AJO-DO

Effects of Twin-block vs sagittal-guidance Twin-block appliance on alveolar bone around mandibular incisors in growing patients with Class II Division 1 malocclusion

Chun-xi Zhang, Gang Shen, Yu-jun Ning, Hong Liu, Yi Zhao, and Dong-xu Liu
Jinan, China

Introduction: The purpose of this study was to comparatively evaluate the effects of Twin-block (TB) appliance and sagittal-guidance Twin-block (SGTB) appliance on alveolar bone around mandibular incisors in growing patients with Class II Division 1 malocclusion, using cone-beam computed tomography. **Methods:** The sample consisted of 25 growing patients with Class II Division 1 malocclusion (14 boys and 11 girls, mean age 11.92 ± 1.62 years) and was randomly distributed into the TB group (n = 13) and the SGTB group (n = 12). The treatment duration was 11.56 ± 1.73 months. Pretreatment (T1) and posttreatment (T2) cone-beam computed tomography scans were taken in both groups. Height, thickness at apex level, and volume of the alveolar bone around mandibular left central incisors were measured respectively on labial and lingual side, using Mimics software (version 19.0; Materialise, Leuven, Belgium). Based on the stable structures, 3-dimensional (3D) registrations of T1 and T2 models were taken to measure the sagittal displacement of incisors. Intragroup comparisons were evaluated by paired-samples *t* tests and Wilcoxon tests. Independent-samples *t* tests and Mann-Whitney U tests were used for intergroup comparisons. **Results:** In both groups, alveolar bone height and volume on the labial side of the incisors significantly decreased after treatment ($P < 0.05$). Lingual alveolar bone height, lingual and total alveolar bone volume, labial, lingual and total alveolar bone thickness showed no significant difference between T1 and T2 ($P > 0.05$). In both groups the incisors tipped labially and drifted to the labial side. Compared with the TB group, less labial alveolar bone loss, less incisor proclination and crown edge drift were found in the SGTB group ($P < 0.05$). **Conclusions:** Labial alveolar bone loss around mandibular incisors was observed after both types of appliances treatment in growing patients with Class II Division 1 malocclusion. Less labial alveolar bone loss, less incisor proclination, and crown edge drift were found in the SGTB group than in the TB group during treatment. (Am J Orthod Dentofacial Orthop 2020;157:329-39)

The Twin-block (TB) appliance is a well-accepted functional appliance in correcting Class II Division 1 malocclusion with mandibular retrognathia. In the course of treatment, the patients' mandibles are guided forward by the inclined plane of the bite-blocks. Condylar growth is stimulated, midfacial complex growth is restricted, and the growth pattern is modified,[1,2] thus patients could achieve favorable dentofacial relationships.[3,4] However, undesirable labial tipping of mandibular incisors was observed after TB appliance treatment,[5-7] and it can cause periodontal consequences.[8-12] Furthermore, the inherently thinner layer of bony support around mandibular incisors is more liable to sustain iatrogenic damage. The alveolar bone in the mandibular anterior region is crucial to the stability of incisors, periodontal health, and acceptable esthetics,[12] therefore, it is an essential consideration during treatment.

To eliminate the potential side effects (ie, incisor proclination, and periodontal risks) of the TB appliance

Department of Orthodontics, Shandong Provincial Key Laboratory of Oral Tissue Regeneration, School of Stomatology, Shandong University, Jinan, Shandong, China.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
This study was supported by the National Natural Science Foundation of China (No. 81571010) and Natural Science Foundation of Shandong Province (No. ZR2016HP25, and 2018GSF118199).
Address correspondence to: Dong-xu Liu, 44-1# West Wenhua Rd, Jinan, Shandong 250012, China; e-mail, liudongxu@sdu.edu.cn.
Submitted, January 2019; revised and accepted, April 2019.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2019.04.029

treatment, numerous types of modified TB appliance have appeared. Gill et al[13] reported a progressively activated TB appliance with the mandible forward 3 mm every time until a normal overjet was achieved. Nevertheless, the authors concluded no significant difference in mandibular incisor proclination, which corresponds to the conclusions of De Vincenzo et al.[14] Van der Plas et al[15] demonstrated that the TB appliance with acrylic capping does not have a significant inhibition on mandibular incisor flaring.

The sagittal-guidance Twin-block (SGTB) appliance has been used as a modified TB appliance in China in recent years.[16] As a type of modified appliance, the indication of the SGTB appliance was the same as the classic TB appliance, but constructive modifications were done[17]: the SGTB appliance had maxillary component bonded to the maxillary posterior teeth. It guaranteed quicker adaptation and more orthopedic outcomes. The 2 brackets embedded into the upper occlusal planes allowed the fixed appliance treatment to be conducted simultaneously and result in shortened treatment time. The mandibular component consisted of extra clasps placed upon the mandibular first permanent molars, which produced better retention. The researchers claimed mild proclination of the mandibular incisors in the case report.[17] So we assume that by using the TB or SGTB appliance, the alveolar bone around mandibular incisors might be affected differently, which has not been quantitatively evaluated so far.

Cone-beam computed tomography (CBCT) has been shown to have acceptable validity and reliability, not only in alveolar bone linear measurements,[18] but also in volumetric measurements.[19,20] It has been used widely in alveolar bone assessment.[21-23] The purpose of this study was to comparatively evaluate the effects of TB appliance and SGTB appliance on the alveolar bone around mandibular incisors in growing patients with Class II Division 1 malocclusion, using CBCT. The null hypothesis was that the 2 types of appliances cause similar effects on alveolar bone around mandibular incisors.

MATERIAL AND METHODS

This research was accepted by the Research Ethics Committee of Shandong University Dental School (Protocol No. 20170702). Before participating in the study, all the patients and their legal guardians were notified of potential risks and provided written informed consent. The study was conducted according to the tenets of the Declaration of Helsinki for research involving human subjects.

The power calculation was performed in order to recruit the smallest sample size that would allow meaningful statistical analysis. It was calculated based on an α of 0.05 and a β of 0.2 to achieve the power of 80% and to detect the difference of 1 mm in mandibular alveolar bone linear height measurements between groups, with a 0.98-mm estimated standard deviation.[24] The power analysis indicated a sample size of 11.8 in each group.

Sample selection was based on the following inclusion criteria: (1) the overjet was 6 to 7 mm with an Angle Class II molar relationship; (2) SNB angle was $<75°$, and ANB angle was $>4°$; (3) mandibular plane angle was $<28°$; (4) the crowding of the lower anterior arches were <4 mm. Exclusion criteria included arch spacing, tooth size anomaly, periodontal disease, and abnormal bone metabolism. A sample of 26 patients was randomly allocated to the TB or SGTB group. Patients were numbered according to the order of their first visit. Then the numbers of the patients were randomly allocated into 2 groups through the random numbers generated in SPSS (version 21.0; IBM, Armonk, NY). The allocation was performed by a staff member who was not involved in the trial. It was concealed from the participants and treating clinicians. After randomized allocation, the TB group comprised 13 patients (7 boys and 6 girls; mean age, 11.83 ± 1.17 years). The SGTB group comprised 13 subjects initially, but only 12 were evaluated in the final sample (7 boys and 5 girls; mean age, 12.00 ± 2.10 years).

In both groups, patients were told to wear appliances for 24 hours a day and see the doctor after 1 month for supervision and adjustments. The appliance would not be removed until a stable mandibular forward position was obtained. The treatment duration was 11.56 ± 1.73 months. After the TB or SGTB appliances were removed, the fixed appliance treatment began.

The TB appliance had the following basic components: the maxillary appliance incorporated a bite-block, a labial bow, a midline screw, 2 delta clasps placed upon the bilateral first permanent molars, 2 ball clasps placed between the premolars; the mandibular appliance incorporated a bite-block, 2 delta clasps placed upon the first premolars, 2 ball clasps placed between the central and lateral incisors. The maxillary and mandibular bite-blocks interlocked at a 70° angle with the mandible positioned forward, the maxillary and mandibular incisors were edge-to-edge with a 2-mm vertical separation.

Comparing with the TB appliance, there were several modifications of the SGTB appliance: (1) the appliance was semifixed with the maxillary component bonded to the maxillary teeth; (2) there was no labial bow on

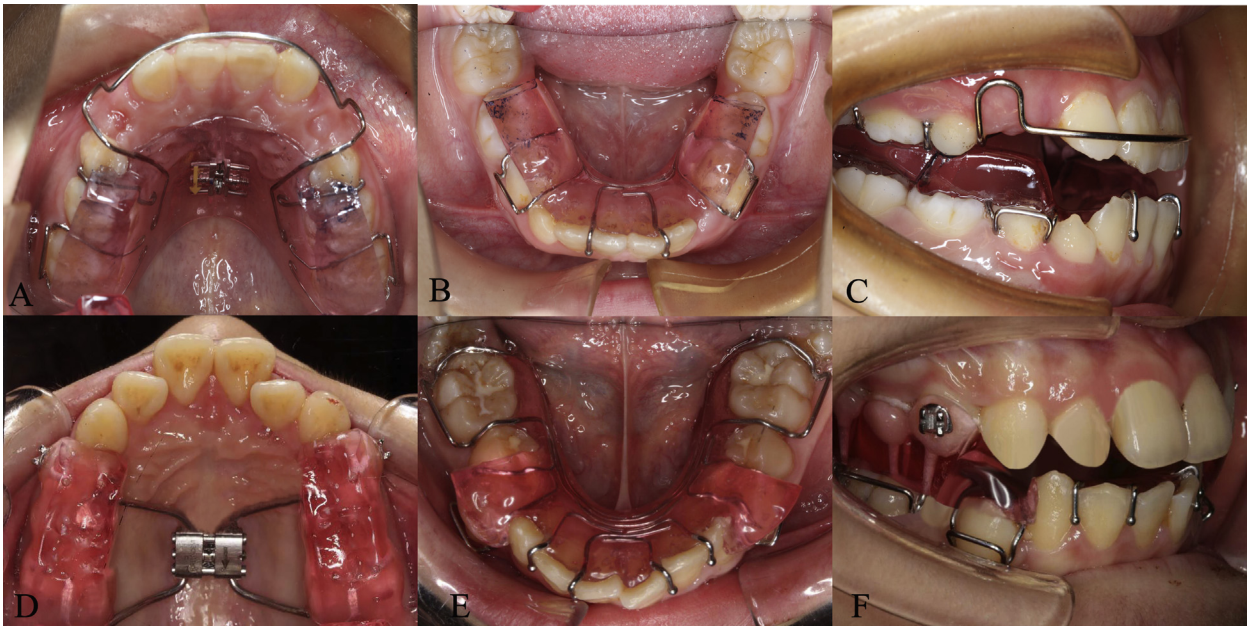

Fig 1. A, A maxillary component of the TB appliance; **B,** mandibular component of the TB appliance; **C,** the mandible was guided forward by the TB appliance; **D,** maxillary component of the SGTB appliance; **E,** mandibular component of the SGTB appliance; **F,** the mandible was guided forward by the SGTB appliance.

the maxillary component. Two brackets were embedded into the buccal facade of the upper occlusal planes; (3) there were 2 Adams clasps on the bilateral mandibular permanent first molars with lingual acrylic pads extending posteriorly. Two extra ball clasps were placed between the mandibular lateral incisors and canines bilaterally (Fig 1).

Before treatment (T1) and immediately after the removal of the appliances (T2), CBCT images were acquired by the same researcher using the CBCT scanner (NewTom 5G, QR srl, Verona, Italy) at these settings: 5mA, 110 kV, exposure time of 10 seconds, voxel size of 0.30 mm, and the slice thickness of 0.3 mm. Then they were exported in the DICOM (digital imaging and communications in medicine) format.

All the CBCT images were transferred into Mimics software (version 19.0; Materialise, Leuven, Belgium). Primarily, thresholding based on Hounsfield Units was used to create the original mandibular masks (401 HU-2347 HU), the teeth masks (1420 HU-3580 HU), and the alveolar bone masks (148 HU-1988 HU). Secondly, they were precisely separated from neighboring tissues through the mask segment tools in Mimics, such as *edit masks*, and *region growing*. Thirdly, 3D virtual models of the mandible, the teeth, and the alveolar bone were reconstructed from their masks respectively. Finally, the surrounding alveolar bone models were separated from the alveolar bone models and were split as labial and lingual 1 through 5 cutting planes, which are described in Figure 2.

In both groups, the mandible, the teeth, and the alveolar bone models of T2 were exported as stereolithography (STL) and imported into T1 CBCT data. Point registrations of the mandible were done by placing 4 pairs of landmark points (bilateral mandibular foramina, mental trigone, and genial tubercle) on T1 and T2 models; then, the T2 points could be moved to the specific locations on T1 points (Figs. 3, *A* and *B*). Afterward, STL registrations were performed to improve accuracy, the minimal point distance filter was set as 0.10 mm (Figs. 3, *C* and *D*).[25] After registration, the stable structures during growth[26] were checked to be precisely overlapped (Figs. 3, *E-G*). Through the entire registration process, the teeth and the alveolar bone models were moved along with the mandibular models of T2, and the contours of them could be visualized respectively after registration.

The measurements were performed by a single-blinded examiner. Sagittal slices where the mandibular left incisor was labio-lingually widest were chosen for alveolar bone linear measurements in all CBCT images. Using the tooth axis as a reference for measuring bone height and thickness has been used in previous studies,[12,21,22] and the surrounding alveolar bone is

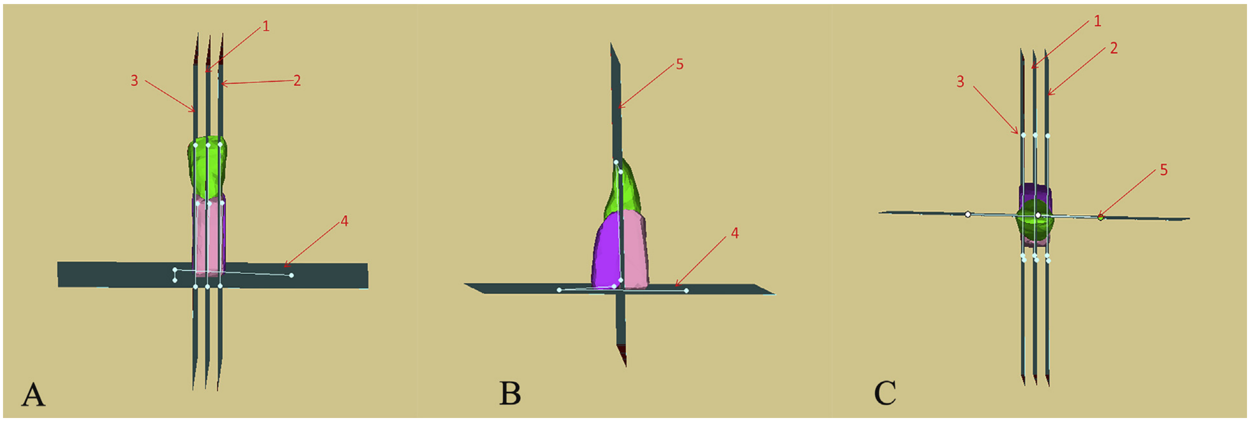

Fig 2. The cutting plane 1 was created sagittally and divided the incisor equally. The cutting planes 2 and 3 were set parallelly at 2 mm bilateral to the cutting plane 1; the cutting plane 4 was set perpendicularly to the cutting plane 1 at the root apex. The cutting planes 2, 3, and 4 were created to separate the surrounding alveolar bone model from the alveolar bone model. The cutting plane 5 was set to cut the incisor coronally and equally and thus split the alveolar bone as labial and lingual ones. **A,** frontal view of the models with the 1, 2, 3, and 4 cutting planes are visible; **B,** lateral view of the models with the 4 and 5 cutting planes are visible; **C,** occlusal view of the models with the 1, 2, 3, and 5 cutting planes are visible.

of clinical significance. Reference points, lines, and measurement variables are described in Tables I and II and Figure 4, *A*. Since the thickness of the alveolar bone around mandibular incisors are inherently small at the midroot and crest level, the linear measurements tend to be underestimated.[27] Therefore, we took the thickness measurements only at apex level and added the surrounding alveolar bone volume as measured variables. The volume of the surrounding labial and lingual alveolar bone models can be shown directly in Mimics (Fig 4, *B*). The total surrounding alveolar bone volume was calculated by adding the labial and lingual volume together. After registration, the sagittal displacement of incisors were measured, which are described in Figures 4, *C* and *D*.

Statistical analysis

Statistical analysis was performed using SPSS (version 21.0; IBM) software package. All measured variables were described by the mean and the standard deviation. Shapiro-Wilk test was used to assess normal distribution. For normal distribution data, the intragroup comparisons were analyzed using paired-samples *t* test, and independent-samples *t* test was used for intergroup comparisons. In case of abnormal distribution, Wilcoxon and Mann-Whitney U tests were used for intragroup and intergroup comparisons, respectively. A *P* value <0.05 was considered to be statistically significant.

The intraexaminer reliability was determined by performing the measurements for each CBCT image on 2 separate occasions by one examiner at a 2-week interval. The intraclass correlation coefficients were calculated, then the mean of the 2 measurements was used in statistical analysis. The errors of measurements were calculated using the Dahlberg formula[28]: measurement error $= \sqrt{\Sigma d^2 / 2n}$ (where d indicates deviations between the 2 measurements, and n indicates number of paired objects).

RESULTS

Of the 26 Chinese adolescents who were involved in this study, the TB group comprised 13 patients (7 boys and 6 girls, 11 in primary school and 2 in junior high school; mean age, 11.83 ± 1.17 years). The SGTB group comprised 13 subjects initially, but only 12 were evaluated in the final sample (7 boys and 5 girls, 9 in primary school and 4 in junior high school, mean age 12.00 ± 2.10 years) with a girl dropped out because of personal reasons (ie, she failed to complete the trail because she moved to another city). Both groups had similar ages and sex distribution at baseline. The cephalometric measurement of mandibular incisor proclination were $(97.2 \pm 8.7)^\circ$ in the TB group and $(97.3 \pm 7.3)^\circ$ in the SGTB group, with no significant difference between the groups. The baseline measured characteristics were similar and were reported as T1 data in Table III.

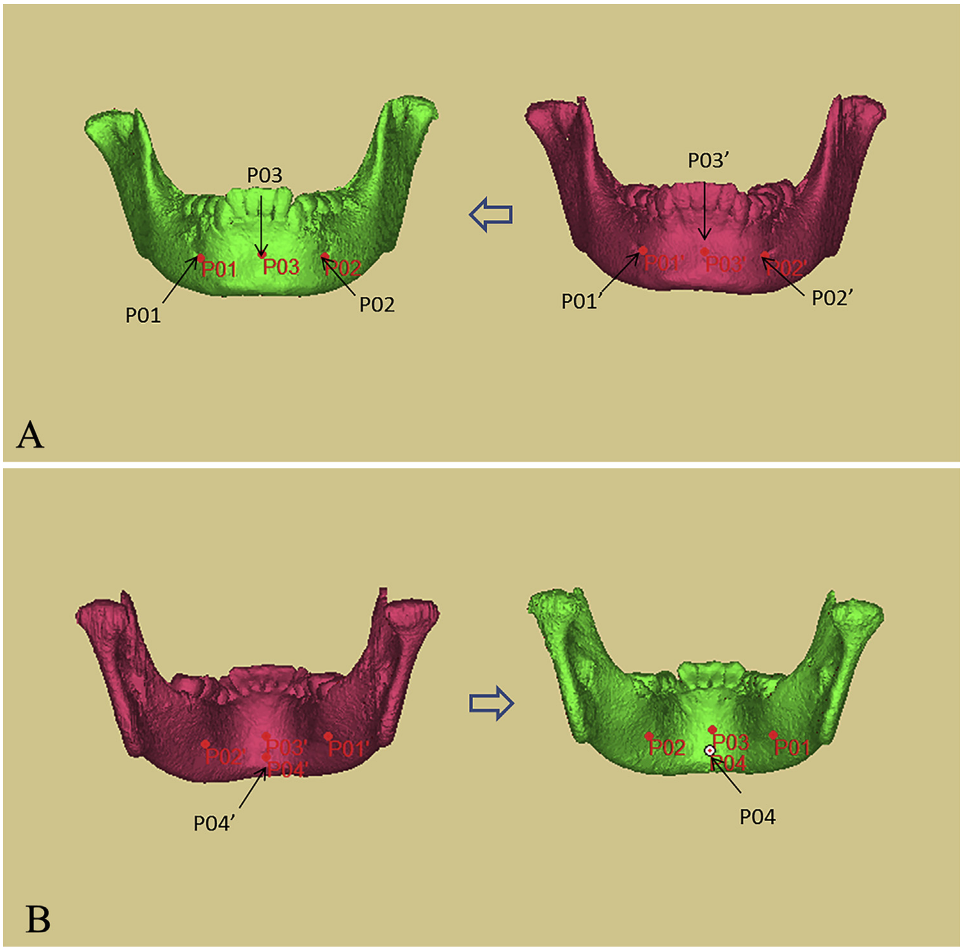

Fig 3. A, frontal view in the point registration process: point P01 and P02 are on the bilateral mandibular foramina of the T1 mandibular model; point P01' and P02' are on the mandibular foramina of the T2 mandibular model. Point P03 and P03' are on the mental trigone of the T1 and the T2 mandibular models respectively; **B,** posterior view in the point registration process: Point P04 and Point 04' are on the genial tubercle of T1 and T2 mandibular models respectively; **C,** the T1 (*green*) and the T2 (*red*) mandibular models after point registration and before STL registration; **D,** the T1 (*green*) and the T2 (*red*) mandibular models after STL registration. **E, F, G,** contours of the mandibular models at coronal, transverse, and sagittal views of CBCT image. The stable structures during growth (contour of the chin below pogonion and inner contour of the cortical plate at the lower border of the symphysis) were precisely overlapped.

The intraclass correlation coefficients for all measurements ranged from 0.93 to 0.95, indicating sufficient reliability. The method errors ranged from 0.16 mm to 0.22 mm for linear measurements, from 1.53 mm^3 to 2.85 mm^3 for volume measurements, and 0.19° for angular measurements.

The results of alveolar bone measurements are shown in Table III and Figure 5. By comparing T1 and T2 data, the labial alveolar bone height (LABH) significantly decreased in both the TB group (*P* <0.05; 9.12 ± 0.64 mm in T1; 8.32 ± 0.9 mm in T2) and the SGTB group (*P* <0.05, 9.98 ± 0.67 mm in T1, 9.67 ± 0.68 mm in T2). The labial surrounding alveolar bone volume (LV) also significantly decreased in both groups (in the TB group, *P* <0.05, 108.88 ± 31.93 mm^3 in T1, 96.34 ± 35.10 mm^3 in T2; in the SGTB group, *P* <0.05, 133.86 ± 46.56 mm^3 in T1, 126.98 ± 51.40 mm^3 in T2). Nevertheless, lingual alveolar bone height, lingual, and total surrounding alveolar bone volume, labial and lingual alveolar bone thickness at apex level showed no statistical significance (*P* >0.05) in both groups.

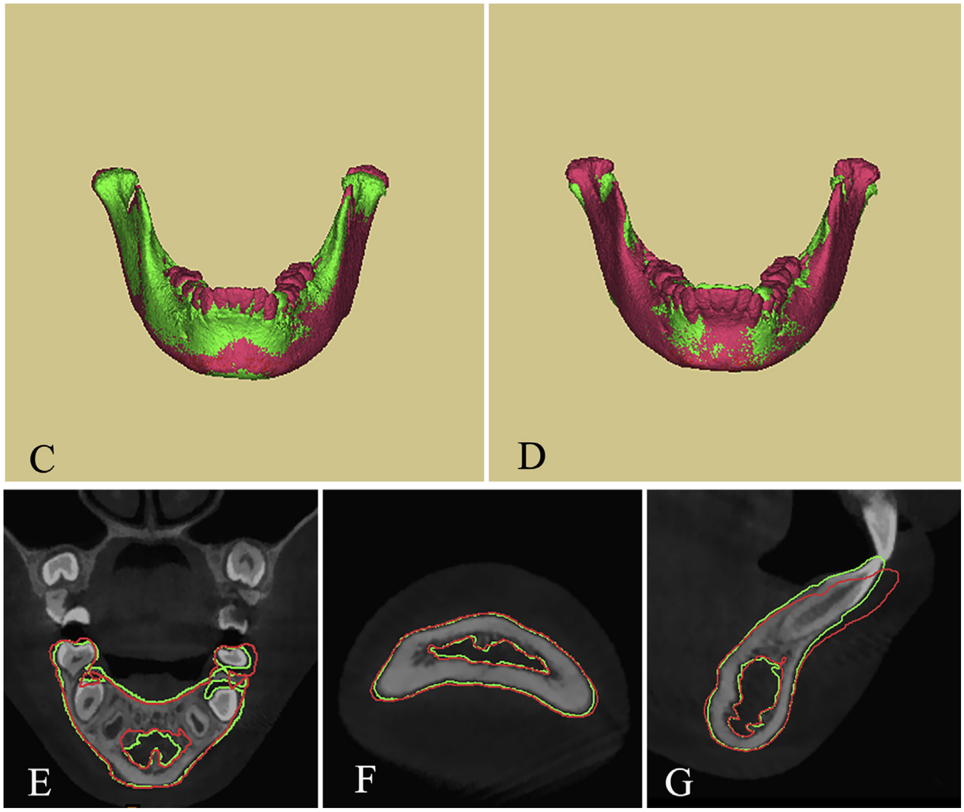

Fig 3. (continued).

Table IV and Figure 6 report the intergroup comparisons of the treatment outcomes. The LABH loss in the SGTB group was significantly less than that of the TB group ($P < 0.05$), as well as the loss of the LV. No statistically significant difference was found for the rest of the measurements.

Table V describes the sagittal displacement of lower incisors. In the TB group, the crown edge drifted by 2.58 ± 1.13 mm and the root apex drifted by 0.61 ± 0.35 mm to the labial side, with the incisors tipped labially by 5.98 ± 2.19°. In the SGTB group, the crown edge drifted by 1.64 ± 0.55 mm and the root apex drifted by 0.18 ± 0.43 mm to the labial side, with the incisors tipped labially by 3.65° ± 1.46°. There were significant differences ($P < 0.05$) between 2 groups in incisor proclination and drift distance of the crown edge. Less drift distance of root apex was observed in the SGTB group than in the TB group, without reaching the level of significance ($P = 0.052$).

DISCUSSION

During treatment, bone modeling occurred around mandibular incisors to adapt to physiology and therapeutic loads.[29-31] The size and shape of the alveolar bone had changed and could be observed by comparing T1 and T2 CBCT images. In both groups of our study, mandibular incisors were tipped and drifted

Table I. Definitions of points and lines used in alveolar bone linear measurements in this study

Reference points and lines	*Definition*
1	Crown edge
2	Root apex
3	Labial alveolar crest
4	Lingual alveolar crest
5	Long axis
6	A line perpendicular to the long axis at the root apex
7	A line parallel to the long axis at the labial alveolar crest
8	A line parallel to the long axis at the lingual alveolar crest
9	The point of intersection of the line perpendicular to the axis of the incisor, with the labial contour of the symphysis
10	The point of intersection of the line perpendicular to the axis of the incisor, with the lingual contour of the symphysis
11	The line connecting point 2 and point 9
12	The line connecting point 2 and point 10

Table II. Definitions of alveolar bone measurements used in this study

Measurements	*Definition*
Tooth length	The length of line 5
LABH	Labial alveolar bone height: the length of line 7
LIABH	Lingual alveolar bone height: the length of line 8
LABT	Labial alveolar bone thickness: the length of line 11
LIABT	Lingual alveolar bone thickness: the length of line 12
TABT	Total alveolar bone thickness: the length of line 6
LV	Labial surrounding alveolar bone volume
LIV	Lingual surrounding alveolar bone volume
TV	Total surrounding alveolar bone volume

labially, and labial alveolar bone loss was observed after treatment. Figure 5 indicates that LABH and LV significantly decreased. The reason is that while mandibular incisors were moving labially, the compression in the labial periodontal ligament region triggered bone resorption; bone formation happened simultaneously on the labial periosteal and endosteal surface to restore the strain levels to an appropriate range.[29] Bone resorption was more whereas formation was relatively less; thus the labial alveolar bone loss was observed. Although LABH and LV decreased significantly, the changes of labial alveolar bone thickness did not reach the level of significance. The results indicated that the labial bone loss mainly happened above the apical level, where the alveolar bone is thinner and more vulnerable. In the meantime, the mechanical strain on the lingual periodontal ligament surface triggered bone apposition; bone resorption happened on the lingual periosteal and endosteal surface. The lingual alveolar bone thickness and lingual alveolar bone volume showed no significant difference, indicating that the bone resorption and

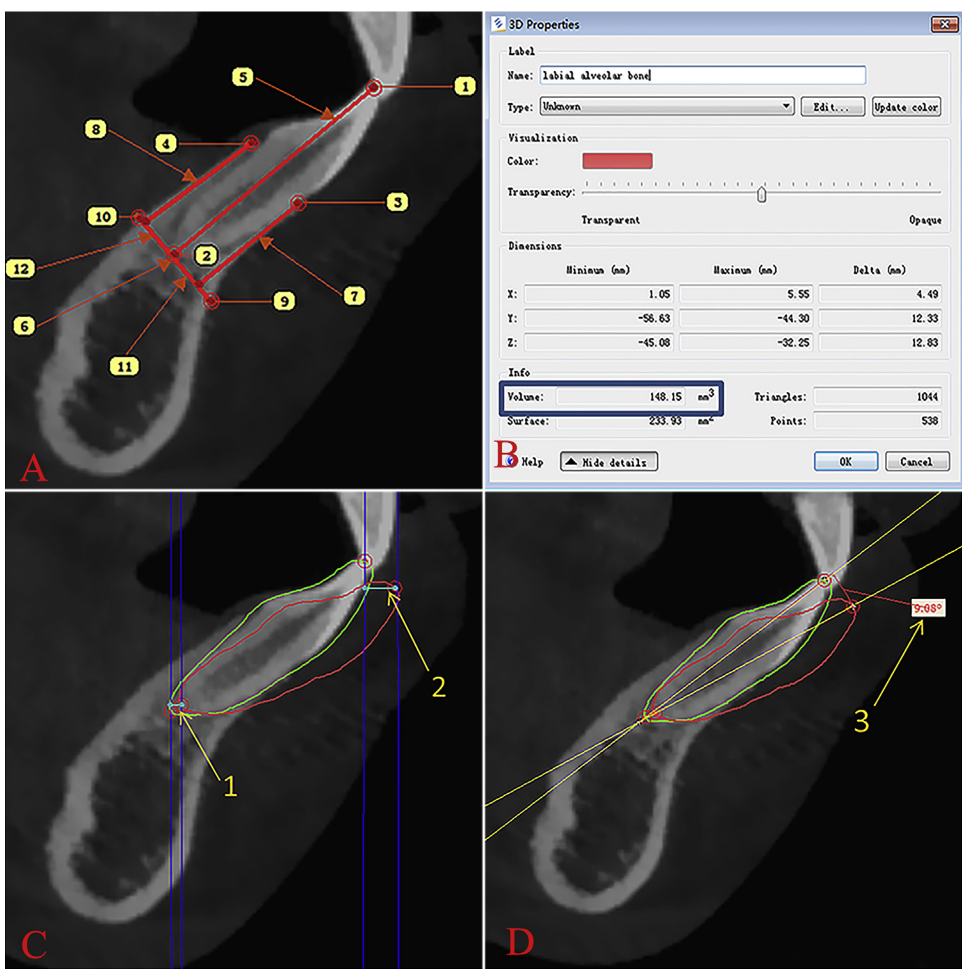

Fig 4. **A,** reference points and lines used in linear measurements; **B,** the volume of the surrounding labial and lingual alveolar bone models can be shown directly by using the tool "3D Properties" in Mimics; **C,** drift distance of (1) the crown edge and (2) the root apex was measured perpendicular to the true vertical line; **D,** (3) angle of long axis.

Table III. The measured variables of alveolar bone in the TB group and the SGTB group

	TB					*SGTB*				
	T1		*T2*			*T1*		*T2*		
Measurements	*Mean*	*SD*	*Mean*	*SD*	P *value*	*Mean*	*SD*	*Mean*	*SD*	P *value*
Tooth length	20.00	1.02	19.96	1.11	0.71*	19.94	0.93	19.84	1.32	0.41*
LABH	9.12	0.64	8.32	0.90	0.001*,‡	9.98	0.67	9.67	0.68	0.01*,‡
LIABH	8.65	0.57	8.02	1.13	0.06*	8.91	0.91	8.87	1.35	0.91*
LABT	4.02	0.68	4.13	1.02	0.63*	3.79	1.02	3.63	1.16	0.4*
LIABT	4.11	0.34	4.18	0.64	0.47*	4.54	1.10	4.77	0.96	0.1*
TABT	8.12	0.71	8.17	0.81	0.83*	8.66	1.29	8.73	1.31	0.74*
LV	108.88	31.93	96.34	35.10	0.009†,‡	133.86	46.56	126.98	51.40	0.028†,‡
LIV	127.91	26.11	134.23	21.81	0.36*	199.13	51.38	200.98	51.09	0.64†
TV	236.79	55.87	230.57	46.72	0.48†	325.86	57.62	320.55	83.13	0.81†

SD, standard deviation; *LIABH*, lingual alveolar bone height; *LABT*, labial alveolar bone thickness at apex level; *LIABT*, lingual alveolar bone thickness at apex level; *TABT*, total alveolar bone thickness at apex level; *LIV*, lingual alveolar bone volume; *TV*, total alveolar bone volume.
*Paired-samples *t* test; †Wilcoxon test; ‡Indicates a statistical significance at $P < 0.05$.

formation was accordance with the lingual side of the incisors.

Table V indicates that the mandibular incisors were tipped labially, with both the crown edge and the root apex drifted to the labial side. Former researches have confirmed the mandibular incisors' flaring after the TB appliance treatment, but most of them based on 2-dimensional cephalometric films.[5-7] With the stable structures during growth precisely overlapped after 3D registration (Figs. 3, *E-G*), our study provides a more accurate way to quantitively evaluate the sagittal displacement of the incisors using CBCT images.

According to Table IV and Figure 6, the SGTB appliance was shown to reduce the labial alveolar bone loss

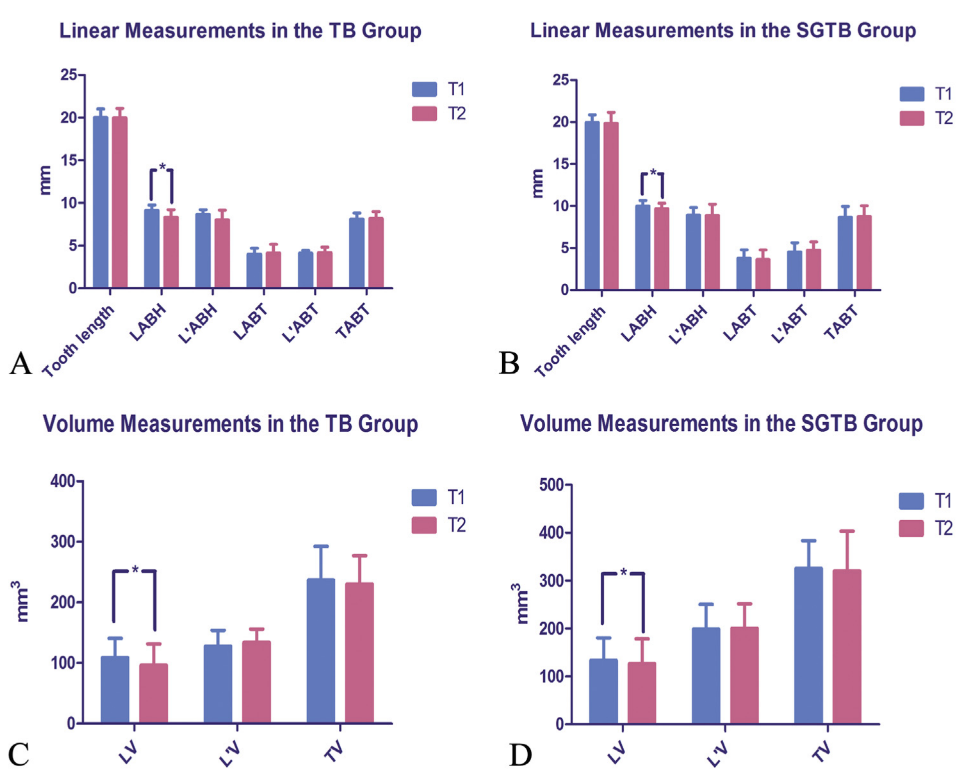

Fig 5. The measured variables of the alveolar bone in the TB group and the SGTB group.

Table IV. Changes of measured variables of alveolar bone in the TB group and the SGTB group

	ΔT of TB		*ΔT of SGTB*		
Measurements	*Mean*	*SD*	*Mean*	*SD*	P *value*
Tooth length	−0.08	0.74	0.03	0.41	0.64*
LABH	−0.81	0.66	−0.31	0.34	0.03*,‡
LIABH	−0.73	1.02	−0.21	1.06	0.23*
LABT	0.11	0.8	−0.16	0.63	0.36*
LIABT	0.08	0.55	0.23	0.44	0.45*
TABT	0.05	0.74	0.07	0.70	0.94*
LV	−13.37	11.77	−3.24	9.74	0.02†,‡
LIV	7.15	23.8	1.85	40.66	0.67†
TV	−6.22	22.04	−1.66	46.6	0.32†

ΔT, the numerical values of T2 measured variables minus that of T1; *SD*, standard deviation; *LIABH*, lingual alveolar bone height; *LABT*, labial alveolar bone thickness at apex level; *LIABT*, lingual alveolar bone thickness at apex level; *TABT*, total alveolar bone thickness at apex level; *LIV*, lingual alveolar bone volume; *TV*, total alveolar bone volume.
*Independent-samples *t* test; †Mann-Whitney U test; ‡Indicates a statistical significance at $P < 0.05$.

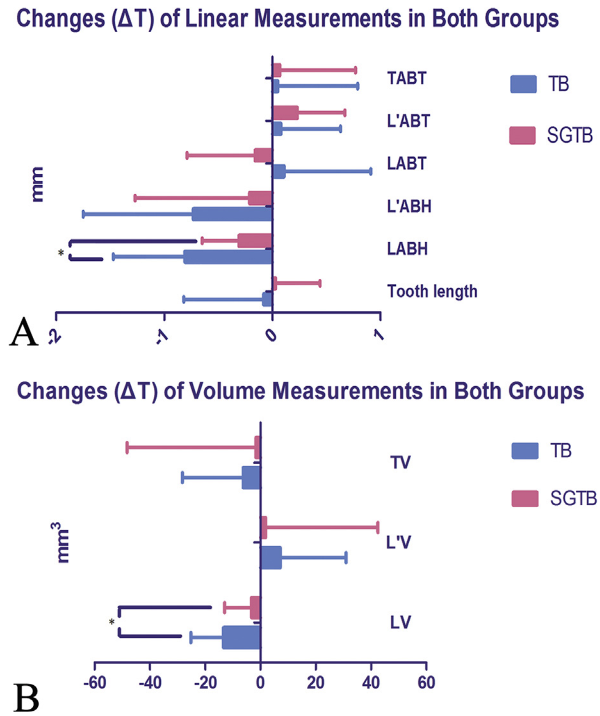

Fig 6. Changes of measured variables of alveolar bone in the TB group and the SGTB group.

and tipping of incisors compared with the TB appliance. This finding may be attributed to the modified construction of the appliance. First, extra clasps on mandibular first molars and lingual acrylic pads, which extend posteriorly took more teeth as the anchorage to move the whole mandible forward. The enhanced retention decreased the dental effects and thus reduced the periodontal damage. Second, the patients who need TB or SGTB treatment were adolescents. Although they were under the supervision of their parents and the orthodontists, the compliance was still a consideration during treatment. The maxillary components of SGTB were bonded and could not be removed by the patients. Therefore, it guaranteed nearly full-time wearing of the appliance, which provided a constant orthopedic force and brought about more orthopedic outcomes. The reduction of mandibular incisor's proclination could allow more space for the mandible to protrude, and it was of benefit to mandibular growth in patients with Class II Division 1 malocclusion with mandibular retrognathia.[32,33] However, the side effects could not be eliminated completely. We assume that it was the inherent disadvantage in all functional appliances that use teeth for anchorage. In recent years, Herbst appliances anchored to miniscrews were reported to have less anchorage loss than teeth anchored appliance.[33] For further study, bone anchorage TB appliance with miniscrews or titanium plates may be a better option.

Our study indicated that the patients who have extremely thin biotype and periodontal disease should be under serious consideration before beginning the TB or SGTB treatment. Furthermore, during the entire treatment procedure, the alveolar bone around mandibular incisors should also be a focus. This study confirmed less periodontal consequences caused by the SGTB appliance compared with the classic TB appliance. With other advantages such as quicker adaptation, more orthopedic outcomes and shortened overall treatment time,[16,17] this type of modified appliance might be a better option for growing patients with Class II Division 1 malocclusion with mandibular retrognathia.

In this study, with the 0.3-mm voxel size resolution CBCT image, the method errors of alveolar bone linear measurements were close to that of previous CBCT studies.[22] However, accuracy would be improved when decreasing the voxel size.[27,34] Many factors such as the soft tissue conditions and artifacts could affect the CBCT image quality and the accuracy of the measurements,[35] so more work needs to be done for further research. There are some other limitations. First, for esthetic reasons, patients with Class II Division 1 malocclusion should be treated immediately after their first visit, so we were unable to obtain the untreated T1 and T2 data. The observation of untreated patients would be crucial to differentiate natural growth from changes derived from treatment. Second, considering the relatively high variance and large individual differences, the results were affected by the limited sample

Table V. The measured variables of mandibular left central incisor displacement in the TB group and the SGTB group

	TB		SGTB		
Variables	*Mean*	*SD*	*Mean*	*SD*	P *value*
Drift distance of crown edge	2.58	1.13	1.64	0.55	0.007†,‡
Drift distance of root apex	0.61	0.35	0.18	0.43	0.052†
Angle of long axis	5.98	2.19	3.65	1.46	0.01*,‡

SD, standard deviation.
*Independent-samples *t* test; †Mann-Whitney U test; ‡Indicates a statistical significance at $P < 0.05$.

size. A larger sample size for studies is needed to get more convincing results. Third, long term follow-up is also necessary because of the possibility of treatment relapse and the influence of growing.

CONCLUSIONS

(1) Labial alveolar bone loss around mandibular incisors was observed after both types of appliances treatment growing patients with Class II Division 1 malocclusion.
(2) Less incisor proclination and crown edge drift were found in the SGTB group.
(3) The null hypothesis was rejected. The SGTB appliance caused less labial alveolar bone loss during treatment than the TB appliance.

REFERENCES

1. Yildirim E, Karacay S, Erkan M. Condylar response to functional therapy with Twin-Block as shown by cone-beam computed tomography. Angle Orthod 2014;84:1018-25.
2. Singh GD, Hodge MR. Bimaxillary morphometry of patients with class II division 1 malocclusion treated with twin block appliances. Angle Orthod 2002;72:402-9.
3. Clark WJ. Twin Block functional therapy. 3rd ed. New Delhi, India: Jaypee Brothers Medical Publishers (P) Ltd; 2015.
4. Trenouth MJ. Cephalometric evaluation of the Twin-block appliance in the treatment of Class II Division 1 malocclusion with matched normative growth data. Am J Orthod Dentofacial Orthop 2000;117:54-9.
5. Lund DI, Sandler PJ. The effects of Twin Blocks: a prospective controlled study. Am J Orthod Dentofacial Orthop 1998;113:104-10.
6. Ehsani S, Nebbe B, Normando D, Lagravere MO, Flores-Mir C. Short-term treatment effects produced by the Twin-block appliance: a systematic review and meta-analysis. Eur J Orthod 2015;37:170-6.
7. Mills CM, McCulloch KJ. Treatment effects of the twin block appliance: a cephalometric study. Am J Orthod Dentofacial Orthop 1998;114:15-24.
8. Nauert K, Berg R. Evaluation of labio-lingual bony support of lower incisors in orthodontically untreated adults with the help of computed tomography. J Orofac Orthop 1999;60:321-34.
9. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. Angle Orthod 1996;66:95-109: discussion 109–10.
10. Pangrazio-Kulbersh V, Jezdimir B, de Deus Haughey M, Kulbersh R, Wine P, Kaczynski R. CBCT assessment of alveolar buccal bone level after RME. Angle Orthod 2013;83:110-6.
11. Guo QY, Zhang SJ, Liu H, Wang CL, Wei FL, Lv T, et al. Three-dimensional evaluation of upper anterior alveolar bone dehiscence after incisor retraction and intrusion in adult patients with bimaxillary protrusion malocclusion. J Zhejiang Univ Sci B 2011;12:990-7.
12. Lee KM, Kim YI, Park SB, Son WS. Alveolar bone loss around lower incisors during surgical orthodontic treatment in mandibular prognathism. Angle Orthod 2012;82:637-44.
13. Gill DS, Lee RT. Prospective clinical trial comparing the effects of conventional Twin-block and mini-block appliances: part 1. Hard tissue changes. Am J Orthod Dentofacial Orthop 2005;127:465-72: quiz 517.
14. DeVincenzo JP, Winn MW. Orthopedic and orthodontic effects resulting from the use of a functional appliance with different amounts of protrusive activation. Am J Orthod Dentofacial Orthop 1989;96:181-90.
15. van der Plas MC, Janssen KI, Pandis N, Livas C. Twin Block appliance with acrylic capping does not have a significant inhibitory effect on lower incisor proclination. Angle Orthod 2017;87:513-8.
16. Shen G. SGTB orthopedic regime to correct protrusive skeletal anomalies: a developmental path through evolution, renovation and innovation. Shanghai Kou Qiang Yi Xue 2015;24:513-8: Chinese.
17. Li PL, Feng J, Shen G, Zhao N. Severe Class II Division 1 malocclusion in an adolescent patient, treated with a novel sagittal-guidance Twin-block appliance. Am J Orthod Dentofacial Orthop 2016;150:153-66.
18. Timock AM, Cook V, McDonald T, Leo MC, Crowe J, Benninger BL, et al. Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. Am J Orthod Dentofacial Orthop 2011;140:734-44.
19. Chaison JB, Chen CS, Herring SW, Bollen AM. Bone volume, tooth volume, and incisor relapse: a 3-dimensional analysis of orthodontic stability. Am J Orthod Dentofacial Orthop 2010;138:778-86.
20. Pinsky HM, Dyda S, Pinsky RW, Misch KA, Sarment DP. Accuracy of three-dimensional measurements using cone-beam CT. Dentomaxillofac Radiol 2006;35:410-6.
21. Thongudomporn U, Charoemratrote C, Jearapongpakorn S. Changes of anterior maxillary alveolar bone thickness following incisor proclination and extrusion. Angle Orthod 2015;85:549-54.
22. Ahn HW, Moon SC, Baek SH. Morphometric evaluation of changes in the alveolar bone and roots of the maxillary anterior teeth before and after en masse retraction using cone-beam computed tomography. Angle Orthod 2013;83:212-21.
23. Ahlqvist J, Eliasson S, Welander U. The effect of projection errors on cephalometric length measurements. Eur J Orthod 1986;8:141-8.
24. Castro LO, Castro IO, de Alencar AHG, Valladares-Neto J, Estrela C. Cone beam computed tomography evaluation of distance from cementoenamel junction to alveolar crest before and after nonextraction orthodontic treatment. Angle Orthod 2016;86:543-9.
25. Liu H, Lv T, Wang NN, Zhao F, Wang KT, Liu DX. Drift characteristics of miniscrews and molars for anchorage under orthodontic

force: 3-dimensional computed tomography registration evaluation. Am J Orthod Dentofacial Orthop 2011;139:e83-9.

26. Björk A, Skieller V. Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies over a period of 25 years. Eur J Orthod 1983;5:1-46.
27. Sun Z, Smith T, Kortam S, Kim DG, Tee BC, Fields H. Effect of bone thickness on alveolar bone-height measurements from cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2011;139:e117-27.
28. Dahlberg G. Statistical methods for medical and biological students. London, United Kingdom: G. Allen & Unwin Ltd; 1940.
29. Roberts WE, Huja S, Roberts JA. Bone modeling: biomechanics, molecular mechanisms, and clinical perspectives. Semin Orthod 2004;10:123-61.
30. Roberts WE, Roberts JA, Epker BN, Burr DB, Hartsfield JK Jr. Remodeling of mineralized tissues, part I: the frost legacy. Semin Orthod 2006;12:216-37.
31. Roberts WE, Epker BN, Burr DB, Hartsfield JK Jr, Roberts JA. Remodeling of mineralized tissues, part II: control and pathophysiology. Semin Orthod 2006;12:238-53.
32. Manni A, Mutinelli S, Pasini M, Mazzotta L, Cozzani M. Herbst appliance anchored to miniscrews with 2 types of ligation: effectiveness in skeletal Class II treatment. Am J Orthod Dentofacial Orthop 2016;149:871-80.
33. Bremen Jv, Ludwig B, Ruf S. Anchorage loss due to Herbst mechanics—preventable through miniscrews? Eur J Orthod 2015;37:462-6.
34. Patcas R, Müller L, Ullrich O, Peltomäki T. Accuracy of cone-beam computed tomography at different resolutions assessed on the bony covering of the mandibular anterior teeth. Am J Orthod Dentofacial Orthop 2012;141:41-50.
35. Wood R, Sun Z, Chaudhry J, Tee BC, Kim DG, Leblebicioglu B, et al. Factors affecting the accuracy of buccal alveolar bone height measurements from cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2013;143:353-63.