Am J Transl Res 2021;13(6):6221-6228
www.ajtr.org /ISSN:1943-8141/AJTR0126502

Original Article

A comparison of the effects of two orthodontic techniques in the orthodontic treatment of sagittal skeletal patterns

Tingting Mai[1*], Xiaoju Guan[2*], Xiaohong Li[3]

*[1]Department of Stomatology, Haikou Longhua Mai Tingting Dental Clinic, Haikou 570105, Hainan, China; [2]Department of Stomatology, Tianjin Women and Children Health Center, Tianjin 300000, China; [3]Department of Stomatology, Haikou Third People's Hospital, Haikou 570105, Hainan, China. *Equal contributors and co-first authors.*

Received November 18, 2020; Accepted January 7, 2021; Epub June 15, 2021; Published June 30, 2021

Abstract: Objective: To compare the differences in the amount of dental root resorption (DRR) measured using different orthodontic techniques in the orthodontic treatment of patients with different sagittal skeletal patterns. Methods: Ninety-three patients undergoing orthodontic treatment were randomly divided into group A (n=46) and group B (n=47). Group A was treated with bracketless invisible orthodontics and group B was treated using the self-ligating fixed orthodontic technique. Cone beam computed tomography (CBCT) was used to measure the amount of DRR in the patients with different sagittal skeletal patterns receiving the orthodontic treatment. Results: After the treatment, the amounts of DRR in the maxillary and mandibular canines in both groups were lower than they were in the other 4 tooth positions ($P < 0.05$). The amount of DRR in the maxillary and mandibular canines in the patients with skeletal class I in both groups was lower than it was at the other four tooth positions ($P < 0.05$). The amount of DRR in the maxillary central incisors and maxillary canines in the patients with skeletal class II in group A was higher than it was in group B, but the amount of DRR in the mandibular canines in group A was lower than it was in group B ($P < 0.05$). The amounts of DRR at the six tooth positions in the patients with skeletal class III in group A were higher than the amounts in group B ($P < 0.05$). Conclusion: DRR occurs in patients with different sagittal skeletal patterns undergoing the two orthodontic techniques in the orthodontic treatment, but there are differences in the amount of DRR among the patients with different sagittal skeletal patterns receiving the orthodontic treatment. Clinically, the orthodontic method should be selected based on the type of patient.

Keywords: Sagittal skeletal patterns, orthodontic treatment, orthodontic technique, dental root resorption, cone beam CT, measurement

Introduction

With the advances in economic and social development, people are increasingly pursuing an attractive appearance. As a result, more and more adults are undergoing orthodontic treatment. As medical technologies progress, bracketless invisible appliances, which are more comfortable and good-looking in appearance and can be freely taken off or worn, have been extensively used to replace conventional ligating brackets. Therefore, bracketless invisible appliances have been widely recognized by physicians and patients [1].

Clinical findings show that with any orthodontic technique, the normal overbite of the anterior teeth and the good occlusion of the posterior teeth can be ensured, and the appearance can be significantly improved, but the patients may have adverse reactions (such as mouth ulcers, painful teeth, and dental caries) [2]. Some studies even suggest that dental root resorption (DRR) occurs after using appliances [3, 4]. Previous studies have found that there are two main causes leading to DRR, namely, treatment-related and patient-related causes. The former includes the type of appliance, the start time, the force magnitude, the forcing method, and the distance and direction of the tooth movement, and the latter includes age, the tooth position, heredity, the root shape, and the severity of the malocclusion deformity [5, 6]. In addition, due to the recent clinical application of bracketless invisible appliances, there are few studies on DRR after treatment with the bracketless invisible appliances. There are many studies on DRR after fixed appliance treatments [7, 8], but there are very few studies on DRR after treating patients with different sagittal skeletal patterns using fixed appliances or bracketless invisible appliances. This study takes this as a starting point for research, which is innovative.

Therefore, a total of 93 patients undergoing orthodontic treatment in the Department of Stomatology were recruited as the study cohort, and they underwent cone beam computed tomography (CBCT) before and after their orthodontic treatment. The DRR of the patients with different sagittal skeletal patterns treated with different appliances was analyzed.

Materials and methods

Data

A total of 93 patients undergoing orthodontic treatment in Haikou Third People's Hospital were recruited as the study cohort. Inclusion criteria: Patients for whom CBCT images were taken before and after the orthodontic treatment, and clear images were obtained; patients in whom, before the orthodontic treatment, the tooth root had developed; patients without DRR; patients whose dentition was slightly or moderately crowded; patients in whom cutting was not implemented in orthodontics; patients without the need for tooth extraction. The patients voluntarily signed the informed consent forms. The study was reviewed and approved by the Haikou Third People's Hospital. Exclusion criteria: patients whose dentition had severe crowding; patients who had undergone a tooth extraction; patients with a past history of orthodontic treatment or tooth and endodontic treatment; patients with a significant bending and overlapping of a tooth root.

Methods

Group A: Silicone rubber impressions were taken before the surgery, the orthodontic plan was formulated based on the silicone rubber impression, and a bracketless invisible appliance was made. The physician treated the dental surface, adhered the accessories of the bracketless invisible appliance, instructed the patients to learn how to remove and wear the appliance, told them to wear the appliance for no less than 22 hours every day and to replace their braces every two weeks, and informed the patients of the precautions for hanging the leather loop and chewing. The patients were informed of the follow-up times and were instructed to maintain their oral hygiene. After the treatment, the attachments were removed, the dental surfaces were polished, and the model was taken as the retaining appliance.

Group B: A fixed, self-ligating appliance was selected. The physician treated the dental surfaces, adhered the brackets of the maxillary and mandibular dentition in sequence, replaced the thin orthodontic archwires with the thick orthodontic archwires in sequence, and adjusted the intermaxillary relationship in accordance with the rubber band with an appropriate diameter at the thickest stage. The patients were instructed to perform a follow-up visit once a month and maintain oral hygiene every day. After the treatment, the brackets and archwires were removed, the dental surface was polished, and the model was taken as a retaining appliance.

Observational indices

CBCT measurement [9]: All the patients received CBCT radiographs using the same kava, intensity, and condition. During the CBCT scans, the patients were instructed to keep sitting upright, with the orbital plane parallel to the ground and the upper and lower teeth slightly bitten in the middle position. The CBCT was performed by a radiologist. The quantitative analysis method was selected to assess the amount of DRR. The DICOM files were imported into Invivo Dental 5. The 3D images were reconstructed using the Reorientation in Section module. The axial, sagittal, and coronal sections were adjusted, the image for the longest dental root was determined, and the dental root length was measured.

Judgment of DRR: The CBCT information was read, and the four hard tissue markers and the four tooth markers were marked on the Super Ceph module in Invivo Dental 5. The following bone tissue measurements were taken [10]: SNA°: the Sella Nasion A point (SNA) angle measures the anterior-posterior position of the maxilla in relation to the cranial base. SNB°:

Table 1. Comparison of the general data between the two groups ($\overline{x}$ ± s)/[n (%)]

Data		Group A (n=46)	Group B (n=47)	*t*/X^2	*P*
Gender	Male	26 (56.52)	24 (51.06)	0.279	0.598
	Female	20 (43.48)	23 (48.94)		
Age (years)		26.83±5.79	28.45±6.37	1.283	0.202
Therapeutic duration (years)		1.85±0.37	1.91±0.40	0.751	0.455
Sagittal skeletal patterns	Skeletal class I	15 (32.61)	12 (25.53)	1.634	0.442
	Skeletal class II	19 (41.30)	17 (36.17)		
	Skeletal class III	12 (26.09)	18 (38.30)		

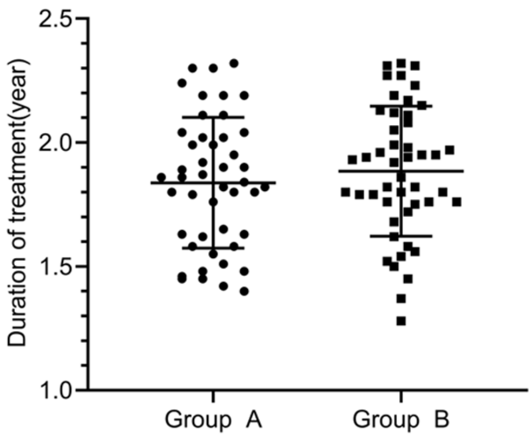

Figure 1. Mean therapeutic duration. There was no significant difference in the mean durations of the orthodontic treatment between groups A and B ($P > 0.05$).

the Sella Nasion B point (SNB) angle measures the antero-posterior position of the mandible in relation to the anterior cranial base. ANB°: The A point, nasion, B point (ANB) angle measures the relative position of the maxilla to the mandible. In accordance with the results of ANB° in the bone tissue measurements, the sagittal skeletal patterns were classified [11]: Class I skeletal pattern: 0° < ANB < 5°, Class II skeletal pattern: ANB > 5°, and Class III skeletal pattern: ANB < 0°. The tooth measurement items were as follows [12]: A represents the palatal (lingual) enamel-cementoenamel junction; B represents the labial enamel-cementoenamel junction; C represents the apical point; line a represents the connecting line between the labial and palatal (lingual) enamel-cementoenamel junction; line b represents the parallel line of line a passing through the apical point, and CD represents the vertical distance between line a and b, namely, the dental root length.

All the patients were measured by the same physician before and after the orthodontic treatment, three times a week. The mean of the three measurements was taken and recorded.

Statistical analysis

SPSS 23.0 was used for the data collation and statistical analysis. The measurement data were expressed as ($\overline{x}$ ± s) and compared using *t* tests. The multi-point comparisons were analyzed using ANOVA, and determined using F tests. The graphs were made with GraphPad Prism 8. $P < 0.05$ indicated a significant significance.

Results

General data

There were no significant differences in the male-to-female ratio, the mean age, or the therapeutic durations in groups A and B ($P > 0.05$), and there were no significant differences in the ratios of sagittal skeletal class I, class II, or class III in groups A and B ($P > 0.05$) (**Table 1** and **Figure 1**).

Amount of DRR in group groups A and B

After the treatment, DRR occurred in the maxillary central incisors, the maxillary lateral incisors, the maxillary canines, the mandibular central incisors, the mandibular lateral incisors, and the mandibular canines in groups A and B. The amounts of DRR in the maxillary and mandibular canines in groups A and B were lower than they were at the other four teeth positions ($P < 0.05$). There were no statistically significant differences in the amounts of DRR in the maxillary central incisors, the maxillary lateral incisors, the maxillary canines, the mandibular central incisors, the mandibular lateral

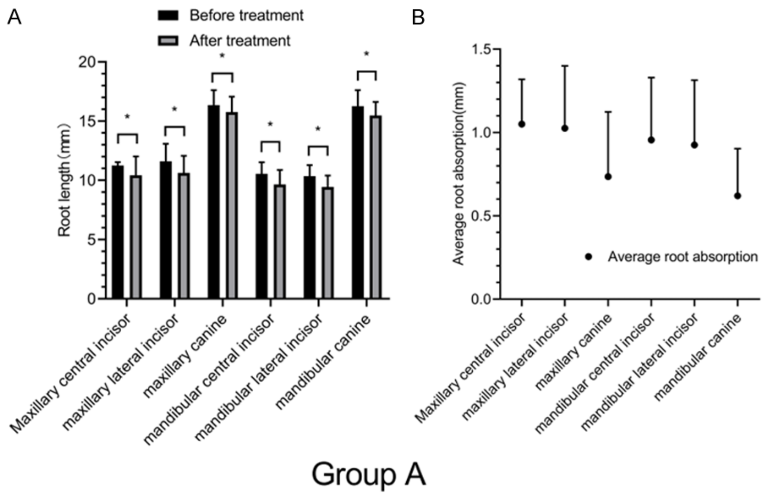

Figure 2. The amount of DRR in group A. Compared with before the treatment, the dental root lengths at the six tooth positions in group A were significantly reduced after the treatment (*P* < 0.05) (A). (B) shows the mean amount of DRR in group A. * indicates a comparison between the two groups' root lengths before and after the treatment (*P* < 0.05).

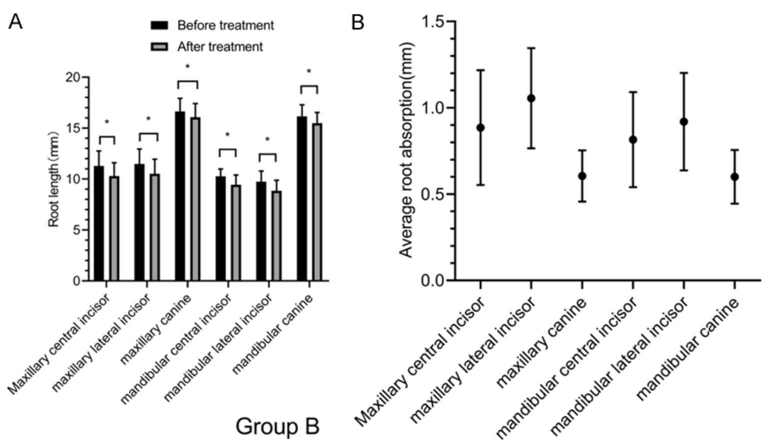

Figure 3. The amount of DRR in group B. Compared with their lengths before the treatment, the dental root lengths at the six tooth positions in group B were significantly reduced after the treatment (*P* < 0.05) (A). (B) shows the mean amount of DRR in group B. * indicates a comparison between the two groups (*P* < 0.05).

incisors, or the mandibular canines in groups A and B (*P* > 0.05) (**Figures 2-4**).

The amount of DRR in the sagittal skeletal class I patients ingroups A and B

Regarding the sagittal skeletal class I patients, the amount of DRR in their maxillary central incisors, maxillary lateral incisors, maxillary canines, mandibular central incisors, mandibular lateral incisors and mandibular canines in group B was higher than it was in group A (*P* < 0.05). The amount of DRR in the mandibular central incisors was significantly higher than it was at the other five teeth positions in group A (*P* < 0.05), and the amount of DRR in the maxillary central incisors was significantly higher than it was at the other five teeth positions in group B (*P* < 0.05). The amount of DRR in the maxillary and mandibular canines was lower than it was at the other four teeth positions in groups A and B (*P* < 0.05) (**Figure 5**).

The amount of DRR in the sagittal skeletal class II patients in groups A and B

Regarding the sagittal skeletal class II patients, there was no significant difference in the amount of DRR in the maxillary lateral incisors, mandibular central incisors, or the mandibular lateral incisors between groups A and B (*P* > 0.05). The amount of DRR in the maxillary central incisors and the maxillary canines in group A was higher than it was in group B, but the amount of DRR in the mandibular canines in group A was lower than it was in group B (*P* < 0.05). The amount of DRR in the mandibular canines was significantly lower than it was in the other five teeth positions in group A (*P* < 0.05), and the amount of DRR in the maxillary canines was significantly lower than it was in the other five teeth positions in group B (*P* < 0.05) (**Figure 6**).

The amount of DRR in the sagittal skeletal class III patients in groups A and B

Regarding the sagittal skeletal class III patients, the amount of DRR in the maxillary central incisors, the maxillary lateral incisors, the maxillary canines, the mandibular central incisors, the mandibular lateral incisors, and the mandibular

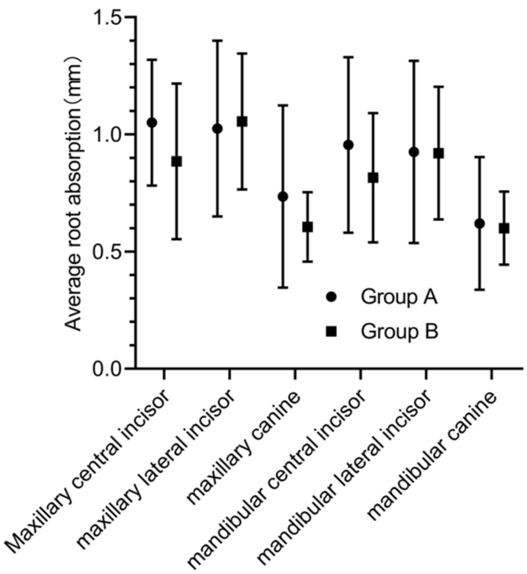

Figure 4. Comparison of the amount of DRR. There was no significant difference in the amount of DRR at the 6 tooth positions in groups A and B after the treatment ($P > 0.05$).

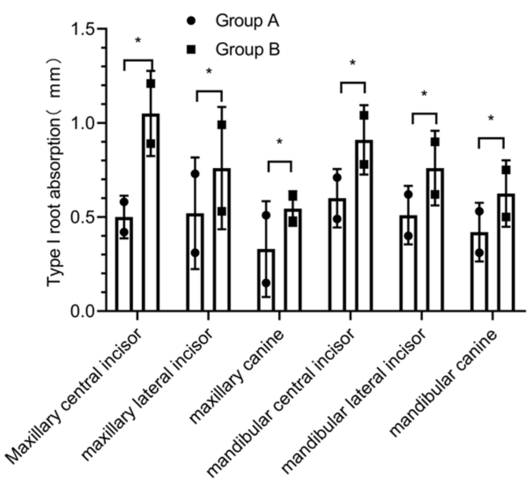

Figure 5. The amount of DRR in the skeletal class I patients. The amount of DRR at the 6 tooth positions in the skeletal class I patients in group B was higher than it was in group A ($P > 0.05$). * indicates a comparison between the two groups ($P < 0.05$).

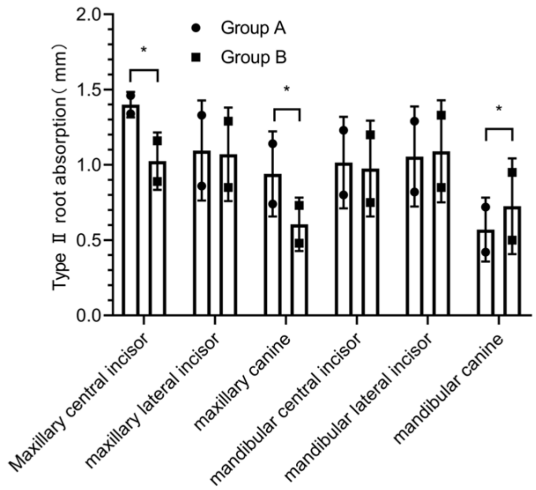

Figure 6. The amount of DRR in the skeletal class II patients. The amounts of DRR in the maxillary central incisors and the maxillary canines of the skeletal class II patients in group A were higher than they were in group B, but the amount of DRR in the mandibular canines of the skeletal class II patients in group A was lower than it was in group B ($P < 0.05$). There was no significant difference in the amounts of DRR in the maxillary lateral incisors, the mandibular central incisors, or the mandibular lateral incisors of the skeletal class II patients between groups A and B ($P > 0.05$). * indicates a comparison between the two groups ($P < 0.05$).

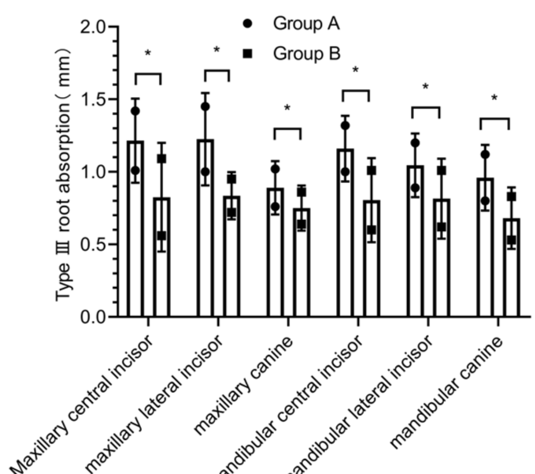

Figure 7. The amount of DRR in the skeletal class III patients. The amounts of DRR at the 6 tooth positions in the skeletal class III patients in group B were lower than they were in group A ($P > 0.05$). * indicates a comparison between the two groups ($P < 0.05$).

canines in group A was higher than it was in group B ($P < 0.05$). The amount of DRR in the maxillary canines was significantly lower than it was in the other five tooth positions in groups A and B ($P < 0.05$) (**Figure 7**).

Discussion

Previous studies have indicated that periapical photographs or pantomograms are used to qualitatively assess the degree of DRR, but these photographs are two-dimensional, so the differences in the shooting angles may lead to overlapping images, significantly affecting the image results [13, 14]. Therefore, it is some-times impossible to accurately reflect the specific tissue structures of the alveolar bones and teeth. In this study, the CBCT method has a higher image resolution, leading to higher definition images. Therefore, the tiny amount of concave resorption on the dental root surface can be accurately detected [15]. A comparative study revealed that compared with the CBCT method, the intraoral periapical photographs show more significant errors in measuring the dental root length [16]. Clinical findings show that the margin of error using the CBCT method is only about 0.3 mm, but the margin of error using intraoral periapical photographs is about 2.5 mm [17]. In this study, sagittal skeletal class I, II, and III patients were treated with bracketless invisible appliances and fixed self-ligating appliances. CBCT was used to measure and compare the amount of DRR before and after the orthodontic treatment. It was found that groups A and B showed different degrees of DRR. The amount of DRR of the anterior teeth of sagittal skeletal class I patients in group A was lower than it was in group B, but the amount of DRR in the maxillary anterior teeth of sagittal skeletal class II patients and the amount of DRR of the maxillary and mandibular anterior teeth of sagittal skeletal class III patients in group A were higher than they were in group B. One study also reported that in the orthodontic treatment of patients with different sagittal skeletal patterns, two orthodontic techniques show the differences in the amount of DRR, and research on sagittal skeletal class III patients showed that the amount of DRR from bracketless invisible appliances was higher than it was from fixed self-ligating appliances [18].

Generally, a smaller orthodontic force leads to a smaller amount of DRR. The study basically agreed that the force magnitude given during orthodontic tooth movement must be lower than the periodontal capillary pressure, and the force should be kept gentle and continuous, so that the periodontal membrane reactions can be stimulated without damaging the periodontal membrane to ensure the expected movement of teeth [19]. Both of the appliances adopted in this study have light force correction characteristics, but there are differences in the principles of orthodontic treatment between the two appliances. The bracketless invisible appliance uses thrust to act on the teeth, and there is a slight deviation between the tooth positions set by all appliances and the actual positions of the patients' teeth. After the teeth are wrapped with an appliance, there is a change in shape, and the resilience formed by its material pushes the teeth into a preset position. Due to the special way of applying force, it is possible to move the molars to the far and middle positions [20, 21]. The amount of DRR in group A was lower than it was in group B. With the intermaxillary traction being excluded, this may be due to the fact that the appliance adopted in group A can locally expand the dental arch, and the interval of 2-3 mm obtained by expanding the arch can relieve the slight crowding of the anterior teeth. Therefore, the DRR caused by lip inclination for alleviating the crowding of the upper and lower anterior teeth can be reduced [22]. A similar conclusion was reached in a previous study, which may be due to the fact that the bracketless invisible appliance can be freely taken off or worn, so that the force exerted on the teeth is intermittent, and the intermittent tooth movement enables the high-quality periodontal cementum to be reconstructed [23]. The findings of another study also showed that the amount of DRR with implant anchorage is significantly higher than it is using conventional anchorage [(1.38±0.49) mm vs. (0.68±0.23) mm] [24]. However, implant anchorage was not implemented in the two groups. Therefore, there was no such influence. In this study, the amount of DRR in the mandibular teeth of sagittal skeletal class II patients in group B was higher than it was in the sagittal skeletal class I and III patients. This may be due to the increased amount of DRR in deep overbite, with skeletal class II patients treated with the fixed appliance and the opening the occlusion using an intrusive arch [25].

In summary, DRR occurs in patients with different sagittal skeletal patterns who receive the two orthodontic techniques in their orthodontic treatment. There are differences in the amount of DRR among the patients with different sagittal skeletal patterns undergoing orthodontic treatment. Clinically, the orthodontic methods should be selected according to the type of patient, so as to control the amount of DRR to the greatest extent possible. Regarding the control of the amount of DRR, physicians should conduct a comprehensive and systematic examination before the orthodontic treatment, identify the DRR risk factors beforehand, comprehensively analyze the measured amount of DRR, and comprehensively consider all factors to determine the most appropriate regimen. For patients with different sagittal skeletal patterns, the appliance should be selected according to experience and to the patients' conditions, and the target position should be determined individually, so as to shorten the length of the orthodontic treatment to the greatest extent possible. In addition, from a macroscopic point of view, the properties of the materials of bracketless invisible appliances should be improved continuously to help reduce the amount of DRR. There are also some insufficiencies in this study. The study only included a small number of cases. Only subjects without tooth extractions were analyzed, so the statuses of tooth extraction patients were not studied. In addition, whether there were differences in the ages and genders of the patients with the same sagittal skeletal patterns treated with the same appliances was not analyzed. All these conditions need further investigation in future studies.

Disclosure of conflict of interest

None.

Address correspondence to: Tingting Mai, Department of Stomatology, Haikou Longhua Mai Tingting Dental Clinic, No. 29, Longhua Two Road, Hua District, Haikou 570105, Hainan, China. Tel: +86-0898-66230618; E-mail: mai306346240@163.com

References

[1] Yang L, Yin G, Liao X, Yin X and Ye N. A novel customized ceramic bracket for esthetic orthodontics: in vitro study. Prog Orthod 2019; 20: 39.
[2] Mazzoleni S, De Stefani A, Bordin C, Balasso P, Bruno G and Gracco A. Dental water jet efficacy in the plaque control of orthodontic patients wearing fixed appliance: a randomized controlled trial. J Clin Exp Dent 2019; 11: e957-e963.
[3] Janson G, Niederberger A, Garib DG and Caldas W. Root resorption in Class II malocclusion treatment with Class II elastics. Am J Orthod Dentofacial Orthop 2016; 150: 585-591.
[4] Jadhav GR, Mittal P, Patil V, Kandekar P, Kulkarni A, Shinde S, Syed S and Elahi S. Accuracy of different apex locators in teeth with simulated apical root resorption: an in vitro study. Folia Med (Plovdiv) 2018; 60: 624-631.
[5] Consolaro A and Bittencourt G. Why not to treat the tooth canal to solve external root resorptions? Here are the principles! Dental Press J Orthod 2016; 21: 20-25.
[6] Li H. Risk during orthodontic treatment of the impacted teeth. Zhonghua Kou Qiang Yi Xue Za Zhi 2019; 54: 819-824.
[7] Yi J, Li M, Li Y, Li X and Zhao Z. Root resorption during orthodontic treatment with self-ligating or conventional brackets: a systematic review and meta-analysis. BMC Oral Health 2016; 16: 125.
[8] Elhaddaoui R, Qoraich HS, Bahije L and Zaoui F. Orthodontic aligners and root resorption: a systematic review. Int Orthod 2017; 15: 1-12.
[9] Gurler G, Delilbasi C and Delilbasi E. Investigation of impacted supernumerary teeth: a cone beam computed tomograph (cbct) study. J Istanb Univ Fac Dent 2017; 51: 18-24.
[10] Wang XC, Wang L, Gu Y, Wang YH and Zhao CY. Cone-beam CT analysis on the treatment efficacy in the vertically impacted maxillary central incisors. Zhonghua Kou Qiang Yi Xue Za Zhi 2019; 54: 739-744.
[11] Verdenik M and Ihan Hren N. Three-dimensional facial changes correlated with sagittal jaw movements in patients with class III skeletal deformities. Br J Oral Maxillofac Surg 2017; 55: 517-523.
[12] Capitaneanu C, Willems G, Jacobs R, Fieuws S and Thevissen P. Sex estimation based on tooth measurements using panoramic radiographs. Int J Legal Med 2017; 131: 813-821.
[13] Xie XY and Zhang ZY. Diagnostic accuracy of cone beam computed tomography and eight-slice computed tomography for evaluation of external root reabsorption. Beijing Da Xue Xue Bao Yi Xue Ban 2012; 44: 628-632.
[14] Zinge PR and Patil J. Comparative evaluation of effect of rotary and reciprocating single-file systems on pericervical dentin: a cone-beam computed tomography study. J Conserv Dent 2017; 20: 424-428.
[15] Patel S, Brown J, Pimentel T, Kelly RD, Abella F and Durack C. Cone beam computed tomography in Endodontics - a review of the literature. Int Endod J 2019; 52: 1138-1152.
[16] Lauber R, Bornstein MM and von Arx T. Cone beam computed tomography in mandibular molars referred for apical surgery. Schweiz Monatsschr Zahnmed 2012; 122: 12-24.
[17] Weissman J, Johnson JD, Anderson M, Hollender L, Huson T, Paranjpe A, Patel S and Cohenca N. Association between the presence of apical periodontitis and clinical symptoms in endodontic patients using cone-beam com-

puted tomography and periapical radiographs. J Endod 2015; 41: 1824-1829.
[18] Gandolfi MG, Taddei P, Siboni F, Modena E, Ciapetti G and Prati C. Development of the foremost light-curable calcium-silicate MTA cement as root-end in oral surgery. Chemical-physical properties, bioactivity and biological behavior. Dent Mater 2011; 27: e134-157.
[19] Gandolfi MG, Ciapetti G, Taddei P, Perut F, Tinti A, Cardoso MV, Van Meerbeek B and Prati C. Apatite formation on bioactive calcium-silicate cements for dentistry affects surface topography and human marrow stromal cells proliferation. Dent Mater 2010; 26: 974-992.
[20] Waring D, McMullin A and Malik OH. Invisible orthodontics part 3: aesthetic orthodontic brackets. Dent Update 2013; 40: 555-556, 559-561, 563.
[21] McMullin A, Waring D and Malik O. Invisible orthodontics part 2: lingual appliance treatment. Dent Update 2013; 40: 391-4, 397-8, 401-2.
[22] Baron P. Invisible and almost invisible orthodontic appliances. Orthod Fr 2014; 85: 59-91.
[23] Bräutigam M, Wilmes B, Tarraf NE and Drescher D. Surgically assisted rapid maxillary expansion in lingual orthodontics - optimizing of coupling and timing: best oral presentation from the 21st Meeting of German Society of Lingual Orthodontics. Head Face Med 2018; 14: 16.
[24] Lu JJ, Qi T and Ge ZL. A scanning electron microscopic study of root surface following mini-implant anchorage for maxillary incisors intrusion. Shanghai Kou Qiang Yi Xue 2009; 18: 406-410.
[25] Iglesias-Linares A, Sonnenberg B, Solano B, Yañez-Vico RM, Solano E, Lindauer SJ and Flores-Mir C. Orthodontically induced external apical root resorption in patients treated with fixed appliances vs removable aligners. Angle Orthod 2017; 87: 3-10.