

External Root Resorption after Orthodontic Treatment with Invisalign®: A Retrospective Study

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Abstract

Aim: To measure the incidence and severity of root resorption after orthodontic treatment with Invisalign.

Material and Methods: This retrospective study was conducted at Riyadh, Saudi Arabia from June 2017 to January 2018. Pre-treatment and post-treatment Orthopantographs were obtained from orthodontic records of 29 patients managed with aligners (Invisalign®, Align Technologies, Santa Clara, CA, USA) at different dental clinics in Riyadh City. The selected sample was fulfilled the following criteria: (1) Class I malocclusion, (2) Mild to moderate crowding, (3) Non-extraction orthodontic treatment, (3) No evidence of root resorption before orthodontic treatment, (4) No root abnormalities or dilaceration, and (5) Good quality of pre- and post-treatment Orthopantographs. One examiner performed the measurements directly on the Orthopantographs using electronic digital caliper (Mitutoyo Manufacturing Co. Ltd., Tokyo, Japan) with an accuracy of 0.01mm. The measurements were performed on maxillary and mandibular central incisors, lateral incisors, and canines pre- and post-operatively, resulting in a total of 696 measurements. The crown length was measured from incisal edge to cemento-enamel-junction, while the root length from cemento-enamel-junction to root apex.

Results: In our study, 72% of the teeth demonstrated root resorption, in regard to the severity of root resorption, we found that mild root resorption > 0% up to 2% in all the affected teeth. Upper Anterior teeth have more significant resorption rate than lower anterior teeth P<0.05.

Conclusion: The present study showed that incidence of root resorption was high after orthodontic treatment with Invisalign®, however the severity is very low and it is limited to the surface resorption only.

Keywords: orthodontics, orthodontic appliances, removable, root resorption

1. Introduction

External apical root resorption (EARR) could be described as the permanent loss of apical root structure including cementum, dentin, or both by either a physiological or a pathological process resulting in a shortened crown root ratio (Jacobs et al., 2014). Such an undesirable outcome should be cared with caution when patients suffer from periodontal bone disease concurrently (Roscoe et al., 2015). The etiology behind it is mostly idiopathic, but other causes can be attributed to localized inflammatory lesions, reimplanted and impacted teeth, tumors, cysts, excessive mechanical and occlusal forces (Tamse, 1982), which includes orthodontic treatment as one of the inducing factors of EARR.

The pathogenesis of root resorption histopathologically has two phases: *during the first phase*, the external surface of the root gets damaged resulting in a layer of denuded mineralized tissue that triggers the activation of polynucleated cells. And in *the second phase*, the polynucleated cells will immigrate into the denuded mineralized tissue, leading to the resorption process (Trope, 1998). If the damage resulting from the inflammatory course ceased and no further provocation is to be noticed; reconstruction of the root apex will take place within 2–3 weeks (Gay et al., 2017). In contrast, if it prevails (e.g. orthodontic forces) resorption will

extend deeper into the root structure and it will be detected radiographically by then (Fuss et al., 2003). The beginning of EARR during the orthodontic process will start roughly 2–5 weeks into the treatment, appearing radiographically within 3–4 months (Gay et al., 2017).

According to Brezniak et al. (Brezniak & Wasserstein, 2002), orthodontically induced EARR was subclassified in regards to severity, extension, and reversibility into:

- Cemental resorption with repair (surface resorption): The resorption terminates at the external cemental layers, and they are later completely reconstructed.
- Dentinal resorption with repair (deep resorption): The resorption progresses through the cementum and terminates at the external dentinal layers and is mostly reconstructed with cementum material. The final morphological appearance of the root subsequent to the reconstruction process may not be identical to the archetypal morphology.
- Circumferential resorption: The resorption progresses through the cementum, dentinal, and hard tissue layers involving further apical structure resulting in a shortened apex. When the root loses apical material beneath the cementum, no regeneration is possible.

The association between EARR and the severity of malocclusion along with the continuance of the applied forces has been proven to be directly related. Implying that a more severe malocclusion induces a greater need of tooth movement (Kaley & Phillips, 1991; Kook et al., 2003; Fox, 2005; Newman, 1975) and long continuous application of forces on the tooth influences the regeneration, on the contrary, a disrupted application of forces yields a higher chance for the apex to regenerate (Acar et al., 1999; Reitan, 1964; Dougherty, 1968). Which makes both the magnitude and the continuity of force, an underlying risk factor for orthodontically induced EARR.

Since the development of the removable Invisalign® aligner system in 1997, it takes into account the previous two underlying risk factors by equally controlling the stress derived from the intermittent orthodontic forces applied on the radicular-apical area (Long, 2012), along with the advantage of shorter treatment time which may take an average duration of 1–2 years coupled with being more predictable, reproducible, esthetically pleasing, comfortable, and sanitary (Azaripour et al., 2015). It achieves such desirable outcomes by advocating CAD/CAM stereolithographic technology to calculate treatment outcomes and generating a custom-made removable aligner tray series for the duration of the treatment (Kou & Miller, 2003).

It has not been determined whether the objectively controlled forces derived from removable aligners can prevent, or at least reduce, the occurrence of orthodontically induced EARR. Hence the study designed to investigate the incidence of EARR in adult patients treated with removable aligners.

2. Material and Method

This retrospective study was conducted at Riyadh, Saudi Arabia from June 2017 to January 2018. Pre-treatment and post-treatment Orthopantographs (Orthopantomograph OP 2, OP 3, or Cranex DC, Charlotte, USA) were obtained from orthodontic records of 29 patients managed with removable aligners (Invisalign®, Align Technologies, Santa Clara, CA, USA) at different dental clinics in Riyadh City. One examiner performed the measurements in ambient room lighting directly on calibrated panoramic radiographs before and after treatment using an electronic digital caliper (Mitutoyo Manufacturing Co. Ltd., Tokyo, Japan) with an accuracy of 0.01mm. The measurements were performed on maxillary and mandibular central incisors, lateral incisors, and canines pre- and post-operatively, resulting in a total of 696 measurements. The crown length was measured from incisal edge to cemento- enamel-junction, while the root length from cemento-enamel-junction to root apex.

The current study consisted of a total of 124 adult healthy (Female/Male) patients from both private practices and governmental hospitals in Riyadh city. From which 29 cases were treated with aligners (Invisalign®, Align Technologies, Santa Clara, CA, USA) were included, while the remaining 95 cases were excluded for not meeting the inclusion criteria. Orthopantographs were obtained from the same device that was taken as standard procedure at the beginning (T0) and at the end (T1) of the orthodontic treatment.

The selected sample was fulfilled the following criteria: (1) Class I malocclusion, (2) Mild to moderate crowding of 6 mm or less, (3) Non-extraction orthodontic treatment, (3) No evidence of root resorption before orthodontic treatment, (4) No root abnormalities or dilaceration, and (5) Good quality of pre- and post-treatment Orthopantographs without distortion.

While the exclusion criteria included the presence of any indications of root resorptions from a mere root irregularity to structural loss on the pre-treatment panoramic radiographs, severely dilacerated roots, or

endodontically treated teeth and patients managed by other orthodontic systems, extraction therapy, or any surgical treatments.

On the basis of Krieger et al. (2013), Fritz et al. (2003), and Linge and Linge (1983), the distance between the incisal edge and the cement-enamel junction (CEJ) was considered as the *crown length*, while the distance from the CEJ to the root apex was considered as the *root length*. The two measurements were calculated using a digital electronic caliper ruler on the long axis of the permanent central incisors, lateral incisors, and canines of each quadrant and totaled in the root-crown ratio (RCR). All the required analysis of root and crown lengths were evaluated by one examiner in a stochastic order and resulted in a total of 232 teeth and 464 reading/calibrations.

Owing to Krieger et al. (2013) and Fritz et al. (2003) we considered the change in pre- and post-treatment RCRs as the relative root-crown ratio (rRCR). Calculations of rRCR that resulted in 100%; it denoted that there was a null relative difference between the pre- and post-treatment RCRs, while a lower percentage demonstrated altered RCRs during the treatment.

2.1 Statistics

Data analysis and collection were performed using the SPSS® software program (Statistical Package for Social Science) for Mac Version 23.0 (Inc., Armonk, NY, USA).

The averages of the two measurements were used to calculate RCR and the changes in RCR. The absolute and relative frequencies of RCR was calculated for every tooth. Quantitative measurements are described by the mean and standard deviation. And we calculated method-error before we start the experiment and intra examiner reliability.

3. Results

A multicentric retrospective cohort study was conducted, using a purposive non-probability sampling method. The final sample included 29 patients both male and female additionally, the treatment time did not exceed 2 years. 72% of the final sample demonstrated external root resorption.

Upper Anterior teeth have a more significant resorption rate than lower anterior teeth $P < 0.05$. A total of 29 patients were included according to the selection criteria, 12 teeth were examined in each patient pre and postoperatively, a total of 696 measurements were performed by one examiner, Intra examiner calibration is 0.8 which indicates high reproducibility. The power of the sample size is 80.

3.1 Incidence and Severity of Root Resorption

Post-treatment root length (rRCR $< 100\%$) were reduced in 72% of the cases, as for the severity of the RR, a reduction in the percentage of $> 0\%$ up to 2% was found in all affected teeth (slight RR).

Upper teeth presented 24.1% RR in the right lateral incisor followed by left lateral incisor (20%). right and left canines showed 20% and 17.2% respectively as shown in Figure 1.

In the lower teeth, all left central incisor showed RR, while 96.6% of right central incisor demonstrated RR. Both left and right canine showed lower percentage of RR compared to central and lateral incisors (Figure 2).

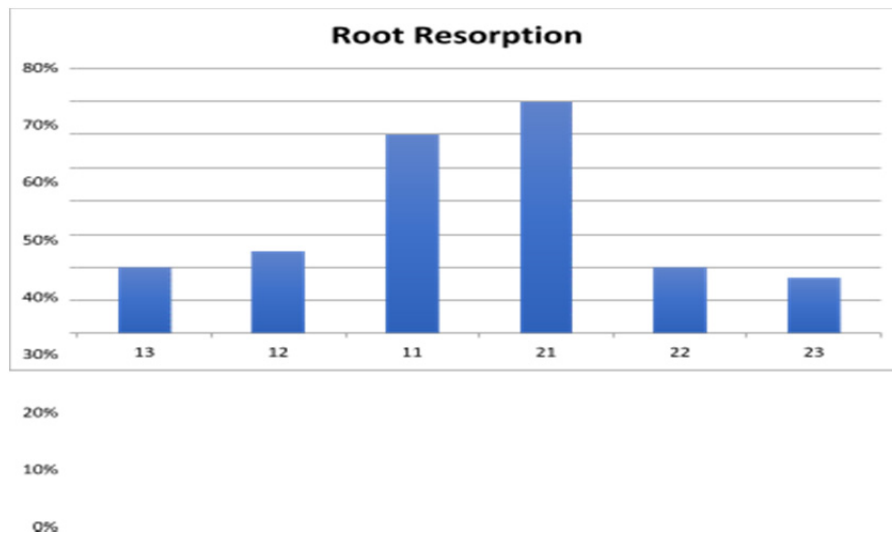


Figure 1. Percentage of upper teeth presenting RR (Number according to the ISO Dental Notation System)

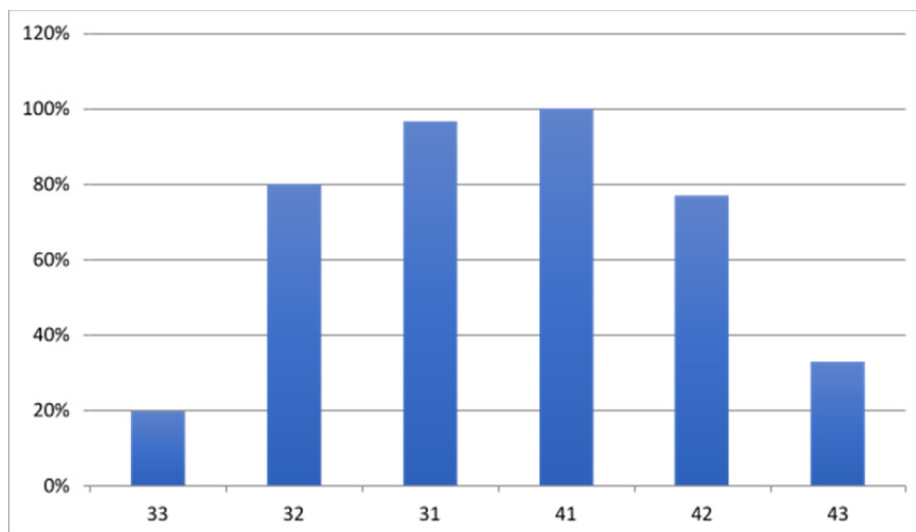


Figure 2. Percentage of lower teeth presenting RR (Number according to the ISO Dental Notation System)

The mean difference of the upper and lower teeth of the right quadrant was correlated with the left quadrant as shown in Table 1. The comparison was done using Wilcoxon signed ranks test for a paired sample. Each tooth on the right quadrant was compared to the correspondent tooth.

A statistically significant difference between RR was observed in the lower teeth between the right and left quadrant, especially in the lower central incisor ($p < 0.05$).

The mean difference in RR was higher in the right central incisor on both arches.

Table 1. Mean difference of the upper and lower teeth on the right quadrant was compared with the correspondent on the left quadrant

		Mean Difference	SD	p value
Upper central incisor	<i>Right (11)</i>	0.13	0.29	0.512
	<i>Left (21)</i>	0.09	0.26	
Upper lateral incisor	<i>Right (12)</i>	0.01	0.07	0.56
	<i>Left (22)</i>	0.07	0.4	
Upper canine	<i>Right (13)</i>	0.03	0.09	0.890
Lower central incisor	<i>Right (41)</i>	0.32	0.02	0.000*
	<i>Left (31)</i>	0.20	0.05	
Lower lateral incisor	<i>Right (42)</i>	0.04	0.19	0.317
	<i>Left (32)</i>	0.000	0.000	
Lower canine	<i>Right (43)</i>	0.04	0.11	0.41
	<i>left (33)</i>	0.06	0.19	

4. Discussion

This study was not directed towards data differentiation on the bases of gender nor age, since previous studies reported that gender and age have no statistical significance when it comes to root resorption incidence (Iglesias-Linares et al., 2017; Kreich et al., 2016).

Current samples included cases treated with aligners without relation to conventional fixed appliance cases, however other studies conducted on root resorption following orthodontic treatment with fixed conventional appliance proved compatible results. In our study, 72% of the teeth demonstrated root resorption, in agreement with a study done by Handem et al. (2016) that stated root resorption will accompany fixed conventional orthodontic treatment in 50.3% of the cases, whilst according to Kreich et al. (2016) all patient demonstrated a degree of root resorption on different scales. In a comparison done in 2017 by Iglesias-Linares et al. (2017) concluded that patients treated with fixed conventional orthodontic treatment were as half as less susceptible to EARR compared to patients treated with removable aligners. However, Elhaddaoui et al, contradicts that in study conducted in 2016 that revealed that thermoplastic aligners induced EARR following orthodontic treatment, has a lower incidence and severity when compared to conventional fixed orthodontic treatment (Elhaddaoui et al., 2017).

While the incidence of EARR with removable aligners was considerably high in this study, the severity of root resorption was found to be mild (> 0% up to 2%) in all the affected teeth. The mild severity may be contributed to the short duration of treatment using removable aligners along with the light intermittent nature of the force applied, unlike fixed appliances which require longer duration and higher continuous force to be implemented to reach the desired goal. In other study done by Giulia Gay et al. assessed root resorption severity in adult patients treated with thermoplastic appliance, demonstrated that 26% had slight root resorption (<10%), 12% revealed a moderate score (10–20%) and 3.69% had a severe score (>20%). Along with a range of 1.54% (12) to 7.81% (22) severe root resorption in maxillary anteriors and a lower percentage in mandibular anterior were reported by the same study (Gay et al., 2017).

In current study, lateral incisors have more significant resorption rate which was similar to (Jamil & Alam, 2017), many Factors have been reported in the literature as a confounding to greater root resorption including and not limited to the extent of tooth movement combined with tooth type and the nature of the force applied. (Elhaddaoui et al., 2016) root morphology and its periodontal membrane and bone association all these factors will lead to a cascade of root resorption (Iglesias-Linares et al., 2016).

5. Conclusion

The present study showed that the incidence of root resorption was high after orthodontic treatment with Invisalign®, However, the severity is very low and limited to the surface resorption exclusively.

5.1 Limitation and Suggestions

- 1) The authors recommend that future studies be conducted in a prospective manner with a control group involved.
- 2) One limitation of this study is that one examiner was involved in the measurement process.

Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

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