



Original Article

External apical root resorption in non-extraction cases after clear aligner therapy or fixed orthodontic treatment



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Received 1 March 2017; Final revision received 17 September 2017

Available online 1 February 2018

KEYWORDS

Clear aligner;
Fixed orthodontics;
Root resorption

Abstract *Background/purpose:* The application of removable aligner in orthodontic treatment has increased rapidly in recent years, while its effects on root resorption remains unclear. The aim of this study was to comparatively evaluate the amount of external apical root resorption (EARR) in non-extraction patients receiving clear aligner therapy (CAT) or fixed orthodontic treatment (FOT).

Materials and methods: Eighty non-extraction patients treated with CAT or FOT exclusively were evaluated retrospectively. Panoramic radiographs were used to measure the length of crowns and roots of the incisors before and after treatment. The amount of EARR was determined by the relative change of root-crown ratio and compared between the two groups. The potential predictive factors of EARR were investigated using spearman correlation analysis.

Results: The overall EARR in the CAT patients was significantly less than the FOT. Similar results were observed in maxillary central incisors, maxillary lateral incisors, mandibular central incisors and mandibular lateral incisors. The duration of treatment positively correlated with the amount of EARR in both modalities. Gender, age, skeletal pattern or degree of malocclusion did not affect the occurrence of EARR.

Conclusion: Clear aligner therapy may have a superiority of reducing external apical root resorption compared to fixed orthodontic treatment in non-extraction patients.

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Introduction

External apical root resorption (EARR) is defined as a physiologic or pathological process characterized by the loss of cementum or dentine resulting in the shortening of root apex.¹ The reduction of root length could cause the tooth mobility and even affect the long-term viability of dentition.² Since most of the structural injuries at root surface are irreversible, the identification of protective and risk factors is critical to dental practitioners to facilitate the prevention of EARR.³

As a common and iatrogenic problem in orthodontic treatment, the occurrence of EARR has been proved to be associated with the combination of individual biological variability and mechanical stimulations.⁴ In terms of the mechanical factors, the treatment duration, force magnitude, amount of tooth movement, force type and treatment appliance have been suggested to influence the degree of EARR.⁵ Previous studies found the incidence of EARR in orthodontically treated teeth was higher than 90%.⁵ Another radiographic investigation reported the teeth with EARR increased remarkably from 15% to 73% after orthodontic treatment. The high incidence of root resorption could be derived from the nature of tooth movement. Among the series of biological activities during orthodontic tooth movement, the elimination of hyaline zone is considered as the prerequisite for the launch of physiological tooth movement but could also absorb the root outer surface,⁶ after which, the exposed dentine would be more vulnerable to resorption by scavenger cells.⁷

In recent years, clear aligner therapy (CAT) has been widely applied in orthodontic clinics. Since the inherent advantage of esthetics and comfortability, CAT has been gradually become a prior option in treatment planning, especially to adult patients. Moreover, due to the removability, CAT could also offer the convenience in oral health care to patients.⁸

From the perspective of mechanics, there are several distinct differences between CAT and fixed orthodontic treatment (FOT). First, since aligners are suggested to be removed during eating and oral hygiene procedures, orthodontic forces applied to teeth in CAT is intermittent rather than continuous in FOT. Second, the magnitude of forces and moments generated by aligners could differ from that of brackets and archwires. Third, the force is transmitted to teeth by bracket which is generally located in the center of tooth crown in FOT while by aligner *per se* and the attachment in CAT. The different mechanical properties may affect the rate of root resorption of these two modalities. However, the available evidence regarding this issue is limited. Thus, we performed the present study to evaluate the amount of EARR in patients treated with CAT and FOT. Since CAT has not yet been a totally mature technique for extraction cases,⁹ we focused on the non-extraction patients in this study.

Material and methods

The protocol of this retrospective investigation was approved by institutional review board of authors' university. The patient pool of the orthodontic department in

authors' hospital from 2011 to 2015 was screened. The inclusion criteria were as follows: (1) complete treatment using CAT or FOT exclusively; (2) the medical records and pre-/post-treatment x-ray examinations (lateral cephalometric and panoramic radiograph) were available; (3) No tooth extraction (except for the third molar) or space closure for missing tooth; (4) No radiographic evidence of EARR prior to the treatment; (5) No root canal treatment was performed in the evaluated teeth; (6) The root growth should be completed before treatment; (7) No orthognathic surgery was involved in the treatment.

Patients of FOT group received the treatment using preadjusted edgewise appliance with 0.022-in slot. Patients of CAT group were treated with sequential thermoplastic appliances. A data extraction form was established to collect the basic information including gender, age, skeletal pattern, treatment duration, degree of irregularity from the medical records for each participant. The irregularity was quantified using peer assessing rating index.¹⁰ The time wearing retainers before refinement was included in the treatment duration of CAT patients.

The digital panoramic radiographs were used to evaluate the root length before and after treatment. All radiographs were taken using the same digital orthopantomograph machine (Veraviewepocs, Morita, Kyoto, Japan) by professional radiologists. The panoramic images were obtained and reviewed on the picture archiving and communication system (Marosis Enterprise PACS; Infinitt Healthcare, Seoul, Korea). The innate tool with an accuracy of 0.01 mm was employed to measure the crown and root lengths of incisors as previously reported.¹¹ In brief, the mesial and distal cemento-enamel-junction was connected by a straight line. The lengths of crown and root were defined as the greatest distance from the cemento-enamel-junction line to incisal edge and root apex respectively (Fig. 1). The

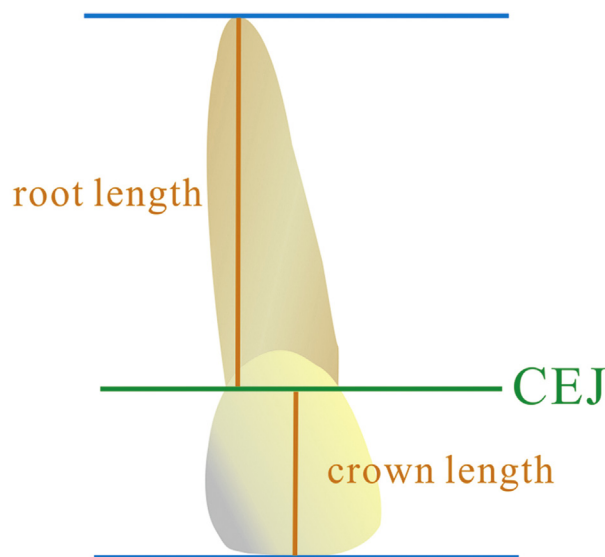


Figure 1 Measurement using panoramic radiograph. The cemento-enamel-junction (CEJ) line was determined by the connection of mesial and distal CEJ. The lengths of root and crown were measured as the distance from root apex and incisal edge to CEJ line respectively.

measurements were performed by the same clinician blinding to the random sequence of panoramic radiographs. Though errors from distortions or magnifications were hardly to be avoided, previous study suggested that the root-crown-ratio (RCR) could remain stable in different panoramic radiographs.^{11,12} Thus in the present study, the EARR was calculated as follows: $EARR = 1 - RCR$ after treatment/RCR before treatment. The reliability of measurements was evaluated via statistically analyzing the assessments of 20 randomly selected panoramic radiographs by the same investigator after a 10-day interval.

Statistical analysis

The t test was used to compare the continuous data. The chi-square test was performed to compare the categorical variables. The intraclass correlation coefficient generated by kappa statistics was adopted to assess the agreement between two measurements. The spearman correlation analysis was applied to investigate the correlation between potential predictors and the amount of EARR. The *p* value less than 0.05 was considered as the indicator of statistical significance.

Results

The intraclass correlation ranged from 0.87 to 0.96 for the root length measurements, and from 0.84 to 0.93 for the crown length measurements. The coefficients indicated the high reproducibility and reliability of measures with panoramic radiographs.

Eighty patients (60 females and 20 males; average age: 22.54 years) were enrolled in this investigation. The demographic characteristics and clinical variables of the participants were summarized in Table 1. The baseline information of patients receiving two types of treatment was well matched. No significant difference was detected

Table 1 Demographic and clinical information of participants in clear aligner therapy (CAT) group and fixed orthodontic treatment (FOT) group.

Characteristics	CAT (n = 40)	FOT (n = 40)	P value
Age	21.80 ± 5.11	23.28 ± 5.60	0.222
Gender			
Female	31 (77.5%)	29 (72.5%)	0.317
Male	9 (22.5%)	11 (27.5%)	
Skeletal pattern			0.589
Class I	34 (85%)	32 (80%)	
Class II	5 (12.5%)	5 (12.5%)	
Class III	1 (2.5%)	3 (7.5%)	
Pretreatment PAR index	21.90 ± 6.69	23.33 ± 7.97	0.389
Posttreatment PAR index	5.33 ± 3.39	4.30 ± 2.483	0.127
PAR index reduction	16.57 ± 5.76	19.03 ± 7.68	0.116
Treatment duration (month)	22.08 ± 4.51	20.83 ± 5.29	0.259

PAR = peer assessment rating.

Table 2 Amount of external apical root resorption (EARR) by tooth type.

	CAT (%)	FOT (%)	P value
Maxillary central incisor (n = 160)	5.67 ± 2.92	6.80 ± 3.90	0.039*
Maxillary lateral incisors (n = 160)	5.32 ± 3.08	7.08 ± 3.86	0.002*
Mandibular central incisors (n = 160)	5.36 ± 2.31	6.51 ± 3.52	0.016*
Mandibular lateral incisors (n = 160)	4.18 ± 2.71	7.48 ± 3.34	0.001*
Overall (n = 640)	5.13 ± 2.81	6.97 ± 3.67	0.001*

* indicates statistical significance.

CAT = clear aligner therapy; FOT = fixed orthodontic treatment.

between the distribution of gender, age, skeletal pattern, treatment duration, pretreatment or posttreatment peer assessment rating index between CAT and FOT group.

A total of 640 teeth were analyzed for root length alteration in this study, 320 in each group respectively. The mean value of EARR in CAT group was $5.13 \pm 2.81\%$, which was significantly less than that of FOT group ($6.97 \pm 3.67\%$). Similarly, maxillary central incisors, maxillary lateral incisor, mandibular central incisor and mandibular lateral incisor of CAT group had less EARR than the counterparts of FOT group respectively (Table 2).

Among the tested potential predictors, treatment duration was found to positively correlate with the amount of EARR in two treatment modalities. Variables including gender, age, skeletal pattern and degree of malocclusion showed no significant correlation with EARR (Table 3).

Discussion

Though EARR is difficult to be prevented due to the multifactorial etiology, innovations in orthodontic techniques and materials might reduce its occurrence.¹³ CAT has been widely applied in orthodontic clinics in recent years, but study concerning its influence on root resorptions is limited. This retrospective investigation, to the best of our knowledge, is the first study comparing the amount of EARR in non-extraction patients receiving CAT and FOT.

Previous studies suggested the incisors are more vulnerable to EARR during orthodontic treatment than other types of tooth.¹⁴ Furthermore, it is difficult to precisely measure the root length of multi-rooted teeth in panoramic radiographs. Therefore only the incisors were investigated in the present study. Our results showed the EARR in non-extraction patients using CAT was less than those using FOT (Table 2), suggesting a superiority of CAT in relieving teeth from root resorption. This finding is inconsistent with a recently published study indicating no difference in the EARR between patients using removable aligners and fixed appliances.¹⁵ However, it should be noted that both extraction and non-extraction patients were involved and only the tooth with highest EARR value was recruited to the statistical analysis process in the aforementioned trial.¹⁵ The substantial heterogeneity in study designs could

Table 3 Correlations between the amount of external apical root resorption (EARR) and contributory factors.

	EARR in CAT (n = 320)	EARR in FOT (n = 320)
Age (y)		
r	0.1342	-0.2420
P value	0.4090	0.1324
Gender		
r	0.2278	0.1040
P value	0.0717	0.5229
Skeletal pattern		
r	0.1494	0.0521
P value	0.3576	0.7496
Pretreatment PAR index		
r	-0.0164	0.0440
P value	0.9198	0.7876
Posttreatment PAR index		
r	-0.0638	-0.0748
P value	0.6956	0.6462
PAR index reduction		
r	0.1291	0.0567
P value	0.4272	0.7284
Treatment duration (month)		
r	0.3651	0.3827
P value	0.0205*	0.0148*

* indicates statistical significance.

CAT = clear aligner therapy; FOT = fixed orthodontic treatment; PAR = peer assessment rating.

contribute to the different results. Sawicka et al. found the continuous force induced more resorption activity and thus led to more severe root resorption in human premolars than discontinuous force.¹⁶ Aras et al. also observed significantly higher incidence of EARR in teeth subjected to continuous force than intermittent force.¹⁷ In contrast to the continuous force produced by fixed appliances, force applied to teeth in CAT is discontinuous since aligners are suggested to be removed during food consumption and oral health care. Moreover, 26 out of the 40 CAT patients involved in this investigation underwent refinement. The wear of retainers before refinement frees the dentition from intense mechanical stimulations and could allow the root repair after resorption.^{18,19} The mechanical stimulation regimens of 2 modalities could be the main reason for the different amount of EARR in the present study.

The aligner therapy used the CAD/CAM stereolithographic technology to forecast the tooth movement and fabricate sequential thermoplastic aligners accordingly. Each step of aligner is prescribed to move a tooth or a small group of teeth 0.2 mm in approximate 10–14 days.²⁰ Thus the tooth movement in CAT is programmed to a comparatively slower rate comparing to fixed appliances (about 1 mm per month).²¹ The slow tooth movement could be the indicator of less absorptive activity in periodontium, which might contribute to the merit of CAT in reducing EARR.⁶ Interestingly, though CAT is less efficient than FOT in most types of tooth movement, the treatment durations of two systems in the present study are similar (Table 1). Moreover, a recent study reported the duration of Invisalign

treatment was significantly shorter than conventional fixed appliances.²² In most cases, several months are required for the delicate adjustment to obtain appropriate occlusion for the delicate adjustment to obtain appropriate occlusion for FOT patients due to the inaccurate positioning of brackets and the mismatch between preadjusted brackets and tooth shapes, which is normally avoided in CAT since the tooth movement was precisely planned. It should also be noted that teeth often undergo back-and-forth movement in FOT, while this rarely happens in CAT. The back-and-forth movement could not only pose higher risk of EARR to patients but also extend the treatment duration.²³ Furthermore, the frequent application of interproximal enamel reduction in CAT could reduce the crowding severity and therefore decrease the amount of tooth movement. Due to the foregoing reasons, the treatment time of CAT is comparable to FOT even with a slower tooth movement velocity, at least in non-extraction cases.

Recently, cone-beam computed tomography (CBCT) has been widely applied to dental clinics and considered as a more reliable tool to diagnose external root resorption than panoramic radiographs.²⁴ CBCT provides three-dimensional data and enables clinicians to evaluate the root resorption occurring at the lingual and buccal surface, which is not available in periapical radiograph and may result in the underestimation of EARR.²⁵ However, panoramic radiographs were used to evaluate the root resorptions at root apex in the present study, thus the influence of deficiency in evaluating the lingual or buccal root surface could be reduced. Moreover, we adopted the relative changes of root-crown-ratio rather than the absolute values as the outcomes. Except few patients involving selected grinding in incisors, the tooth crown lengths remain almost stable after orthodontic treatment and the reliability of the relative change in root-crown-ratio could be acceptable even different degrees of distortion and magnification exist between the panoramic radiographs before and after treatment.^{11,12}

Among the potential predictors of EARR, treatment duration was found to positively correlate with the amount of EARR in both modalities (Table 3). The association between longer treatment duration and more severe root resorption is supported by previous studies.^{26,27} The occurrence of EARR is resulted from cumulative dissolution of cement and dentine, which is affected by the duration of mechanical stimulations.²⁸ Therefore, more appropriate treatment plans and better compliance are needed to shorten the treatment duration and thus protect teeth from root resorption. None of the other tested variable including gender, age, and degree of irregularity was observed to affect EARR (Table 3).

In the present study, no difference in the peer assessment rating scores of participants between two groups were detected either prior to or after treatment, which is consistent with a recent study comparing the efficiency of Invisalign treatment and conventional fixed appliances.²² We also evaluated the reduction of irregularity after treatment and found similar results between two groups, thus the merit of CAT in reducing EARR amount seems not to be caused by different tooth movement amounts, which indicates the robustness of current study.

The type of tooth movement could affect the rate of root resorption. EARR in teeth with tipping movement is more pronounced than bodily movement.²⁹ Intrusion of

teeth could result in four times more EARR than extrusion.³⁰ However, this issue has not been reported in present study because it is difficult to measure the type of tooth movement accurately using medical records and intraoral photographs in patients with FOT.

Since CAT has not been widely introduced until recent years, a retrospective rather than prospective design is adopted in present study. The rigorous inclusion criteria, similar demographic and clinical characteristics of patients in two groups, and the blinding method in measurements could restrict the influence of innate deficiency of retrospective study. Extraction cases are not involved in present study due to the comparatively high incidence of tip and torque loss during extraction space closure in the past aligner treatment, which has been greatly improved in current CAT. Therefore, prospective studies comparing the amount of EARR between CAT and FOT by CBCT images, especially focusing on extraction cases, are needed to further confirm the results of present study.

Conflicts of interest

There is no potential source of conflict of interest.

Acknowledgement

This work was supported by the National Nature Science Foundation of China Nos.11372202 and 31470904.

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