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Root Resorption in Anterior Open Bite Malocclusions Due to Vertical Correction: A Radiometric Pilot Study

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Abstract

Introduction: One of the most common risks of fixed orthodontic therapy is the evidence of root resorption post orthodontic treatment ranging from mild root blunting to severe root resorption of significant portions of the root structure. The etiology of apical root resorption is multifactorial but largely depends upon the type of orthodontic tooth movement and treatment duration. **Study Objective:** The primary aim of this study is to examine the association of external apical root resorption and vertical correction in anterior open bite malocclusions using panoramic radiographs for evaluation. **Materials and Methods:** Pre-treatment and post-treatment panoramic radiographs of 16 patients with anterior open bite malocclusions were scored to assess root resorption of anterior teeth (U/L 3-3). Initial and final root length and total tooth length for U/L 3-3 were measured on panoramic radiographs in Dolphin imaging. **Results:** Of the 24 pairs of measurements, 7 had a significant p-value ($p < 0.05$). LR 3, LR 1. LL 1, LL 2, and LL 3 demonstrated root resorption post-orthodontic treatment. **Conclusions:** A statistically significant amount of root resorption was observed, from pre-treatment to post-treatment radiographs. All mandibular anterior teeth except the mandibular right lateral incisors showed evidence of root resorption.

Keywords

Open Bite Malocclusion, External Apical Root Resorption, Open Bite Closure

1. Introduction

Orthodontically induced inflammatory root resorption in the permanent dentition is a pathologic consequence of orthodontic treatment, and it can range from mild root blunting to severe resorption of significant portions of the root structure. [1] [2] Root resorption was first described by Bates in 1856. He referred to the process as "absorption" which was caused because of injury to the periodontal membrane. Broomwell, in 1898, was the principal individual to use the term "resorption" when referring to roots of the permanent dentition. [3]

Ottolengui, in 1914, was the first to describe root resorption in the context of orthodontic treatment. [3] Ketcham, in 1927, employed radiographs to explain resorption post-orthodontic treatment. In his article titled, "A Preliminary Report of an Investigation of Apical Root Resorption of Permanent Teeth," Ketcham stated, "A radiographic survey of 385 treated cases in my orthodontic practice has disclosed conditions in regard to apical root resorption so startling, so patent in danger to the orthodontic patient, so prolific of recrimination to the orthodontist himself, that I make bold to present this preliminary report to the orthodontists of the world." He further recognized that patients with pin and tube or ribbon and bracket appliances were more susceptible to root resorption, proposing the term "degree of mobility" which must also be considered as a factor in root resorption post orthodontic treatment. [4]

The etiology of external apical root resorption (EARR) is complex and multifactorial. Risk factors for root resorption post orthodontic treatment can be categorized as patient-related and treatment-related. Patient-related factors such as genetics, gender, age, previous history of trauma, and root shapes are immutable by the orthodontist and must be managed during treatment. [5] Genetically, root resorption can occur in certain individuals without a history of orthodontic treatment. Harris *et al.* also found 70 per cent heritability in root resorption, and siblings were often affected with similar levels of root resorption. [3] [6] Single nucleotide polymorphisms (SNPs) have been studied to identify heritable components most likely associated with root resorption and a polymorphism of Interlukin-6, or IL-6, has been identified, confirming a potential genetic correlation. [7] Certain ethnicities are shown to be more prone to root resorption. Asians experience significantly less resorption than Caucasians or Hispanic patients. This can be explained due to inherent difference in tooth shape and size among different ethnicities suggesting different developmental processes. [8] An irregularity in hormones such as 1,25-DHCC, PTH and Ca have been found to impact root resorption. Endocrine disorders, such as hyperparathyroidism, Paget's disease, hypophosphataemia, hypothyroidism, hypopituitarism and hyperpituitarism have been found to be associated with altered tooth development rates and level of root resorption. [3] Studies have shown that females are more susceptible to root resorption compared to males. [9] [10] An increased prevalence of root resorption is seen in adults undergoing orthodontic treatment. Massler and Malone claimed that the incidence of root resorption increases with age even without orthodontic treatment. [11] Patients who initiate treatment after age eleven are more likely to experience root resorption of the upper anterior teeth than those who started treatment a younger age. Patients with impacted canines are more likely to experience root resorption of upper anterior teeth due to the location of the impacted canine resorbing the neighboring roots as well as the stress placed on neighboring teeth when extrusive forces are applied to the canines to bring them into occlusion. [12] Trauma is also shown to be associated with root resorption. Although the traumatic incident may have occurred more than one year prior to orthodontic treatment, injury may present itself as pulp devitalization, mobility, or fracture, modifying the normal periodontal response to orthodontic treatment and predisposing the tooth to resorption. [13] A higher frequency and severity of root resorption of endodontically treated teeth during orthodontic treatment has also been reported. [14] Abnormal root shape has also been noted to play a role in root resorption. Short roots, blunt roots, apically bent roots (dilacerations) and pipette shape roots are the most susceptible to root resorption. [15]

Treatment-related factors can include frequency of force application, the magnitude of the force applied, duration of treatment, and type of tooth movement. Increased treatment duration has been suggested to be associated with an increase in the amount and severity of root resorption. [15] [16] Therefore, it has been advised to give the patients a break in treatment of four to six months to allow for healing of the resorbed cementum and stop further progress of root resorption. [17] Barbagallo *et al.*, [18] Cheng *et al.* [19] and Paetyangkul *et al.* [20] stated that with increasing forces root resorption also increases. The distribution of resorbed lacunae was directly related to the amount of stress on the root surface. [21] When the force levels are greater than the ability of the periapical tissues to repair the bone, root resorption occurs. It is critical to titrate forces depending on biology. [22] The most detrimental tooth movement causing root resorption is intrusion but tipping, torquing, translation and expansion can also be implicated. In intrusive movements, almost all pressure is gathered in the root apex; the risk of resorption markedly increases because of root anatomy. [23] Additionally, moving teeth in the horizontal direction such as in the correction of excessive overjet has a negative effect on the root apex. [24] Various bracket systems were also studied to determine whether they had an effect on root resorption. No difference has been found between self-ligating and conventional brackets except in the maxillary central incisors where self-ligating brackets have shown less root resorption. [25] Ketcham stated that teeth that are tightly bound are more likely to experience resorption. Self-ligating brackets allow for more sliding and less friction of the archwire and may therefore decrease the amount of root resorption. Rigid fixation of the archwire into the tooth and specifically rectangular archwires can cause increased root resorption. No further resorption occurs after debonding appliances, and although the original root length cannot be restored, a small amount of cementum repair has been observed. [22]

Andreasen described three types of external root resorption types: surface resorption, inflammatory resorption and replacement resorption. [26] Later, Tronstad characterized two kinds of inflammatory resorption: transient inflammatory resorption and progressive inflammatory resorption. [27] Histologically, there are three degrees of severity of orthodontically induced inflammatory root resorption: cemental or surface resorption with remodeling, dentinal resorption with repair (deep resorption) and circumferential apical root resorption. In cemental resorption, only the outer cemental layers are resorbed, and they are fully regenerated or remodeled with bone resembling trabecular bone. In dentinal resorption, the cementum and outer layers of the dentin are resorbed and usually repaired with cementum, but the final shape of the root may or may not be identical to the original form. Circumferential apical root resorption includes full resorption of the hard tissue components of the root apex, and root shortening is evident. Once the root loses apical material beneath the cementum, no regeneration is possible. External surface repair usually occurs in the cemental layer and sharp edges level over time. [28]

Levander and Malmgren [15] represented a classification system for root resorption, which is widely accepted in the orthodontic literature (1988). According to this index, the severity of root resorption increases from grade 1, defined as the presence of irregular root contour, to grade 4, where root resorption is greater than 1/3rd of the original root length.

Grade Definition

0) No evidence for resorption;

1) Irregular root contour;

2) Apical root resorption less than 2 mm;

3) Apical root resorption > 2 mm and <1/3 of original root length;

4) Root resorption exceeding 1/3 of original root length.

Root resorption is usually classified as minor or moderate in most orthodontic patients. Severe resorption, exceeding 4 mm or one-third of the original root length, is seen in only 1% - 5% of teeth. [15] [29] [30]

Root resorption has two phases: injury and stimulation. During the injury phase there is damage of the external surface of the root, which exposes the denuded mineralized tissue, while in the second phase: multinucleated cells are stimulated to colonize the denuded mineralized tissue, leading to a resorptive process. [31] Without further stimulation, cementum like material will spontaneously repair the damage within 2 - 3 weeks. With persistent inflammatory process, deeper root dentin will be involved, and root resorption would be radiographically detected. [32]

When forces at the root apex exceed the resistance and reparative ability of the periapical tissues, root resorption occurs. [30] Resorption begins approximately 2 - 5 weeks following the start of orthodontic treatment, but radiographic appearance requires 3 - 4 months. Furthermore, the association between root resorption and the amount of orthodontic tooth movement has been demonstrated. [33] [34] [35] [36] Application of an orthodontic force on a tooth initiates an inflammatory response, resulting in a cascade of bone remodeling. According to the pressure-tension theory, bone resorption occurs on the compression side and bone deposition occurs on the tension side of the tooth. Within a few seconds of force application, the tooth moves within the PDL space causing decreased blood flow on the compression side and increased blood flow on the tension side. Due to the change in blood flow, there is a change in the oxygen tension and release of biologically active agents such as prostaglandins and cytokines. Distorted nerve endings release vasoactive neurotransmitters, like substance P and calcitonin gene related peptide (CGRP) inducing vasodilation through interaction with endothelial cells. The onset of acute inflammation is associated with the release of leukocytes, monocytes, and macrophages into the bloodstream, and are recruited to the PDL. With continued application of force, acute inflammation transitions into chronic inflammation, and fibroblasts, osteoblasts, osteoclasts, and endothelial cells are transported to the site of tooth movement. Although this inflammatory cascade is essential for orthodontic tooth movement, uncontrolled inflammation can lead to tooth destruction, similar to uncontrolled periodontal disease. In periodontally compromised patients, orthodontic treatment can cause accelerated attachment loss and disease progression. [37]

2. Materials and Methods

This study has been approved by the Rutgers University Institutional Review Board (IRB # Pro2019001803). Subjects were obtained for this retrospective study from the Axium and Dolphin software databases of previously treated orthodontic patients at the Rutgers School of Dental Medicine. A sample of 52 patients was initially identified for this research based on the availability of pre-treatment and post-treatment panoramic records, but only 16 patients had complete records in Axium. There is no race, gender, age, or Angle classification specificity for the subjects in this study. The inclusion criteria were subjects with permanent dentition, patients with anterior open bite only, patients with pre-treatment and post-treatment panoramic radiographs and complete records including dental models or scans, intraoral and extraoral Photographs, cephalometric and panoramic radiographs, in Axium, and complete root formation of maxillary and mandibular teeth based on initial panoramic radiographs. There were no limitations on the treatment modalities such as extraction vs. non- extraction, or fixed orthodontic appliances vs. clear aligners. The exclusion criteria included patients with cranio-facial anomalies including cleft-lip and palate, patients with other significant medical history, patients with impactions of central or lateral incisors, or impacted canines which have caused radiographically evident damage to central or lateral incisors, patients treated with phase one of two-phase treatment and surgical orthodontics. All 16 sample patients were treated and treatment was competed between 2019 and 2023.

The measurement of the panoramic radiographs was performed in Dolphin Imaging. Twelve teeth on each radiograph were scored: the upper right canine, upper right lateral incisor, upper central incisor, upper left central incisor, upper left lateral incisor, upper left canine, lower left canine, lower left lateral incisor, lower left central incisor, lower right central incisor, lower right lateral incisor, and lower right canine. The total length of the tooth was measured as the distance from the incisal edge to root apex. Root length was measured as the distance between the cemento-enamel junction and apex. Individual root length-total tooth length ratio was measured on the pre-treatment and post-treatment panoramic radiographs for all twelve teeth. Each subject had twenty-four measurements recorded, twelve pre-treatment and twelve post-treatment, and all measurements were performed by a single examiner in Dolphin Imaging. (**Figure 1**)

Descriptive statistics and paired t-test results for all twenty-four measurements were obtained from Microsoft Excel analysis. The data was then analyzed using SPSS software (IBM, Armonk, N.Y., and U.S.A). Mean differences of the scored root length and tooth length values between pre-treatment and post-treatment were also calculated and analyzed.

3. Results

16 patients were included in this pilot study. To calculate the overall change in root-length and tooth-length for each of the twenty-four pairs, the pre-treatment score was subtracted from the post-treatment score for each tooth. To compare pre-treatment root length and total tooth length to post-treatment changes within each pair, a paired sample t-test was performed. This was to measure if any root resorption occurred due to orthodontic treatment. 7 out of 24 pairs had a significant value with a p value < 0.05. The 7 pairs with significant results are as follows:

Paired Sample Test	Two-sided P
preLR3 (RL) – postLR3 (RL)	<0.001
preLR3 (TL) – postLR3 (TL)	0.011
preLR1 (TL) – postLR1 (TL)	0.021
preLL1 (TL) – postLL1 (TL)	0.042
preLL2 (TL) – postLL2 (TL)	0.005
preLL3 (RL) – postLL3 (RL)	0.012
preLL3 (TL) – postLL3 (TL)	0.015

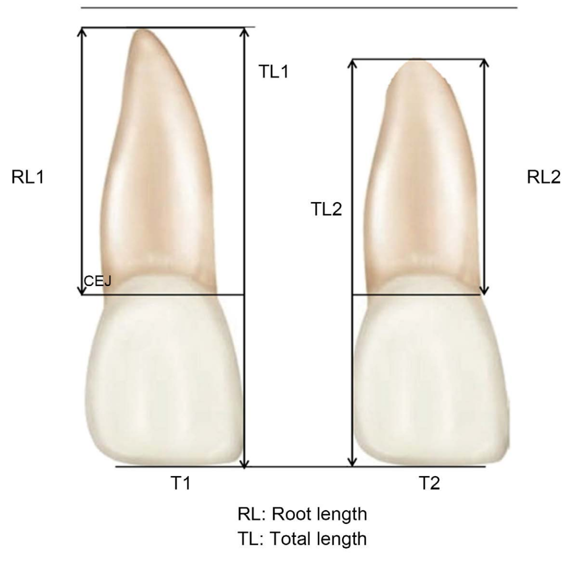

Figure 1. RL: Root length, TL: total length.

Mandibular right canine, mandibular right central incisor, mandibular left central incisor, mandibular left lateral incisor, and mandibular left canine demonstrated a significant reduction in total length due to vertical correction. The post-treatment root length was significantly decreased for mandibular right canine with a p value < 0.001 and for mandibular left canine with a p value of 0.012.

Since this is a pilot study with a limited sample, the main study's sample size for each paired comparison was calculated and would have to be too great a number to determine a conclusive result.

A Data analysis chart can be found in Appendix A.

4. Discussion

Harris and Butler [37] compared 32 adolescent patients with anterior open bite to 31 deep bite cases to assess the pattern of root resorption after orthodontic correction. They found that the roots of the permanent maxillary central incisors were significantly shorter and also showed higher grade of periapical resorption than the matched deep bite cases before treatment. [38] G. Han *et al.* carried out an extensive investigation to compare root resorption in the same individual after application of continuous intrusive and extrusive forces. In nine patients (mean age 15.3 years), eighteen maxillary first premolars were randomly intruded or extruded with a continuous force of 100 cN for eight weeks. The inclusion criteria were periodontally healthy upper premolars with normally shaped and completely developed roots, bimaxillary protrusion without severe crowding and a low mandibular plane angle (<26˚). Eleven maxillary first premolars from six randomly selected orthodontic patients served as the control group. The premolars were extracted before active orthodontic treatment. Root resorption was determined using scanning electron microscopy and quantitative assessment of the resorbed areas was performed on composite micrographs. The study concluded that intrusion of teeth causes about four time more root resorption than extrusion, and no significant difference was found between the extruded and control groups. Root resorption is usually quantified either on panoramic or periapical radiographs because they are the most frequently used clinical tools in regular dental practices. These radiographs can assess only periapical resorption, and root resorption on the cervical and middle parts of the mesial and distal root surfaces goes undetected unless they are very extensive. It has been shown that panoramic films may overestimate the amount of the root resorption by 20% or more, and thus scanning electron microscopy was used in this study for better assessment.

Since root resorption is multifactorial, it is difficult for the orthodontist to discern pre-treatment if a patient is likely to be affected. A comprehensive understanding of root resorption can allow an orthodontist to modify the treatment plan to decrease the likelihood and severity of root resorption by decreasing the force levels and duration of treatment.

The null hypothesis for this study states that there is no root resorption from vertical correction of maxillary and mandibular anterior teeth in anterior open bite cases. Further, no one tooth will experience more resorption than the others.

Pre-treatment root length and total tooth length of maxillary and mandibular anterior teeth was compared to post-treatment root length and total tooth length. A tooth-by-tooth analysis was performed to measure which teeth are more susceptible to root resorption. It was found that the mandibular anterior teeth except for mandibular right lateral incisor were more prone to root resorption. It was not conclusive if any one tooth was more susceptible to resorb than any other.

For this study, panoramic radiographs were used to assess for root resorption of the anterior teeth because they are generally taken in the orthodontic clinic pre and post treatment. Magnification of up to 20% - 35% is also an issue with panoramic radiographs, unlike periapical radiographs which are usually much less magnified, at only 5% and can appear much clearer. Sameshima *et al.* [39] found that after adjusting for magnification differences, panoramic radiographs are sufficient for assessing upper incisor root resorption. When compared to periapical radiographs, measurements from panoramic radiographs for the upper incisors only had a difference of 0.2 mm, which is not a significant difference. For three-dimensional viewing of root resorption, a cone beam computer tomography (CBCT) image would be most accurate in measuring the amount of root resorption. [40]

When assessing incisors on panoramic radiographs, proclined upper incisors may appear foreshortened and shorter than they truly are while retroclined incisors may appear elongated than they are in actuality. This means that a tooth may not have been measured accurately.

Future directions of this study would consider quantifying the pre-treatment anterior open bite, selecting the type of appliances (fixed or aligners), and the method of executing extrusive force, for example elastics, step-bends etc. This study could be strengthened by increasing the number of subjects. Using CBCTs, the gold standard of root resorption assessment, and periapical radiographs with grids, for before and after treatment evaluation rather than panoramic radiographs would also strengthen the outcome of the study.

5. Conclusions

1) Root resorption of mandibular anterior teeth is greater post orthodontic treatment in patients with anterior open bite.

2) The null hypothesis is rejected because there was a difference from pre-treatment to post-treatment in the mandibular anterior teeth.

3) The future direction of this study would consider quantifying the pre-treatment anterior open bite, selecting the type of appliances (fixed or aligners), and the method of executing extrusive force, for example, elastics or step-bends. An anterior open bite may be treated by either intrusion of posterior teeth or extrusion of anterior teeth. A posterior intrusion would be best achieved by the use of

temporary anchorage devices (TADS).

4) Since many offices providing Orthodontic and Dentofacial Orthopedic treatment are now using low dose Cone Beam Computed Tomography, which is the gold standard for making these measurements, this study should be done using this modality in the future.

5) CBCTs and periapical radiographs with a grid could also be used for radiographic evaluation in future studies.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix A

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	preUR1 (RL) - postUR1 (RL)	.3875	2.1984	.5496	-.7840	1.5590	.705	15	.246	.492
Pair 2	preUR1(TL) - postUR1 (TL)	.2812	2.1439	.5360	-.8612	1.4237	.525	15	.304	.607
Pair 3	preUR2 (RL) - postUR2 (RL)	.5563	1.5227	.3807	-.2551	1.3676	1.461	15	.082	.165
Pair 4	preUR2 (TL) - postUR2 (TL)	.2125	1.7780	.4445	-.7349	1.1599	.478	15	.320	.639
Pair 5	preUR3 (RL) - postUR3(RL)	-.0562	2.1618	.5404	-1.2082	1.0957	-.104	15	.459	.918
Pair 6	preUR3 (TL) - postUR3(TL)	.4500	2.0759	.5190	-.6562	1.5562	.867	15	.200	.400
Pair 7	preUL1 (RL) - postUL1(RL)	.1250	2.8607	.7152	-1.3993	1.6493	.175	15	.432	.864
Pair 8	preUL1 (TL) - postUL1(TL)	-.2187	2.5701	.6425	-1.5883	1.1508	-.340	15	.369	.738
Pair 9	preUL2 (RL) - postUL2(RL)	.2562	2.1017	.5254	-.8637	1.3762	.488	15	.316	.633
Pair 10	preUL2 (TL) - postUL2(TL)	-.1187	1.7638	.4409	-1.0586	.8211	-.269	15	.396	.791
Pair 11	preUL3 (RL) - postUL3(RL)	.8562	2.2103	.5526	-.3215	2.0340	1.550	15	.071	.142
Pair 12	preUL3 (TL) - postUL3(TL)	1.2375	2.5845	.6461	-.1397	2.6147	1.915	15	.037	.075
Pair 13	preLR1 (RL) - postLR1(RL)	.0875	1.1938	.2985	-.5486	.7236	.293	15	.387	.773
Pair 14	preLR1 (TL) - postLR1(TL)	-.8375	1.3007	.3252	-1.5306	-.1444	-2.576	15	.011	.021
Pair 15	preLR2 (RL) - postLR2(RL)	-6.6125	28.0951	7.0238	-21.5833	8.3583	-.941	15	.181	.361
Pair 16	preLR2 (TL) - postLR2(TL)	-.6063	1.1699	.2925	-1.2296	.0171	-2.073	15	.028	.056
Pair 17	preLR3 (RL) - postLR3(RL)	-1.4375	1.3053	.3263	-2.1331	-.7419	-4.405	15	<.001	<.001
Pair 18	preLR3 (TL) - postLR3(TL)	-1.0875	1.4993	.3748	-1.8864	-.2886	-2.901	15	.005	.011
Pair 19	preLL1 (RL) - postLL1(RL)	-.4687	1.1406	.2851	-1.0765	.1390	-1.644	15	.060	.121
Pair 20	preLL1 (TL) - postLL1(TL)	-.8062	1.4512	.3628	-1.5795	-.0330	-2.222	15	.021	.042
Pair 21	preLL2 (RL) - postLL2(RL)	-.4188	1.4914	.3729	-1.2135	.3760	-1.123	15	.140	.279
Pair 22	preLL2 (TL) - postLL2(TL)	-1.0562	1.2681	.3170	-1.7319	-.3806	-3.332	15	.002	.005
Pair 23	preLL3 (RL) - postLL3(RL)	-1.0312	1.4416	.3604	-1.7994	-.2631	-2.861	15	.006	.012
Pair 24	preLL3 (TL) - postLL3(TL)	-1.0813	1.5800	.3950	-1.9232	-.2393	-2.737	15	.008	.015

Figure A1. Paired sample t-test results of all 16 patients showing the difference between pre and post treatment root length and total tooth length.