risk Factors can also be classified as:

- Local
- Patient related
- Treatment related
- Systemic
- Genetic

Local patient related risk factors

Tooth type

Maxillary teeth are affected commonly because their root structure and relationship to bone and periodontal membrane tend to transfer the forces mainly to the apex [17]. Sequence of affected teeth is as follows: Maxillary laterals > Maxillary centrals > Mandibular incisors > Distal root of mandibular first molars > Mandibular second premolars > Maxillary second premolars [17-19].

Anomalies of position and the number of teeth

Hypodontia is thought to increase risk of root resorption [20]. Impacted teeth may also induce root resorption of adjoining teeth. Impacted third molars may cause root resorption of the second molar [21]. Impacted maxillary canine can induce root resorption of the incisors and first premolars [22].

Tooth structure/morphology

Levander and Malmgren divide root forms to: normal, pipette-shaped, blunt, dilacerated and short [23]. Normal and blunt tooth roots are least Susceptible to resorption. Pipette-shaped roots are most susceptible to resorption [24]. Deviating root form, convergent apical root canal narrower roots are also more susceptible to root resorption after orthodontic treatment [25].

Short vs Long roots

Short roots have a two times greater risk for root resorption than average length roots [24]. Longer roots are displaced farther for equal torque, hence, longer roots may be more likely to be resorbed than shorter ones [26]. More strong force are needed to move teeth with longer roots and the actual displacement of the root apex is greater during tipping or torquing movements [25].

Previously traumatized teeth

Orthodontically moved traumatized teeth which have history of previous root resorption are more sensitive to further root loss [24]. Traumatized teeth without signs of resorption behave similar to non-traumatized teeth. After the tooth transplantation or replantation, orthodontic treatment can be initiated after three months. A completely assimilated transplanted tooth reacts to orthodontic force as a normal tooth [20].

Endodontically treated teeth

The quality of endodontic treatment of teeth affects the frequency and severity of root resorption. 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 [24].

Alveolar bone density

Alveolar bone density on root resorption is assessed controversially. Denser is the alveolar bone, the more root resorption occur during the orthodontic treatment [27]. Contradictory opinion is that bone density determines rate of tooth movement but has no relation to the extent of the root resorption [28].

Malocclusion

No specific orthodontic malocclusion is immune to root resorption [20]. In cases with large overjet, maxillary incisors move a large distance to close the extraction spaces leading to the greater root resorption. Increased overbite may correlate with more root resorption of maxillary lateral incisors. It was established that the deeper is overbite, the greater is root resorption of a maxillary permanent first molar distal root and maxillary incisor [26,29].

Chronologic age

Changes in periodontal membrane, bone and cementum with age increase the susceptibility of tooth to EARR [24]. Risk of root resorption increases in patients more than 11 years of age because of presence of many resorbed lacunae and fewer repair zones in adult population [26].

Dental age

Lesser root resorption is seen with incompletely formed roots than with completely formed roots. The average loss of root length is 0.5 mm in orthodontically treated teeth [24].

Gender

Males are chronologically less mature than females and hence, due to difference in root maturity, females are more susceptible to root resorption. Also, male roots are less susceptible to the traumatic effects of orthodontic stress [30,31].

Presence of root resorption prior to orthodontic treatment

Root resorption after orthodontic treatment is highly correlated with the amount and severity of root resorption present before treatment. According to a study, incidence of root resorption increased from 4% before orthodontic treatment to 77% after treatment [32].

Local treatment related risk factors

Appliance System and Mechanics

Fixed appliances are more detrimental to the roots [33]. Splinting effect of orthodontic fixed appliances over a long period can disturb the normal function which can cause root resorption [34]. Light wire Begg technique causes less root resorption than edgewise [35]. With advances in bracket systems, neither of the two is frequently used in orthodontics. Pre-adjusted edgewise appliances are in frequent use which overcomes the shortcomings of the older bracket systems. Upper intrusion arch used for intrusion of maxillary incisors induces root resorption of maxillary central incisors than straight wire appliance [36]. Jiggling forces as a result of function combined with elastics are responsible for the resorption of roots of incisors [33]. Root resorption was less with 2-phase orthodontic treatment (functional removable appliance and later fixed appliance) than with fixed orthodontic appliances only [37].

Extraction versus nonextraction

Chances of root resorption are more with extraction of four first premolars as compared to the patients with non-extracted teeth or with extraction of just maxillary first premolars [24].

Type of orthodontic tooth movement

There is no safe tooth movement [24]. Intrusion is most damaging to the roots involved and causes four times more root resorption than extrusion [38]. Between bodily movement and tipping movement, the risk of root resorption is less with bodily movement than with tipping movement because the stress distribution along the roots during bodily movement is less than the stress concentration at the apex resulting from tipping [39]. Rotation causes only minor injuries of periodontal tissues especially in single-root teeth.

Orthodontic force

When an orthodontic force is applied, the periodontal ligaments is injured which leads to activation of inflammation [1]. Resorbed lacunae get concentrated in the area of stress on the root surface and development of resorption lacunae was more rapid with increasingly applied forces. Hence, there is more root resorption with higher forces. 7 - 26 g/cm^2 force on root surface area is the optimal force for orthodontic tooth movement which doesn't result in root resorption [40]. Applied force beyond of 20 to 26 gm/cm^2 causes periodontal ischemia, which can lead to root resorption [41]. Use of intermaxillary elastics or active removable appliances results in jiggling forces which cause occlusal trauma and can result in root resorption. During orthodontic treatment, occlusal forces on poorly aligned dental inclined planes can cause root resorption [31].

Continuous versus intermittent forces

Intermittent forces have been linked in their detrimental effects to jiggling forces. On the other hand, it is believed that due to the pause in treatment with intermittent forces, the resorbed cementum is allowed to heal [39]. Hence, intermittent force rarely cause root resorption as it allows reorganization of hyalinized periodontal ligaments and restoration of blood circulation at the time, when forces are not active [40]. Whereas continuous force leaves no time to repair of damaged blood vessels and other periodontal tissues which may be the cause of more root resorption.

Treatment duration

Severity of root resorption is directly related to treatment duration. Patients whose orthodontic treatment with fixed appliances lasts longer, experience significantly more grade 2 root resorption. It has been observed that average treatment duration for patients without root resorption is less (1.5 years) as compared to treatment duration for patients with severe root resorption (2.3 years) [42].

Root resorption detected during orthodontic treatment

It is advisable to check radiographically for presence of root resorption after 6-9 months of start of treatment. Minor resorption or an irregular root contour seen after 6 to 9 months indicates an increased risk of further root resorption. Usually if there is no root resorption at 6 - 9 months, no severe resorption is detected at the end of treatment [24].

Root resorption after appliance removal

Root resorption usually ceases with termination of active orthodontic treatment or after about a week of completion of treatment. It is followed by a period of cementum repair which lasts for 5 to 6 weeks after orthodontic treatment. If root resorption continues after treatment then it is mostly due other causes such as occlusal traumatism, active retainers [24,43].

Influence of Systemic diseases and medications

A detailed case history of the patient should be taken before starting orthodontic treatment as some systemic diseases and drugs may interfere with treatment.

High bone turnover (i.e. hyperthyroidism) increases the amount of tooth movement compared with the normal or low bone turnover state and adult patients. In such patients, appliance can be reactivation more frequently. The risk of root resorption could be increased in low bone turn over (i.e. hypothyroidism). Reactivation should be done after long intervals [24].

Drugs

Synthetic steroids are used as anti-inflammatory and immunosuppressive agents in the treatment of wide range of chronic and medical condition. Administration of prednisolone reduces root resorption and interferes with tooth movement in rats [44]. Non-steroidal anti-inflammatory drugs suppress root resorption induced by orthodontic therapy by interfering in the arachidonic acid cascade depending on dose thresholds [45,46].

S. No	Drug	Group
1	Prednisolone	Corticosteroid
2	L-thyroxine	Hormone
	Celebrex	Non-steroidal anti-inflammatory
	Doxycyclin	Broad Spectrum antimicrobial agent
	Clodronate	Bisphosphonates

Table 2: Drugs that Decrease Root resorption.

Broad-spectrum antibiotic Doxycyclin is a potent antimicrobial agent has been shown to have some anti-inflammatory effect. It reduces the resorption by directly inhibiting the osteoclasts. Low dose of doxycyclin may be useful in controlling root resorption clinically [47].

Bisphosphonates causes a significant dose-dependent inhibition of root resorption in rats after force application. Soaking the teeth in alandronate solution rather than Hanks Balanced salt solution reduces the chance of root resorption [48,49].

Genetic factors

Genetic factors account for one half to two third of the variation in EARR [43]. Role of genes in occurrence of EARR has been studied by various authors.

Interleukin 1

IL-1 has been frequently associated with inflammatory events in connective and bone tissues. The IL-1 gene cluster on chromosome 2 contain genes coding for pro-inflammatory cytokines that include IL1α and IL1β, as well as the anti-inflammatory cytokines, Interleukin receptor antagonist, IL1ra. IL1α and IL1β are encoded by distinct genes but bind to same receptor IL 1R1[50].

Interleukin 6

IL 6 acts as multifunctional cytokine with both inflammatory and anti-inflammatory effects. It promotes the secretion of inflammatory factors such as IL-1, exerting inflammatory effect. It also promotes the form of anti-inflammatory factors such as IL-1ra, exerting anti-inflammatory effects [51].

Purinergic receptor, P2RX7

P2RX7 is expressed in osteoblasts and osteoclasts and seem to have a pro-osteogenic effect, activating osteoblast function and inducing osteoclast apoptosis. It also stimulates release of inflammatory cytokines such as IL-1B by immune cells by acting through ATP/P2RX7/IL-1B inflammation modulation pathway [52].

RANK/RANKL/OPG

Osteoblasts and stromal stem cells express receptor activator of NF-kappa B ligand (RANKL), which binds to its receptor activator of nuclear factor-kappa B (RANK, coded by TNFRSF11A gene), on the surface of osteoclasts and their precursors. Osteoprotegerin (OPG, coded for by the TNFRSF11B gene) is secreted by osteoblasts and osteogenic stromal stem cells and protects from excessive bone resorption by binding to RANKL and preventing it from binding to RANK [53].

Vitamin D receptor gene

Vitamin D stimulates osteoclastogenesis acting through its nuclear receptor, Vitamin D receptor (VDR) in immature osteoblast/stromal cells via RANKL/OPG regulatory pathway [54].

OPN (Osteopontin) gene

It is an acidic phosphorylated glycoprotein. It plays role in odontoclast activation during root resorption process [55].

Other factors and their gene namely IL-17, IRAK1, Wnt, CASP1, TNF-α, TNSALP have also been associated with EARR [56-59]. Different gene polymorphisms with respect to these factors indicate higher incidence of EARR in some individuals undergoing orthodontic treatment [50-62].

Clinical considerations

1. The patient or his parents must be informed about unpredictability of occurrence of root resorption as an unfavorable consequence of orthodontic treatment.
2. At 6-9 months after start of treatment, periapical radiographs of the incisors should be taken. Minor root resorption or an irregular tooth root contour detected at this time indicate high risk for further root resorption.
3. Orthodontic treatment timing. Developing roots show less root resorption as compared to mature roots. Hence, orthodontic treatment should begin as early as possible. Also, young patients show better muscular adaptation to occlusal changes.
4. The orthodontic force should be light and intermittent.
5. When root resorption is detected during active treatment, treatment objectives must be reassessed. A decision should be made to terminate the treatment or to arrive at a treatment compromise.
6. No tooth movement is safe. Be careful while intruding the teeth.
7. Occlusal traumatism and jiggling are potentially detrimental to the roots.
8. In choosing treatment appliances, the risk of root resorption should be weighed against appliance efficiency and individual treatment objectives.

9. Treatment time should be as short as possible while adhering to other important principles.
10. Traumatized teeth are more prone to root resorption during orthodontic treatment.
11. Medical examination and familial history are of value especially in cases of severe or extensive root resorption.

Conclusion

EARR is an undesirable complication of orthodontic tooth movement. Individual susceptibility is the main risk factor for root resorption in orthodontic patients during treatment. It is essential to develop a sound and well-constructed database of genetic predisposition that can be used in orthodontic practice to enable 'high-risk' subjects to be identified on the basis of their genetic information before orthodontic treatment is initiated. Relevant studies in this specialized area have recently begun the task. Hence, In the near future, genetically based studies could provide insights into the nature of external apical root resorption in orthodontics, which would undoubtedly be useful for preventing or even eradicating its occurrence.

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