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Root resorption during orthodontic treatment with Invisalign®: a radiometric study

Giulia Gay¹, Serena Ravera^{1*} , Tommaso Castroflorio¹, Francesco Garino¹, Gabriele Rossini¹, Simone Parrini¹, Giovanni Cugliari² and Andrea Deregibus¹

Abstract

Background: Root resorption (RR) is described as a permanent loss of tooth structure from the root apex. Many reports in the literature indicate that orthodontically treated patients are more likely to have severe apical root shortening, interesting mostly maxillary, followed by mandibular incisors. The aim of the study was to investigate the incidence and severity of RR in adult patients treated with aligners. The study group consisted of 71 class I adult healthy patients (mean age 32.8 ± 12.7) treated with aligners (Invisalign®, Align Technologies, Santa Clara, CA, USA). All incisors, canines, upper first premolars, and first molars were assessed. Root and crown lengths of 1083 teeth were measured in panoramic radiographs at the beginning (T0) and at the end (T1) of clear aligner therapy. Individual root-crown ratio (RCR) of each tooth and therefore the relative changes of RCR (rRCR) were determined. A decrease of rRCR was assessed as a reduction of the root length during treatment.

Results: All patients had a minimum of one teeth affected with a reduction of root length, on average 6.38 ± 2.28 teeth per patient. Forty one, 81% of the 1083, measured teeth presented a reduction of the pre-treatment root length. A reduction in percentage of >0% up to 10% was found in 25.94% ($n = 281$), a distinct reduction of >10% up to 20% in 12.18% ($n = 132$) of the sample. 3.69% ($n = 40$) of the teeth were affected with a considerable reduction (>20%).

Conclusions: Orthodontic treatment with Invisalign® aligners could lead to RR. However, its incidence resulted to be very similar to that described for orthodontic light forces, with an average percentage of RR < 10% of the original root length.

Keywords: Adult patients, Aligners, Root resorption

Background

Root resorption (RR) is a permanent loss of tooth structure from the root apex [1]. Its clinical outcomes in orthodontic patients are highly variable and depend on genetic predisposition, individual biologic variability, and mechanical factors [2]. Several authors demonstrated that RR occurs even without orthodontic treatment [3–6], but patients who underwent orthodontic treatment are more likely to show severe apical root shortening [7].

In histological studies, orthodontically moved teeth show an occurrence of RR greater than 90% [8–10]. Lower

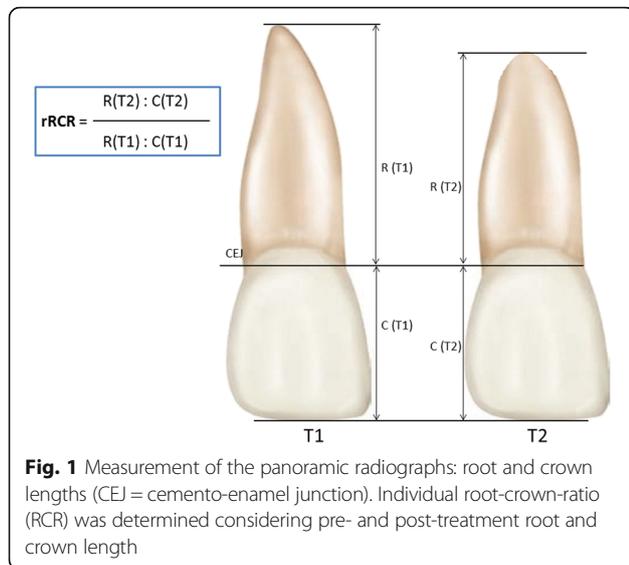
percentages are reported for diagnostic radiographic techniques. The average amount of tissue loss is less than 2.5 mm [11–14] or varies from 6 to 13% for different teeth [15] in radiographic studies.

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 teeth⁷ [16–18].

Root resorption has two phases: during the first phase, the damage of the external surface of the root causes the exposition of denuded mineralized tissue, while in the second one, multinucleated cells are stimulated to colonize the denuded mineralized tissue, getting to a resorption process [19]. Without any

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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 RR radiographically detected [20]. When forces at the root apex exceed the resistance and reparative ability of the periapical tissues, RR occurs [21]. It begins approximately 2–5 weeks into treatment, but radiographical appearance requires 3–4 months.

Furthermore, the association between RR and the amount of orthodontic tooth movement²¹ [22–24] has been demonstrated. Since the amount of tooth movement depends on the severity of the malocclusion, a severe malocclusion represents a risk factor for RR. Class I patients with normal overjet show less RR than class II or III patients [25].

Several studies [26–28] suggest that light continuous forces are perceived as intermittent ones and allow the healing of the resorbed cementum, preventing further resorption. The Invisalign® treatment technique belongs to removable appliances, so intermittent forces are applied to the teeth. The aim of the present study was to investigate the incidence

and severity of RR in adult patients treated with aligners.

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 ± 12.7 (age range 18–71). We did not differentiate data by gender or age since previous studies pointed out that sex and age of patients could not be considered as potential confounding factors [29, 30]. In this prospective study, patients were recruited from December 2014 to December 2015 among the private practice patients in xxx, xxx. The panoramic radiographs were taken at the beginning (T0) and at the end (T1) of orthodontic treatment with the same device. The average treatment duration was 14 months.

Inclusion criteria for all the patients were adult patients (>18yo), normodivergent, and class I malocclusion with crowding (arch length discrepancy <6 mm).

Exclusion criteria were evidence of root resorption on pre-treatment panoramic radiographs, severely dilacerated roots, endodontically treated teeth, patients requiring other orthodontic systems, extraction therapy or any surgical treatment, and patients presenting tooth wear with dentin exposure at the initial examination.

The anterior crowding was resolved by IPR (interproximal enamel reduction) and/or protrusion of anterior teeth, determined by the orthodontist, depending on the initial overjet (protrusion) or crown’s shape (IPR). The mean IPR was 0.33 mm (min. 0 mm, max. 0.5 mm).

All incisors and canines, upper first premolars, and first molars were assessed. A total of 1083 teeth were evaluated.

The measurement of the dental panoramic radiographs was performed by using Orisceph® (Orisceph Rx®, Elite Computer Italia, Vimodrone, MI, Italia).

On the basis of Krieger et al. [31], Fritz et al. [32], and Linge and Linge¹¹, all root and crown measurements were assessed by one examiner blinded about the study, in a stochastic sequence. The crown length was represented by the distance between incisal edge and

Table 1 Number of measured elements, mean, and standard deviation of RCR for every tooth

| | | | | | | | | | | |
|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 1.6 | 1.4 | 1.3 | 1.2 | 1.1 | 2.1 | 2.2 | 2.3 | 2.4 | 2.6 |
| No. of teeth | 69 | 66 | 67 | 65 | 70 | 69 | 64 | 69 | 65 | 58 |
| Mean rRCR (%) | 100 | 103 | 104 | 104 | 102 | 103 | 100 | 104 | 102 | 101 |
| Standard deviation | 13.09 | 12.47 | 14.93 | 11.82 | 14.15 | 13.58 | 15.38 | 14.55 | 14.66 | 13.42 |
| | | | 4.3 | 4.2 | 4.1 | 3.1 | 3.2 | 3.3 | | |
| No. of teeth | | | 71 | 71 | 70 | 70 | 68 | 71 | | |
| Mean rRCR (%) | | | 107 | 102 | 100 | 106 | 104 | 105 | | |
| Standard deviation | | | 13.78 | 16.5 | 13.28 | 13.48 | 12.27 | 13.48 | | |

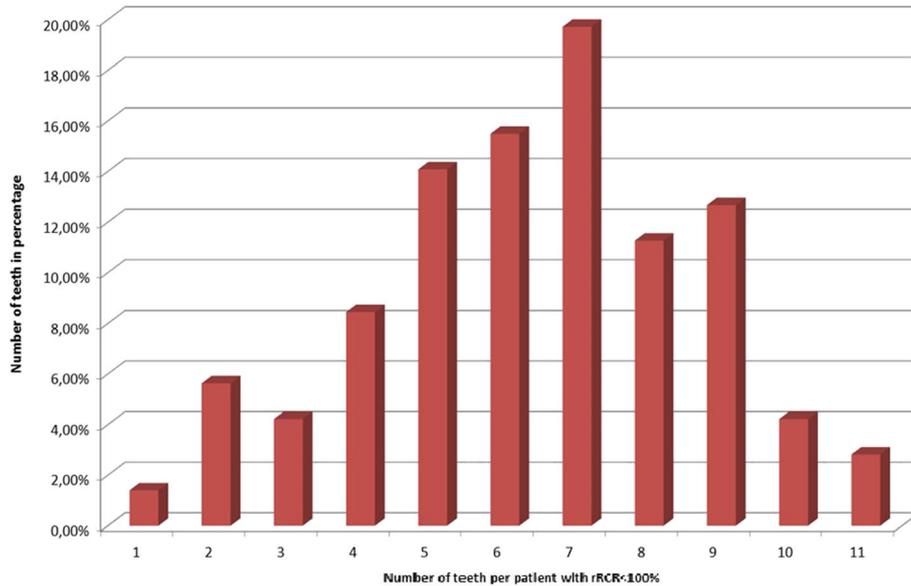


Fig. 2 Distribution of the amount of affected teeth per patient

cemento-enamel junction (on the long axis). The root length was represented by the distance between cemento-enamel junction and apex (Fig. 1).

As stated by Krieger et al. [31] and Fritz et al. [32], individual root-crown ratio (RCR) and therefore the relative changes of RCR (rRCR) were 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 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. Quantitative measurements are described by mean and standard deviation.

Table 2 Number and percentage of teeth presenting rRCR ≥ 100% (no RR), rRCR between 90 and 100 (slight RR), rRCR between 80 and 90 (moderate RR), rRCR ≤ 80 (severe RR)

| rRCR (%) | No. of teeth | Percent |
|--------------|--------------|---------|
| ≥100 | 630 | 58.12 |
| 90 ≤ X < 100 | 281 | 25.94 |
| 80 ≤ X < 90 | 132 | 12.18 |
| <80 | 40 | 3.69 |
| TOT | 1083 | 100 |

Results

The mean rRCR for every tooth is shown in Table 1.

All patients had a minimum of one teeth affected with a reduction of the root length (rRCR < 100%), on average 6.38 ± 2.28 teeth per patient (Fig. 2).

Forty one percent ($n = 29$) of all patients had a minimum of one tooth with a 20% root length reduction.

In this study, 41.81% of the 1083 teeth ($n = 453$) showed a reduction of post-treatment root length (rRCR < 100%). A reduction up to 10% was found in 25.94% ($n = 281$), a distinct reduction from 10% up to 20% in 12.18% ($n = 132$) of the sample. 3.69% ($n = 40$) of the teeth were affected with a considerable reduction (>20%) (Table 2).

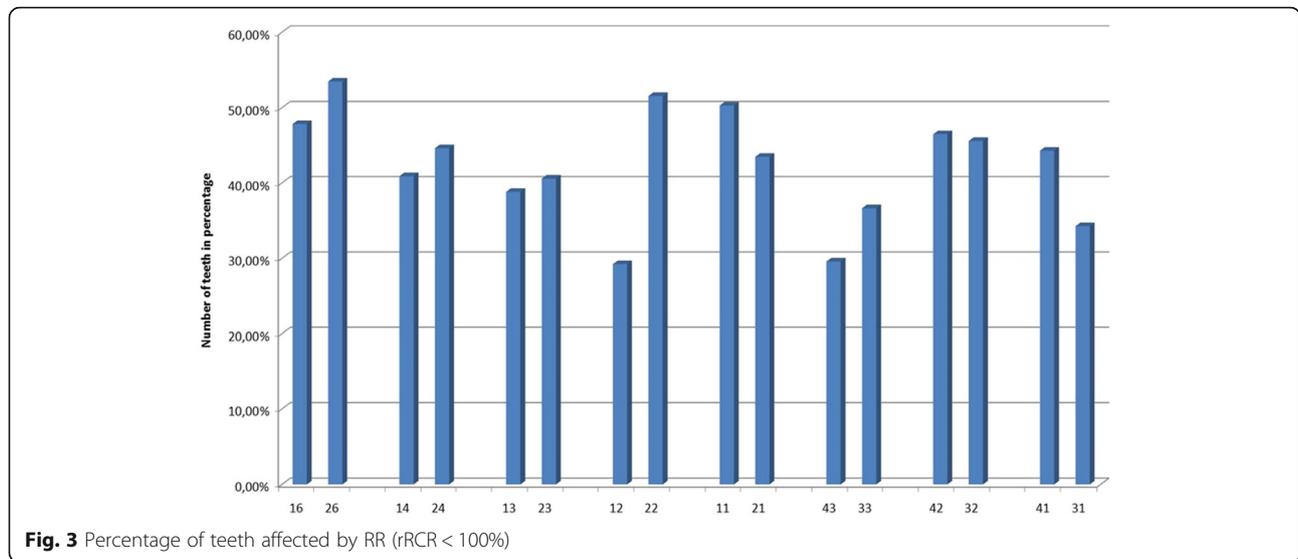
The values of the individual teeth are shown in Tables 3 and 4.

The percentage of teeth with rRCR < 100% are shown in the Fig. 3.

A severe RR was observed only in 3.69% of teeth. As shown in Fig. 4, severe RR occurs mostly in the upper left premolars, upper left lateral incisors, lower right lateral, and central incisors.

Discussion

A previous review from Rossini et al. [33] demonstrated that Invisalign® is effective for simple malocclusions treatment. Starting from this consideration, the present study investigated the incidence of RR in a sample of adult patients with class I malocclusions, showing a very limited incidence of significant severe RR.



resorption generated by treatment with ClearSmile® (ClearSmile, Woollongong, Australia) aligners using x-ray microtomography. Comparing the obtained values with those of a fixed appliance generating heavy or light orthodontic forces, the results showed that the aligner group had a similar RR to the light-force group and approximately six times greater than the untreated control group. These findings could be explained by the finite element analysis conducted by Cattaneo et al. in 2009 [47] on the PDL performance under light force loading: light continuous forces are perceived as intermittent by the periodontium because of the viscoelastic nature of PDL and the application of vertical forces during function and parafunction.

Orthodontic treatment with Invisalign® aligners could lead to RR as any other orthodontic treatment. The incidence of RR resulted consistent to the one described for orthodontic light forces (RR < 10% of original root length). Further studies on more complex malocclusions treated with aligners are

guaranteed in order to analyze RR incidence with respect to comprehensive orthodontic treatments.

Conclusions

The present study investigated the incidence and severity of RR in adult patients treated with aligners during class I treatments. Every patient showed a minimum of one tooth with root length reduction. On average, 6.39 teeth per patient were affected. Overall, 41.81% of the measured 1083 teeth showed signs of apical root resorption, but only 3.69% a reduction of over 20% of the pre-treatment root length. Severe RR affected mostly the upper lateral incisors and lower lateral and central incisors.

Abbreviations

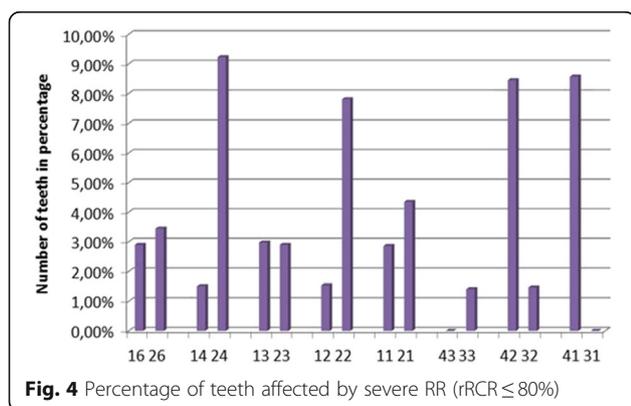
IPR: Interproximal enamel reduction; RCR: Root-crown ratio; RR: Root resorption; rRCR: Relative changes of RCR

Authors' contributions

GG has made substantial contributions in acquisition and interpretation of data and has been involved in drafting the manuscript and revising it critically for important intellectual content. SR has made substantial contributions in acquisition and interpretation of data and has been involved in drafting the manuscript and revising it critically for important intellectual content. TC has made substantial contributions to conception and design of the study and has been involved in drafting the manuscript and revising it critically for important intellectual content. FG has made substantial contributions to conception and design of the study and has been involved in drafting the manuscript and revising it critically for important intellectual content. GR has made substantial contributions in interpretation of data. SP has made substantial contributions in interpretation of data. GC carried out the statistical analysis and interpretation of data. AD has been involved in supervision during the draft of the manuscript, revising it critically for important intellectual content, and has given final approval of the version to be published. All authors read and approved the final manuscript.

Competing interests

Dr. Castorflorio and Dr. Garino have held lectures and conferences for Align Technology in the past 5 years. The presented study was conducted without any support (financial or technical) by Align Technology.



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