



Root Resorption in Mandibular Incisors During Orthodontic Treatment with Invisalign®: A Radiometric Study

Giulia Gay^{1,*}, Serena Ravera¹, Tommaso Castroflorio¹, Francesco Garino², Giovanni Cugliari³ and Andrea Deregibus¹

¹Post-graduate School of Orthodontics, Lingotto-Dental School, Department of Surgical Sciences, University of Turin, Turin, Italy

²Private Practice, Turin, Italy

³Department of Statistics and Quantitative Methods, University of Milano-Bicocca, Milan, Italy

*Corresponding author: Giulia Gay, Department of Orthodontics, Dental School, University of Turin, Turin, Italy. Tel: +39-3384505990, E-mail: gay.giulia@gmail.com

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Abstract

Background: Existing literature indicates that orthodontics patients are more likely to have severe apical root shortening, interesting mostly maxillary, followed by mandibular incisors.

Objectives: The aim of the present study was to investigate the incidence and severity of root resorption (RR) in mandibular incisors of adult patients treated with aligners.

Methods: The study group consisted of 71 adult healthy patients (mean age 32.8 ± 12.7) treated with aligners (Invisalign®, Align Technologies, San Jose, CA, USA) for the intrusion of the lower incisors. Root and crown lengths of a total of 279 lower incisors were measured in panoramic radiographs at the beginning (T0) and at the end (T1) of aligner therapy. Individual root-crown-ratio (RCR) of each tooth and therefore the relative changes of RCR (rRCR) were determined.

Results: 44% of the 279 measured teeth presented a reduction of the pre-treatment root length. A reduction in percentage of > 0% up to 10% was found in 26.76% (n = 76), a distinct reduction of > 10% up to 20% in 12.32% (n = 35) of the sample. 4.58% (n = 13) of the teeth were affected by a clinically relevant reduction (> 20%).

Conclusions: Orthodontic treatment with Invisalign® aligners could lead to RR in cases in which intrusion of the lower incisors is planned. However, the incidence of RR is comparable to data described in case of application of light forces with fixed appliances, and considerably lower than what has been described for traditional comprehensive orthodontic treatments.

Keywords: Adult Patients, Aligners, Root Resorption

1. Background

Root resorption (RR) is described as a permanent loss of tooth structure from the root apex and its clinical manifestation among orthodontic patients is highly variable (1). The etiopathogenesis of RR is complex and multifactorial, and influenced by individual biologic variability, genetic predisposition and mechanical factors (2). As a matter of fact, several authors demonstrated that RR occurs even without orthodontic treatment (3-6). However the existent literature shows that orthodontically treated patients are more likely to have severe apical root shortening (7).

The occurrence of RR in orthodontically moved teeth is reported as greater than 90% in histological studies (8-10). Lower percentages are reported when diagnostic radiographic techniques are used. The average amount of tissue loss is usually less than 2.5 mm (11-14) or varies from 6

to 13% for different teeth in radiographic studies (15).

RR is usually classified as minor or moderate in most orthodontic patients. Severe resorption, if exceeding 4 mm or one - third of the original root length, is seen in 1 - 5% of teeth (7, 16-18).

The mechanism of root resorption has two phases: the first is represented by the damage of the external surface of the root with exposition of denuded mineralized tissue while the second phase is characterized by the stimulation of multinucleated cells (19). Those multinucleated cells colonize the denuded mineralized tissue and initiate the resorption process. If there are no further stimulations, spontaneous repair will occur with cementum - like material within 2 - 3 weeks. If the inflammatory process will persist involving deeper root dentin, then RR can be detected radiographically (20). Apical RR may be observed during or at the end of the treatment. It begins approximately 2 - 5 weeks into treatment, but it takes 3 - 4 months before ra-

diographical appearance. Even if it is a complex biological process and many aspects are unknown, RR occurs when forces at the root apex exceed the resistance and reparative ability of the periapical tissues.

Furthermore the association between the amount of orthodontic tooth movement and the resulting RR, has been demonstrated (21-24). The amount of tooth movement depends on the severity of the malocclusion, suggesting that the presence of a severe malocclusion represents a risk factor for RR. Class I patients with acceptable overjet show less RR than Class II or III patients (25).

Several studies, suggest that the pause in orthodontic treatment conducted with intermittent force allows the re-sorbed cementum to heal and prevent further resorption (26-28).

Since the Invisalign® treatment technique belongs to removable appliances, intermittent forces are applied to the teeth.

2. Objectives

The aim of the present study was to investigate the incidence and severity of RR in mandibular incisors of adult patients treated with aligners in order to obtain their intrusion.

The study was conducted to answer the following clinical question: does the lower incisors intrusion obtained with interrupted forces result in RR?

3. Methods

In the present study we evaluated 71 (25 males and 46 females) adult healthy patients treated with aligners (Invisalign®, Align Technologies, Santa Clara, CA, USA). The mean age was $32, 8 \pm 12.7$ (age range 18-71). The panoramic radiographs were taken at the beginning (T0) and at the end (T1) of orthodontic treatment. The average treatment duration was 18 months.

All of the pre- and post- panoramic radiographs were taken with the same device.

Inclusion criteria for all the patients were: need for intrusion of the lower incisors, moderate crowding (arch length discrepancy < 6 mm).

Exclusion criteria were: evidence of root resorption on the pre-treatment panoramic radiographs, presence of severely dilacerated roots or endodontically treated teeth, patients requiring other orthodontic systems, extraction therapy or any surgical treatment.

The treatment plan was designed in order to obtain an intrusion movement of the lower incisors. All lower incisors were assessed. Considering inclusion and exclusion criteria, a total of 279 teeth were evaluated (Table 1).

The measurement of the dental panoramic radiographs were performed by using Orisceph (Orisceph R \times ®, Elite Computer Italia, Vimodrone, MI, Italy).

On the basis of Krieger et al., Fritz et al. and Linge and Linge, all root and crown measurements were assessed by one examiner blinded in a stochastic sequence (11, 29, 30). To evaluate the pre- and post-treatment root length a symmetric cross was defined by two connecting lines: the first from the width of the incisal edge of the tooth to the apex, the second from the mesial and distal edge of cemento-enamel-junction. The crown length was represented by the distance between incisal edge and cemento-enamel-junction (on the long axis). The root length was represented by the distance between cemento-enamel-junction and apex (Figure 1).

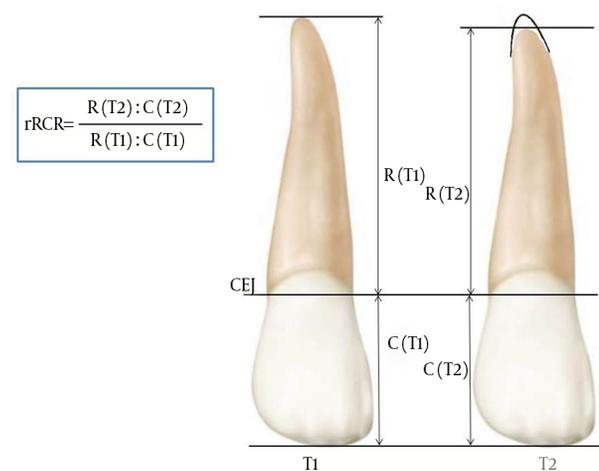


Figure 1. Measurement of the Panoramic Radiographs: Root and Crown Lengths (CEJ = Cemento-Enamel Junction), Individual root-crown-ratio (RCR) was determined considering pre- and post-treatment root and crown length.

As stated by Krieger et al. (25) and Fritz et al. (31) individual root-crown-ratio (RCR) of each tooth and therefore the relative changes of RCR (rRCR) was determined considering pre- and post-treatment root and crown length. An rRCR of 100% indicates no change of the pre-treatment root length relative to the post-treatment root length. A decrease of rRCR indicates a reduction of the root length during treatment.

Data analysis and data collection were performed using the SPSS® software program (statistical package for social science) for windows version 23.0 (Inc., Chicago, IL, USA).

The averages of the two measurements were used to calculate RCR and the changes in RCR. Absolute and relative frequencies of RCR were calculated for every tooth.

Table 1. Number of Teeth Evaluated

TOT	42	32	41	31
279	71	68	70	70

Quantitative measurements are described by mean and standard deviation.

For testing difference in RCR between right and left side of the arch we performed a student's T-test for paired sample.

4. Results

The mean rRCR for every tooth is shown in [Table 2](#).

All patients had a minimum of one teeth affected with a reduction of the root length (rRCR < 100%), on average 2.14 ± 0.92 teeth per patient ([Table 3](#)).

In the present study, 43.66% of the 279 teeth (n = 124) were affected by reduction of the post-treatment root length (rRCR < 100%).

Considering the severity of the RR, a reduction in percentage of > 0% up to 10% was found in 26.76% (n = 76), a distinct reduction of > 10% up to 20% in 12.32% (n = 35) of the sample. 4.58% (n = 13) of the teeth were affected with a considerable reduction (> 20%) ([Table 4](#)).

The values of the individual tooth ([32-35](#)) are shown in [Table 5](#).

The difference in rRCR between right and left side of the arch was also tested by using a Student's t-test for paired sample. Every tooth on the right side of the arch was compared with the corresponding on the left side.

Lower central incisors showed a statistically significant difference between RR on the right side and on the left side of the arch ([Table 6](#)).

5. Discussion

In previous studies it has been demonstrated that maxillary incisors showed a consistent average apical root resorption, more than any other analyzed tooth, followed by mandibular incisors and mandibular first molars ([12, 23-25, 31-33, 36-39](#)).

As shown in [Table 2](#), 43.66% of the 279 teeth (n = 124) were affected by post-treatment reduction of the root length with aligner therapy. These data are encouraging if compared to the ones recently reported by Castro et al. ([40](#)); in their study the incidence of RR in patients treated with straight wire appliances was 72% for mandibular central incisors and 70% for mandibular lateral incisors.

Tieu et al. ([41](#)) in their systematic review evaluated RR to maxillary and mandibular incisors during non-surgical

orthodontic treatment (extraction and non-extraction) in class II division I malocclusions, measured using radiographs (periapical or lateral cephalometric). Each study classified root resorption differently; however, all reported that the majority of teeth experienced mild to moderate resorption following treatment. Prevalence of incisors root resorption ranged between 65.6% and 98.1%.

When considering the severity of RR in our study sample, the incidence of minimal RR (< 10%) was 27%, mild RR (between 10% and 20%) was 12% and severe RR (between 20% and 30%) was only 4.58%. These values are consistent with those reported in a retrospective study of Krieger et al. ([29](#)) who examined the incidence and severity of RR in patients who underwent a fully implemented orthodontic treatment with aligners: 46% of all teeth presented RR; in particular mandibular incisors showed a minimal RR ranged from 25% to 32%, mild RR from 11% to 18% and severe RR from 1% to 14%.

The major incidence of RR in maxillary and mandibular incisors may be explained with the greater extending of movement of maxillary incisors that usually occurs, the root structure of the incisors, and its relationship to bone and the periodontal membrane, which transfers most of the forces to the apex ([34](#)).

As far as the force system applied to teeth is concerned, a comprehensive orthodontic treatment causes increased incidence and severity of RR, and heavy force application significantly produces a greater RR than light force application or control ([1](#)). Therefore, the use of light forces, especially for intrusion of anterior teeth, is recommended.

It has been suggested that an orthodontic force greater than the partial pressure of the periodontal capillaries (26 g per square centimeter) ([35](#)) will cause periodontal ischemia and lead to RR.

In their prospective study, Barbagallo et al. ([42](#)) used x-ray microtomography to quantify premolar cementum resorption generated by treatment with ClearSmile® (ClearSmile, Woollongong, Australia) aligners: these values obtained were compared with the ones of a fixed appliance generating heavy or light orthodontic forces. The results showed that the aligner group had a similar RR with respect to the light-force group and approximately six times greater than the untreated control group.

Similar results between the aligners group and the light-force group could be explained by the study conducted by Cattaneo et al. in 2009 ([43](#)). In their finite ele-

Table 2. Lower Teeth: Number of Measured Elements, Mean and Standard Deviation of RCR for Every Tooth

	42	32	41	31
N	71	68	70	70
Mean	101.9	104.7	100.20	105.70
SD	16.50	12.27	13.28	13.48
Min.	57	79	71	82
Max.	140	171	127	137

Table 3. Distribution of the Amount of the Affected Teeth Per Patient (n = 56)

N. Teeth (RCR < 100%)	Frequency (n)	Percent (%)
1	16	28.57
2	20	35.71
3	16	28.57
4	4	7.14

ment analysis the PDL performance under light force loading was evaluated. The authors did not confirm the classical ideas of distinct and symmetrical compressive and tensile areas in the periodontium: light continuous orthodontics forces are perceived as intermittent by the periodontium, because of the viscoelastic nature of PDL and of the vertical forces released during function and parafunction. This finding could explain the similar results between the aligners group and the light-force group.

Orthodontic treatment with Invisalign® aligners could led to RR in cases in which intrusion of the lower incisors is planned. However the incidence of RR results comparable to what has been described for the application of orthodontic light forces, with in most of the cases a percentage of RR < 10% of the original root length, and considerably lower than what has been described for comprehensive orthodontic treatments.

5.1. Conclusions

The present study investigated the incidence and severity of RR in mandibular incisors of adult patients treated with aligners during Class II treatments with sequential distalization protocol applied on the upper arch and intrusion in the lower incisors area. Every patient showed a minimum of one teeth with root length reduction. On average, 2.14 teeth per patient were affected. Overall, 44% of the measured 279 teeth showed signs of apical root resorption, but only 4.58% a reduction of over 20% of the pre-treatment root length.

Footnotes

Authors' Contribution: Study concept and design: Tommaso Castroflorio, Francesco Garino; acquisition of data: Giulia Gay, Serena Ravera; analysis and interpretation of data: Giovanni Cugliari; drafting of the manuscript: Giulia Gay, Serena Ravera; critical revision of the manuscript for important intellectual content: Andrea Deregibus; statistical analysis: Giovanni Cugliari; administrative, technical, and material support: Tommaso Castroflorio, Francesco Garino; study supervision: Andrea Deregibus

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Table 4. Distribution of the root length reduction during orthodontic treatment. Post-treatment RCR relative to pre-treatment RCR (rRCR), absolute (n) and relative (%) frequencies (n=279): rRCR < 80 means a reduction over 20 % of pre-treatment root length.

rRCR	Frequency (n)	Cumulative Frequency (n)	Percent (%)	Cumulative Percent (%)
rRCR < 80	13	13	4.58	4.58
80 ≤ rRCR < 90	35	48	12.32	16.90
90 ≤ rRCR < 100	76	124	26.76	43.66
rRCR ≥ 100	160	284	56.34	100.00

Table 5. Distribution of the root length reduction during orthodontic treatment of the individual teeth (each n = 68 ± 3, overall n = 279): post-treatment RCR relative to pre-treatment RCR (rRCR), absolute (n) and relative (%) frequencies.

rRCR	Tooth			
	42	32	41	31
rRCR < 80	6	1	6	0
	8.45	1.47	8.57	0.00
80 ≤ rRCR < 90	10	5	13	7
	14.08	7.35	18.57	10.00
90 ≤ rRCR < 100	17	25	12	17
	23.94	36.76	17.14	24.28
rRCR ≥ 100	38	37	39	46
	53.52	54.41	55.71	65.71
Total (n)	71	68	70	70

Table 6. Lower incisor tooth on the right side of the arch was compared with the corresponding on the left side using Welch Two Sample t-test. Estimate shows the mean of the differences.

42 - 32	41 - 31
-2.79	-5.49
-8.01 2.43	-9.96 -1.01
0.293	0.017 ^a

^aP value < 0.05. 41-31 showed a statistically significant difference.

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