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Assessment of buccal and lingual alveolar bone thickness and buccolingual inclination of maxillary posterior teeth in patients with severe skeletal Class III malocclusion with mandibular asymmetry

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Introduction: The purpose of this study was to evaluate the buccal and lingual alveolar bone thickness and buccolingual inclination of maxillary posterior teeth in patients with severe skeletal Class III malocclusion with and without mandibular asymmetry and compare with those in patients with skeletal Class I malocclusion. **Methods:** Cone-beam computed tomography images of 69 patients with severe skeletal Class III malocclusion and 30 patients with skeletal Class I malocclusion were collected and reconstructed with Dolphin 3D software. Based on the distance from menton to the sagittal plane (d), the patients with skeletal Class III malocclusion were divided into a symmetry group (d ≤ 2 mm) and an asymmetry group (d ≥ 4 mm). Buccal and lingual alveolar bone thickness and buccolingual inclination of maxillary posterior teeth were measured and compared. Correlations among dental measurements, severity of sagittal discrepancy, and mandibular deviation were analyzed. **Results:** Maxillary posterior teeth on the deviated side in Class III asymmetry group and symmetry group were buccally inclined compared with the Class I group ($P < 0.001$). A significant negative correlation was noted between buccolingual inclination of maxillary posterior teeth and ANB value with Spearman correlation coefficient of maxillary first molar, second premolar, and first premolar of –0.687, –0.485 and –0.506, respectively ($P < 0.001$). Maxillary first molar showed thinner buccal alveolar bone on deviated side in asymmetry group and symmetry group of Class III, compared with the Class I group, with average values of 1.21 mm, 1.19 mm, and 1.83 mm, respectively ($P < 0.05$). The maxillary first premolar also showed thinner buccal alveolar bone on deviated side in Class III asymmetry group compared with the Class I group, with average values of 0.87 mm and 1.28 mm, respectively ($P < 0.05$). **Conclusions:** Decompensation of buccally inclined posterior teeth in patients with skeletal Class III malocclusion should be more cautious owing to thinner buccal alveolar bone to avoid a high risk of fenestration and dehiscence. (Am J Orthod Dentofacial Orthop 2020;157:503-15)

Skeletal Class III malocclusion is a kind of maxillofacial deformity with high prevalence in Asian populations, displaying sagittal discrepancy between maxilla and mandible.[1-3] Facial asymmetry happens more frequently in patients with skeletal Class III malocclusion with overdeveloped mandible.[4-7] Patients with skeletal Class III malocclusion with mandibular asymmetry have both sagittal and transverse skeletal discrepancies, leading to a great challenge to orthodontists.

Patients with severe skeletal Class III malocclusion with or without mandibular asymmetry usually require orthognathic surgery to normalize skeletal deformity,

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Table I. Patient characteristics in different groups

Characteristics	*Group III (asymmetry) n = 39*	*Group III (symmetry) n = 30*	*Group I n = 30*	*Multiple comparison*
Age (y)	20.2 ± 3.00	21.3 ± 4.62	22.9 ± 4.16	
ANB (°)	−3.7 ± 2.88	−4.2 ± 2.86	2.8 ± 1.57	AS = S < I
Wits (mm)	−12.3 ± 4.44	−12.8 ± 5.22	−1.3 ± 2.34	AS = S < I
Mandibular deviation (mm)	7.5 ± 3.03	0.9 ± 0.67	0.9 ± 0.66	I = S < AS
MP-SN (°)	37.5 ± 6.76	36.8 ± 7.00	34.8 ± 5.36	AS = S = I

AS, group III (asymmetry); *I*, group I; *S*, group III (symmetry); I, group I.
Data presented as mean ± standard deviation. One-way analysis of variance and post-hoc Bonferroni test were used to compare the values among 3 groups at a significance level of $P < 0.001$.

and presurgical orthodontic treatment directly influences the effects and long-term stability.[8]

Patients with skeletal Class III malocclusion usually present with proclined maxillary incisors and retroclined mandibular incisors to compensate for sagittal discrepancy.[1] In transverse dimension, patients with symmetrical skeletal Class III malocclusiont end to have buccally inclined upper posterior teeth and lingually inclined lower posterior teeth.[9] However, the inclination of posterior teeth in patients with skeletal Class III malocclusions with mandibular asymmetry is different between deviated and nondeviated sides.[9-11]

Dental decompensation in presurgical orthodontic treatment relies on adequate supporting periodontal tissue. Previous research on alveolar bone in patients with skeletal Class III malocclusion mainly focused on anterior teeth, indicating that patients with skeletal Class III malocclusion presented with thinner alveolar bone in the anterior area compared with patients with skeletal Class I malocclusion and morphology of alveolar bone in mandibular central incisor region adapted to the inclination of teeth.[8,12-14] Assessment of alveolar bone boundary around posterior area is also necessary to facilitate planned dental decompensation and avoid periodontal complications, including fenestration and dehiscence, during presurgical decompensation process.[15,16] Sendyk et al research noted that buccal and lingual alveolar bone thickness of teeth in patients with symmetrical skeletal Class III malocclusion was thinner compared with patients with normal occlusions.[12]

Assessment of posterior teeth inclination and alveolar bone thickness in previous studies usually relied on dental casts or 2-dimensional anteroposterior radiographs.[11,17-19] However, dental casts could not reflect true inclination of the root, and evaluation on 2-dimensional anteroposterior radiographs had shortcomings of magnification, geometric distortion, superimposed structures, and inconsistent head position.[16] Compared with traditional methods, cone-beam computed tomography (CBCT) could overcome these shortcomings and measure the inclination as well as alveolar bone thickness of teeth with great accuracy on different levels and dimensions.[9,10,20,21]

The purposes of this study were to (1) assess buccolingual inclination and alveolar bone thickness of maxillary posterior teeth in patients with severe skeletal Class III malocclusion with and without mandibular asymmetry and compare with that in patients with skeletal Class I malocclusion; and (2) investigate the potential correlations among buccolingual inclination and alveolar bone thickness of maxillary posterior teeth, severity of mandibular deviation, and sagittal discrepancy.

MATERIAL AND METHODS

All patient images in this study were collected in the Department of Oral Maxillofacial Surgery and Department of Orthodontics, Peking University School and Hospital of Stomatology. This project was approved by the Biomedical Ethics Committee of Peking University School and Hospital of Stomatology.

After applying the inclusion and exclusion criteria, 69 patients with skeletal Class III malocclusion were included in the sample (Table I). The inclusion criteria for the Class III group were as follows: (1) aged at least 16 years; (2) Mongolian; (3) permanent dentition; (4) no prior orthodontic or orthognathic treatment; (5) skeletal Class III (ANB angle, < 0°; Wits appraisal, ≤ −3.6 mm); (6) anterior teeth in crossbite or edge-to-edge position; and (7) MP-SN ≥ 27°. Exclusion criteria included: (1) congenitally missing teeth, retained deciduous teeth, or impacted teeth; (2) severe crowding in posterior teeth; (3) crowns or significant restorations in posterior teeth; (4) maxillary sinus obviously bulging into buccal or lingual alveolar bone of maxillary posterior teeth; (5) severe periodontitis; (6) systemic diseases; and (7) cleft lip or palate, temporomandibular joint disease. In addition, 30 patients with skeletal Class I malocclusion were included with the following inclusion criteria: (1) ANB angle between 0.7° and 4.7°; (2)

mandibular deviation < 2 mm; and (3) other inclusion criteria the same as that for skeletal Class III subjects. Exclusion criteria included: (1) severe crowding or crossbite in posterior teeth; (2) crossbite or edge-to-edge position in anterior teeth; and (3) the same exclusion criteria as patients with skeletal Class III malocclusion.

Patients with skeletal Class III malocclusion were further divided into 2 subgroups according to the degree of mandibular deviation from midsagittal plane measured on 3-dimensional CBCT images: (1) group III (asymmetry), which included 39 patients (25 males, 14 females; average age, 20.2 ± 3.00 years) with mandibular deviation more than 4 mm; and (2) group III (symmetry), which included 30 patients (10 males, 20 females; average age, 21.3 ± 4.62 years) with mandibular deviation < 2 mm. Twenty-one patients with mandibular deviation from 2 to 4 mm were excluded from the study. Group I included 30 patients (10 males, 20 females; average age, 22.9 ± 4.16 years) with mandibular deviation < 2 mm. The mandibular deviation was evaluated by menton (Me) deviation to the midsagittal plane. The deviated side was defined as the side Me shifted toward the midsagittal plane, while the other side was defined as the nondeviated side (Table II).

The sample size calculation was based on buccal and lingual alveolar bone thickness of maxillary posterior teeth measured at 3 mm apical to the mandibular cementoenamel junction in Sendyk et al[12] study and a standard deviation of 0.6 mm of maxillary second molar was reported.[12] If 0.35 mm was set as clinically relevant difference, a minimum sample size of 20 subjects was required per group to achieve a significant analysis, with a significance level of 0.05 and a statistical power of 90%. The sample size was calculated using the Power Analysis and Sample Size software (version 11; NCSS, Kaysville, Utah).

CBCT images were taken with NewTom Scanner (NewTom AG, Marburg, Germany) set as follows: 15 × 15 cm field of view, 110 kV, 2.81 mA, 3.6-second exposure, with axial slice thickness of 0.3 mm. The CBCT images were saved as digital imaging and communications in medicine format and reconstructed in Dolphin 3D Imaging software (version 11.8; Dolphin Imaging and Management Solutions, Chatsworth, Calif). Landmarks were located with Dolphin software and judged on 3-dimensional sections. The location of each landmark was calculated based on 3-dimensional coordinates. To standardize the orientation of craniofacial structures, 3-dimensional reference planes were set: (1) horizontal plane was defined as Frankfort plane; (2) midsagittal plane was perpendicular to Frankfort plane, passing through nasion and basion point; and (3) coronal plane was perpendicular to the above 2 planes and passing through basion point. Landmarks and reference planes are defined and shown in Table II and Figure 1.[22-24]

Table II. Reorientation of reference planes

Variable	*Definition*
Landmark	
Or (orbitale)	Lowest point of skeletal infraorbital margin
Po (porion)	Most superior point of skeletal external auditory meatus when the meatus is entirely encircled in bone
N (nasion)	Most anterior and median point along the frontonasal suture
Ba (basion)	Most inferior point along the anterior border of the foramen magnum
Me (menton)	Most inferior point of skeletal symphysis
Reference plane	
Horizontal plane (Frankfort plane)	Plane passing through bilateral orbitale and right porion
Midsagittal plane	Plane perpendicular to horizontal plane, passing through nasion and basion
Coronal plane	Plane perpendicular to the above 2 planes, passing through basion

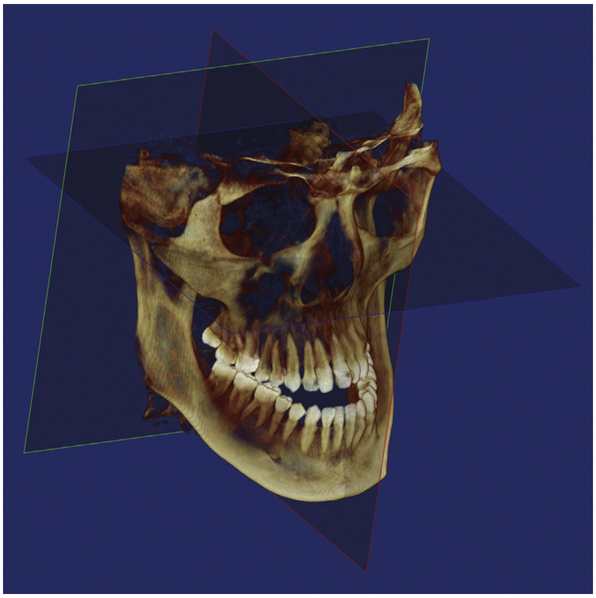

Fig 1. Reorientation of reference planes.

On long-axis plane, angle between long axis of tooth and midsagittal line was defined as buccolingual inclination of the tooth. Definition and measurement of long axis of teeth are shown in Table III and Figures 2 and 3.[9,10,25] If a tooth was buccally inclined, inclination angle of the tooth was defined as positive, and if it was lingually inclined, inclination angle was defined as negative.

Buccal and lingual alveolar bone thickness and alveolar width were measured at the level of buccal furcation plane of maxillary first molars. To adjust measurement plane as follows[26,27]: (1) sagittal view: rotate the section to make long axis of tooth parallel to the vertical reference line (Fig 4, *A*); (2) coronal view: rotate the section to ensure the horizontal line parallel to the palatal plane and nasal floor (Fig 4, *B*); (3) axial view: position the section at the level of buccal furcation of maxillary first molar to get the measurement plane (Fig 4, *C*). Measurements of buccolingual alveolar width and buccal and lingual alveolar bone thickness of teeth are described in Table IV and Figures 4-6.[26,27] Dehiscence and fenestration were defined according to the criteria published by Evangelista.[28] If bone defect happened in the measured horizontal plane, the value of bone thickness was marked as zero.

Statistical analysis

Landmarks of 20 patients chosen randomly were measured by 2 authors (X.N.H and X.Y.H) with 2-week interval to test interobserver and intraobserver reliability. Intraclass correlation coefficient was calculated with acceptable reproducibility of measurements. (Table V).

Paired *t* test was used to compare the parameters between deviated and nondeviated sides in each group (Tables VI and VII). If no significant difference was found, the average value was used. One-way analysis of variance and post-hoc Bonferroni test were used to compare the difference of the parameters among 3 groups (Tables VIII-XI). Spearman correlation test was used to evaluate the correlation among buccolingual inclination and alveolar bone thickness of maxillary posterior teeth, severity of mandibular deviation and sagittal discrepancy (Tables XII and XIII). All statistical tests were 2-sided, performed with SPSS software (version 23; IBM, Armonk, NY). Significance was defined as $P < 0.05$.

RESULTS

Intraclass correlation coefficient values of both intraobserver and interobserver reliability were > 0.75, indicating acceptable reproducibility of measurements (Table V).

Table III. Definition of long-axis planes and lines of maxillary posterior teeth

Variable/tooth	*Definition*
Long-axis plane of teeth	
Maxillary first molar	Plane perpendicular to midsagittal plane, passing through the central fossa and trifurcation of maxillary first molar
Maxillary premolar	Plane perpendicular to midsagittal plane, passing through the central fossa and furcation (multirooted) or root apex (single-rooted) of the premolar
Long axis of teeth	
Maxillary first molar	Line passing through the central fossa and trifurcation
Maxillary premolar (multirooted)	Line passing through the central fossa and furcation
Maxillary premolar (single-rooted)	Line passing through the central fossa and root apex

In group I and group III (symmetry), no significant difference was found in tooth inclination between the 2 sides; thus, the average value was used for subsequent statistical analysis ($P > 0.05$; Table VI). In group III (asymmetry), maxillary first molar and premolars were all more buccally inclined on deviated side than that of the nondeviated side ($P < 0.001$; Table VI).

The inclination of maxillary posterior teeth showed a significant difference among the 3 groups ($P < 0.001$; Table VIII). The results for multiple comparisons were shown in Table VIII. Maxillary first molar showed similar buccal inclination in group III (symmetry) and on the deviated side in group III (asymmetry), with average values of 14.12°and 13.84°, respectively. These values were significantly greater than that of group I, with an average value of 5.57°, and nondeviated side in group III (asymmetry), with an average value of 6.11° ($P < 0.001$; Table VIII).

Maxillary first premolar showed the greatest buccal inclination on the deviated side in group III (asymmetry) with an average value of 6.24° (Table VIII), which was significantly greater than that of group III (symmetry) with an average value of 3.07° ($P < 0.05$). In addition, both of these mean values were greater than that of the nondeviated side of group III (asymmetry) and Group I with average values of –0.12° and –1.04°, respectively ($P < 0.05$; Table VIII).

On the deviated side of the Class III group, a significant positive correlation was noted between the buccolingual inclination of maxillary posterior teeth and

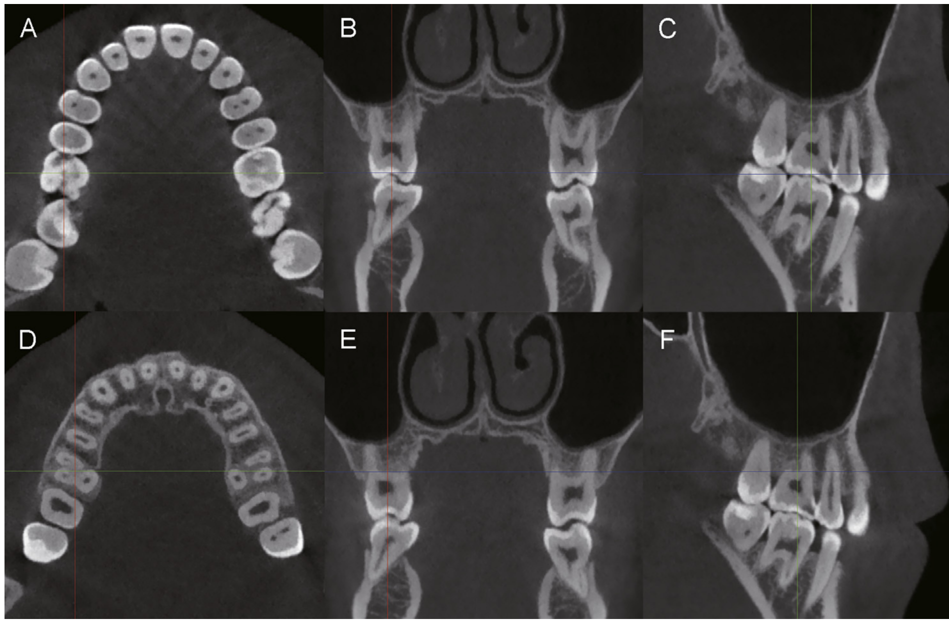

Fig 2. Location of central fossa and trifurcation of the maxillary first molar. Central fossa point in **A,** axial; **B,** coronal; and **C,** sagittal views. Trifurcation point in **D,** axial; **E,** coronal; and **F,** sagittal views.

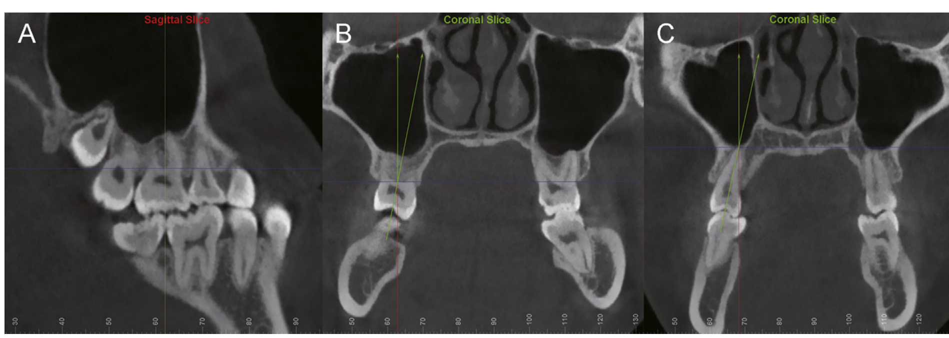

Fig 3. Measurement of buccolingual inclination of maxillary posterior teeth. **A,** in sagittal view, position the vertical reference line (*green*) to obtain the long-axis plane of maxillary first molar; **B** and **C,** in the long-axis plane, measure the inclination angle of teeth (*green arrows*).

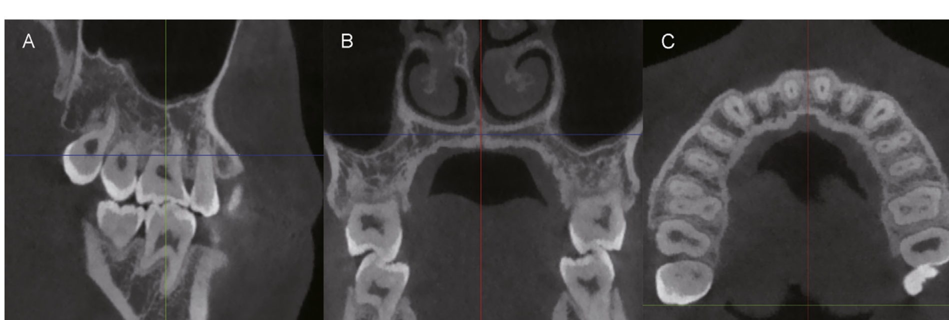

Fig 4. Reorientation of the buccal furcation plane on the right side. **A,** sagittal view; **B,** coronal view; and **C,** axial view.

Table IV. Measurements of buccolingual alveolar width, and buccal and lingual alveolar bone thickness of maxillary posterior teeth

Variable/tooth	*Definition*
Alveolar width	
Maxillary first molar	Distance of outer limits from buccal to lingual cortical plate, passing through the center of maxillary first molar's trifurcation, nearly perpendicular to each cortical plate
Maxillary premolar	Distance of outer limits from buccal to lingual cortical plate, passing through the center of furcation (multirooted) or center of root (single-rooted) of maxillary premolar, nearly perpendicular to each cortical plate
Buccal alveolar bone thickness	
Maxillary first molar	Distance between the most prominent point of mesiobuccal root and the nearest outer buccal cortical bone edge point
Maxillary premolar	Distance between the most prominent point of premolar root on buccal side and the nearest outer buccal cortical bone edge point
Lingual alveolar bone thickness	
Maxillary first molar	Distance between the most prominent point of palatal root and the nearest outer lingual cortical bone edge point
Maxillary premolar	Distance between the most prominent point of premolar root on lingual side and the nearest outer lingual cortical bone edge point

mandibular deviation, except for the maxillary first molar, with Spearman correlation coefficient of 0.297 for maxillary second premolar ($P < 0.05$; Table XII) and 0.399 for maxillary first premolar ($P < 0.001$; Table XII). On the nondeviated side, a significantly negative correlation was noted between the buccolingual inclination of maxillary posterior teeth and mandibular deviation, except for maxillary second premolar, with Spearman correlation coefficient of −0.489 for maxillary first molar ($P < 0.001$; Table XII) and −0.262 for maxillary first premolar ($P < 0.05$; Table XII).

A significant negative correlation was noted between the buccolingual inclination of maxillary posterior teeth and ANB angle in patients with symmetrical skeletal Class III and skeletal Class I malocclusion. The Spearman correlation coefficients of the maxillary first molar, second premolar, and first premolar were −0.687, −0.485 and −0.506, respectively ($P < 0.001$; Table XIII).

In group I and group III (symmetry), buccal and lingual alveolar bone thickness had no statistically significant difference between deviated and nondeviated sides in each group; thus, the average value of both sides was used for subsequent statistical analysis ($P > 0.05$; Table VII). In group III (asymmetry), buccal alveolar bone thickness of maxillary first molar and second premolar was thinner on deviated side than that of the nondeviated side ($P < 0.01$; Table VII), whereas lingual alveolar bone thickness of maxillary posterior teeth was thinner on nondeviated side than that of the deviated side ($P < 0.05$; Table VII).

The buccal alveolar bone thickness of the maxillary first molar and first premolar showed a significant difference among all groups ($P < 0.05$; Table X). The results from multiple comparisons are shown in Table X. The maxillary first molar showed a similar buccal alveolar bone thickness in group III (symmetry) and the deviated side of group III (asymmetry), with average values of 1.19 mm and 1.21 mm, accounting for 8.91% and 8.53% of buccolingual alveolar width of the maxillary first molar, respectively. These values were significantly thinner than that of the nondeviated side in group III (asymmetry) and group I, with an average value of 1.76 mm and 1.83 mm, accounting for 12.51% and 12.69% of buccolingual alveolar width in these 2 groups, respectively ($P < 0.05$; Table X).

Maxillary second premolar showed the thinnest buccal alveolar bone thickness on the deviated side in group III (asymmetry), with an average value of 1.88 mm, accounting for 16.38% of buccolingual alveolar width of maxillary second premolar. Although it showed the thickest buccal alveolar bone thickness in group I, with an average value of 2.33 mm, accounting for 20.05% of buccolingual alveolar width, there was no significant difference noted when compared to the values among all groups ($P > 0.05$; Table X).

Maxillary first premolar showed the thinnest buccal alveolar bone thickness on the deviated side in group III (asymmetry), with an average value of 0.87 mm, accounting for 8.36% of buccolingual alveolar width. This value was significantly thinner than that of group I, with an average value of 1.28 mm, accounting for 11.82% of buccolingual alveolar width ($P < 0.05$; Table X).

The lingual alveolar bone thickness of the maxillary first molar and second premolar showed a significant difference among all groups ($P < 0.01$; Table XI). The results of multiple comparisons are shown in Table XI.

The maxillary first molar showed the thinnest lingual alveolar bone thickness on nondeviated side in group III (asymmetry) with the average value of 0.94 mm, accounting for 6.68% of buccolingual

Fig 5. Measurements of buccolingual alveolar width, and buccal and lingual alveolar bone thickness of maxillary posterior teeth. **A,** Measurement of buccolingual alveolar width (*green lines*) of maxillary posterior teeth: D6, alveolar with of maxillary first molar; D5, alveolar width of maxillary second premolar; and D4, alveolar width of maxillary first premolar. **B,** Measurement of buccal and lingual alveolar bone thickness (*green lines*) of maxillary posterior teeth: 6B, buccal alveolar bone thickness of maxillary first molar; 5B, buccal alveolar bone thickness of maxillary second premolar; 4B, buccal alveolar bone thickness of maxillary first premolar; 6L, lingual alveolar bone thickness of maxillary first molar; 5L, lingual alveolar bone thickness of maxillary second premolar; and 4L, lingual alveolar bone thickness of maxillary first premolar. *B*, buccal alveolar bone thickness; *D*, distance of buccolingual alvoelar width; *L*, lingual alveolar bone thickness.

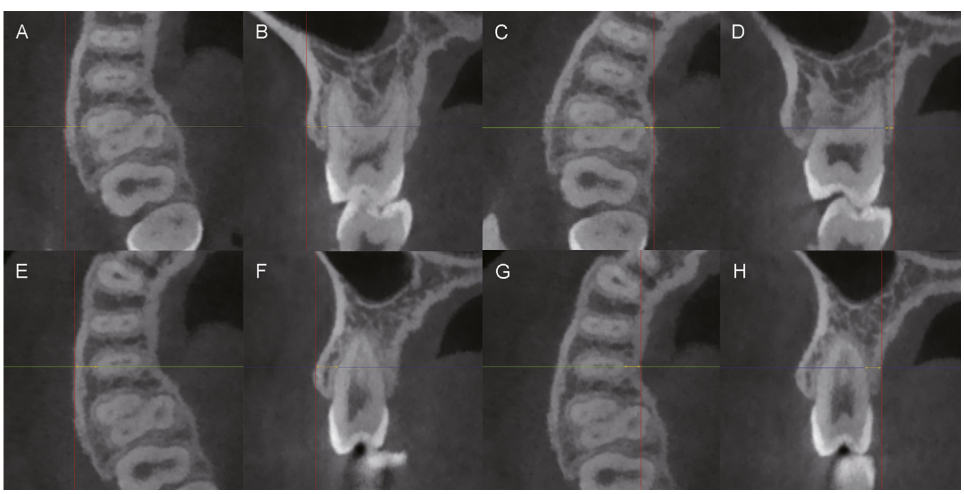

Fig 6. Representative cone-beam computed tomography images of alveolar bone thickness (*yellow lines*) of a patient in group I. Buccal alveolar bone thickness of maxillary first molar: **A,** axial; and **B,** coronal views. Lingual alveolar bone thickness of maxillary first molar: **C,** axial; and **D,** coronal views. Buccal alveolar bone thickness of maxillary second premolar: **E,** axial; and **F,** coronal views. Lingual alveolar bone thickness of maxillary second premolar: **G,** axial; and **H,** coronal views.

alveolar width. This value was similar to that of group III (symmetry), with an average value of 1.11 mm, accounting for 8.31% of buccolingual alveolar width ($P > 0.05$; Table XI). However, it was significantly thinner than that of the deviated side in group III (asymmetry) and group I, with each having an average value of 1.32 mm ($P < 0.05$; Table XI), accounting for 9.42% and 9.26% of buccolingual alveolar width in these 2 groups, respectively (Table XI).

Table V. Intraclass correlation coefficient of maxillary posterior teeth variables for interobserver and intraobserver reliability

	Interobserver		*Intraobserver*	
Variable/tooth	*Deviated*	*Nondeviated*	*Deviated*	*Nondeviated*
A6	0.804	0.821	0.900	0.933
A5	0.893	0.820	0.958	0.932
A4	0.864	0.934	0.976	0.968
D6	0.941	0.944	0.988	0.985
D6B	0.871	0.855	0.980	0.912
D6L	0.895	0.891	0.891	0.900
D5	0.966	0.965	0.985	0.981
D5B	0.920	0.908	0.979	0.972
D5L	0.834	0.819	0.949	0.963
D4	0.880	0.966	0.938	0.980
D4B	0.833	0.878	0.911	0.968
D4L	0.803	0.926	0.896	0.955

A4, buccolingual inclination of maxillary first premolar; *A5,* buccolingual inclination of maxillary second premolar; *A6,* buccolingual inclination of maxillary first molar; *D4,* buccolingual alveolar width of maxillary first premolar; *D4B,* buccal alveolar bone thickness of maxillary first premolar; *D4L,* lingual alveolar bone thickness of maxillary first premolar; *D5,* buccolingual alveolar width of maxillary second premolar; *D5B,* buccal alveolar bone thickness of maxillary second premolar; *D5L,* lingual alveolar bone thickness of maxillary second premolar; *D6,* buccolingual alveolar width of maxillary first molar; *D6B,* buccal alveolar bone thickness of maxillary first molar; *D6L,* lingual alveolar bone thickness of maxillary first molar.

The lingual alveolar bone thickness of maxillary second premolar showed a significant difference between the nondeviated side and the deviated side in group III (asymmetry) with an average value of 1.75 mm and 2.25 mm, respectively ($P < 0.01$; Table VII).

Maxillary first premolar showed the thinnest lingual alveolar bone thickness on nondeviated side in group III (asymmetry) with average value of 1.85 mm, accounting for 17.87% of buccolingual alveolar width, which was thinner than that of group I, the deviated side in group III (asymmetry), and group III (symmetry) with average value of 1.91 mm, 2.16 mm and 2.19 mm, respectively; however, differences were not statistically significant ($P > 0.05$; Table XI).

The buccal alveolar bone thickness of the maxillary first molar on nondeviated side showed a significantly positive correlation with mandibular deviation with a Spearman correlation coefficient of 0.307 in patients with skeletal Class III malocclusion ($P < 0.01$; Table XII). The buccal alveolar bone thickness on deviated side and the lingual alveolar bone thickness on deviated and nondeviated sides showed no significant correlation with mandibular deviation ($P > 0.05$; Table XII).

The buccal alveolar bone thickness of maxillary first molar and first premolar showed a significantly positive correlation with ANB angle, with Spearman correlation coefficients of 0.479 and 0.257, respectively ($P < 0.05$; Table XIII). The buccal alveolar bone thickness of maxillary second premolar and lingual alveolar bone thickness showed no significant correlation with ANB angles ($P > 0.05$; Table XIII). The buccolingual alveolar width of maxillary posterior teeth in each group was shown and compared in Tables VII and IX. The values of the maxillary first molar and second premolar showed a positive correlation with ANB angle ($P < 0.05$; Table XIII).

DISCUSSION

Researches have reported that the sagittal skeletal patterns can affect buccolingual inclination of the maxillary posterior teeth.[9] In our study, we found that the ANB angle had a significant negative correlation with buccolingual inclination of the maxillary posterior teeth in patients with symmetrical skeletal Class III and Class I malocclusion ($P < 0.001$; Table XIII). Thus, with a decreasing ANB angle, the posterior teeth were more likely to incline buccally.

Mandibular deviation correlated with buccolingual inclination of the maxillary posterior teeth in patients with skeletal Class III malocclusion, but with the opposite effect on deviated and nondeviated sides. On the deviated side, patients with asymmetrical skeletal Class III malocclusion showed more buccally inclined maxillary posterior teeth from maxillary first molar to first premolar, which were significantly greater than that of patients with skeletal Class I malocclusion ($P < 0.001$; Table VIII).

Similar to Ahn et al,[9] the maxillary posterior teeth were buccally inclined on the deviated side compared with the nondeviated side in patients with asymmetrical skeletal Class III malocclusion ($P < 0.001$; Table VI). The buccolingual inclination of maxillary premolars had a positive correlation with mandibular deviation, which was also consistent with Ahn et al,[9] indicating that maxillary premolars on deviated side were more likely to incline buccally with increasing severity of mandibular deviation ($P < 0.05$; Table XII). It was a kind of compensation for transverse discrepancy with increased buccal inclination of the maxillary posterior teeth on deviation side. However, in contrast to Ahn et al,[9] our study did not find a correlation with maxillary first molars, which was consistent with Lee et al.[29] These findings may be due to our inclusion of patients with asymmetrical skeletal Class III malocclusion with crossbite in the maxillary first molar region on deviated side in this study. These

Table VI. Comparison of buccolingual inclination of maxillary posterior teeth between deviated and nondeviated sides in each group

	Group III (asymmetry)			Group III (symmetry)			Group I		
Variable/tooth	*Deviated*	*Nondeviated*	P	*Deviated*	*Nondeviated*	P	*Deviated*	*Nondeviated*	P
Maxillary first molar (°)	13.84 ± 6.43	6.11 ± 7.74	0.000*	14.45 ± 4.93	13.80 ± 7.06	0.548	5.93 ± 5.41	5.21 ± 5.62	0.435
Maxillary second premolar (°)	7.96 ± 5.34	2.45 ± 5.85	0.000*	5.47 ± 4.76	4.84 ± 5.10	0.573	0.14 ± 4.93	0.11 ± 5.75	0.972
Maxillary first premolar (°)	6.24 ± 5.22	−0.12 ± 4.54	0.000*	3.32 ± 4.63	2.83 ± 4.11	0.536	−0.40 ± 3.65	−1.68 ± 4.10	0.069

Data presented as mean ± standard deviation. Paired *t* test was used to compare the values on deviated and nondeviated sides in each group.
*$P < 0.001$.

Table VII. Comparison of buccolingual alveolar width and buccal and lingual alveolar bone thickness of maxillary posterior teeth between deviated and nondeviated sides in each group

	Group III (asymmetry)			Group III (symmetry)			Group I		
Variable/tooth	*Deviated*	*Nondeviated*	P	*Deviated*	*Nondeviated*	P	*Deviated*	*Nondeviated*	P
Alveolar width (mm)									
Maxillary first molar	13.92 ± 1.22	13.83 ± 1.31	0.573	13.22 ± 1.01	13.26 ± 0.99	0.788	14.27 ± 1.44	14.19 ± 1.34	0.535
Maxillary second premolar	11.19 ± 1.25	10.99 ± 1.16	0.155	10.86 ± 1.02	10.87 ± 1.27	0.937	11.57 ± 1.21	11.55 ± 1.17	0.878
Maxillary first premolar	10.51 ± 1.13	10.30 ± 1.02	0.121	10.17 ± 0.99	10.26 ± 1.33	0.606	10.84 ± 1.16	10.93 ± 1.22	0.495
Buccal alveolar bone thickness (mm)									
Maxillary first molar	1.21 ± 0.79	1.76 ± 0.95	0.000‡	1.20 ± 0.66	1.18 ± 0.66	0.800	1.87 ± 0.84	1.78 ± 0.78	0.392
Maxillary second premolar	1.88 ± 0.96	2.15 ± 0.87	0.006†	2.03 ± 0.74	2.05 ± 0.91	0.858	2.36 ± 0.79	2.31 ± 0.76	0.703
Maxillary first premolar	0.87 ± 0.62	0.94 ± 0.64	0.364	0.98 ± 0.62	0.96 ± 0.66	0.864	1.24 ± 0.52	1.32 ± 0.51	0.363
Lingual alveolar bone thickness (mm)									
Maxillary first molar	1.32 ± 0.57	0.94 ± 0.54	0.000‡	1.16 ± 0.52	1.06 ± 0.64	0.396	1.33 ± 0.44	1.32 ± 0.40	0.901
Maxillary second premolar	2.25 ± 0.66	1.75 ± 0.81	0.001†	2.05 ± 0.66	2.00 ± 0.73	0.717	1.82 ± 0.70	1.88 ± 0.59	0.651
Maxillary first premolar	2.16 ± 0.96	1.85 ± 1.01	0.044*	2.21 ± 0.82	2.17 ± 1.14	0.878	1.82 ± 0.73	1.99 ± 0.79	0.194

Data presented as mean ± standard deviation. Paired *t* test was used to compare the values on deviated and nondeviated sides in each group.
*$P < 0.05$; †$P < 0.01$; ‡$P < 0.001$.

Table VIII. Comparison of buccolingual inclination of maxillary posterior teeth among 3 groups

	Group III (asymmetry)					
Variable/tooth	*Deviated*	*Nondeviated*	*Group III (symmetry)*	*Group I*	P	*Multiple comparison*
Maxillary first molar (°)	13.84 ± 6.43	6.11 ± 7.74	14.12 ± 5.31	5.57 ± 4.92	0.000‡	I = ND ND < D‡ D = S
Maxillary second premolar (°)	7.96 ± 5.34	2.45 ± 5.85	5.15 ± 3.90	0.12 ± 4.64	0.000‡	I = ND ND = S, I < S* S = D ND < D‡
Maxillary first premolar (°)	6.24 ± 5.22	−0.12 ± 4.54	3.07 ± 3.83	−1.04 ± 3.41	0.000‡	I = ND ND < S* S < D*

D, deviated side of group III (asymmetry); *I,* group I; *ND,* nondeviated side of group III (asymmetry); *S,* group III (symmetry).
Data presented as mean ± standard deviation. One-way analysis of variance and post-hoc Bonferroni tests were used to compare the values among 3 groups.
*$P < 0.05$; ‡$P < 0.001$.

Table IX. Comparison of buccolingual alveolar width of maxillary posterior teeth among 3 groups

Variable/tooth	Group III (asymmetry) Deviated	Nondeviated	Group III (symmetry)	Group I	P	Multiple comparison
Maxillary first molar (mm)	13.92 ± 1.22	13.83 ± 1.31	13.24 ± 0.93	14.23 ± 1.34	0.018*	S = ND = D D = 1 S < 1*
Maxillary second premolar (mm)	11.19 ± 1.25	10.99 ± 1.16	10.87 ± 1.08	11.56 ± 1.13	0.106	S = ND = D = 1
Maxillary first premolar (mm)	10.51 ± 1.13	10.30 ± 1.02	10.22 ± 1.09	10.88 ± 1.14	0.081	S = ND = D = 1

D, Deviated side of group III (asymmetry); *I,* group I; *ND,* nondeviated side of group III (asymmetry); *S,* group III (symmetry).
Data presented as mean ± standard deviation. One-way analysis of variance and post-hoc Bonferroni tests were used to compare the values among 3 groups.
*$P < 0.05$.

Table X. Comparison of buccal alveolar bone thickness of maxillary posterior teeth among 3 groups

Variable/tooth	Group III (asymmetry) Deviated	Nondeviated	Group III (symmetry)	Group I	P	Multiple comparison
Maxillary first molar (mm)	1.21 ± 0.79	1.76 ± 0.95	1.19 ± 0.61	1.83 ± 0.76	0.000‡	S = D D < ND* ND = 1
Maxillary first molar (%)	8.53 ± 5.21	12.51 ± 6.27	8.91 ± 4.35	12.69 ± 4.62	0.000‡	D = S S < ND* ND = 1
Maxillary second premolar (mm)	1.88 ± 0.96	2.15 ± 0.87	2.04 ± 0.72	2.33 ± 0.70	0.151	D = S = ND = 1
Maxillary second premolar (%)	16.38 ± 7.27	19.38 ± 6.97	18.46 ± 5.42	20.05 ± 5.22	0.086	D = S = ND = 1
Maxillary first premolar (mm)	0.87 ± 0.62	0.94 ± 0.64	0.97 ± 0.56	1.28 ± 0.46	0.028*	D = ND = S ND = S = 1 D < 1*
Maxillary first premolar (%)	8.36 ± 6.03	9.07 ± 6.12	9.30 ± 5.11	11.82 ± 4.29	0.071	D = ND= S = 1

D, Deviated side of group III (asymmetry); *I,* group I; *ND,* nondeviated side of group III (asymmetry); *S,* group III (symmetry).
Data presented as mean ± standard deviation. Percent of variables: (buccal alveolar bone thickness/alveolar width) × 100. One-way analysis of variance and post-hoc Bonferroni tests were used to compare the values among 3 groups.
*$P < 0.05$; ‡$P < 0.001$.

patients accounted for nearly 75% of the asymmetrical subjects, while half of the asymmetrical patients in Ahn et al[9] had the same situation.[9] In addition, the difference in study findings might be explained by greater severity of skeletal Class III subjects in our study, with a mean ANB angle of −3.9°, while the experimental groups in Ahn et al[9] had an average ANB angle of −1.9° to −1.7°. It has been previously reported that with a more severe skeletal Class III pattern, posterior teeth inclined more buccally to compensate for transverse discrepancy, and a posterior crossbite was commonly observed.[9,11] Thus, on deviated side of patients with asymmetrical skeletal Class III malocclusion, the increased posterior crossbite tendency might constrict the increasing buccal inclination of maxillary first molars.

On the nondeviated side, patients with asymmetrical skeletal Class III malocclusion showed more lingually inclined maxillary posterior teeth similar to that of skeletal Class I patient ($P > 0.05$; Table VIII). Maxillary posterior teeth on nondeviated side were more likely to incline lingually with increasing severity of mandibular deviation ($P > 0.05$; Table XII)

It has been reported that compared with patients with skeletal Class I malocclusion, labiolingual alveolar bone thickness in anterior teeth area of patients with skeletal Class III malocclusionis was thinner.[8,12,14] Our research on alveolar bone thickness of posterior teeth area in patients with severe skeletal Class III malocclusion has supplemented information of periodontal condition for these patients, which might help doctors to minimize the risk of dehiscence and fenestration during presurgical decompensation treatment.

Taking patients with symmetrical skeletal Class III and skeletal Class I malocclusion into consideration, our study found that with a decreasing ANB value, thinner buccal alveolar bone thickness of the maxillary first molar and first premolar was noted, which is consistent with Sendyk et al[12]($P < 0.05$; Table XIII). In

Table XI. Comparison of lingual alveolar bone thickness of maxillary posterior teeth among 3 groups

	Group III (asymmetry)					
Variable/tooth	*Deviated*	*Nondeviated*	*Group III (symmetry)*	*Group I*	P	*Multiple comparison*
Maxillary first molar (mm)	1.32 ± 0.57	0.94 ± 0.54	1.11 ± 0.49	1.32 ± 0.38	0.003†	ND = S S = D = 1 ND < D† ND < 1*
Maxillary first molar (%)	9.42 ± 3.64	6.68 ± 3.51	8.31 ± 3.46	9.26 ± 2.39	0.002†	ND = S S = 1 ND < 1* 1 = D
Maxillary second premolar (mm)	2.25 ± 0.66	1.75 ± 0.81	2.02 ± 0.59	1.85 ± 0.57	0.010†	ND = 1 = S 1 = S = D ND < D†
Maxillary second premolar (%)	20.16 ± 5.77	15.87 ± 7.45	18.54 ± 4.94	15.87 ± 3.76	0.003†	ND = 1 = S S = D ND < D† 1 < D*
Maxillary first premolar (mm)	2.16 ± 0.96	1.85 ± 1.01	2.19 ± 0.81	1.91 ± 0.67	0.273	ND = 1 = D = S
Maxillary first premolar (%)	20.49 ± 8.97	17.87 ± 9.97	21.42 ± 7.43	17.34 ± 4.76	0.135	1 = ND = D = S

Data presented as mean ± standard deviation. Percent of variables: (lingual alveolar bone thickness/alveolar width) × 100. One-way analysis of variance and post-hoc Bonferroni tests were used to compare the values among 3 groups.
D, Deviated side of group III (asymmetry); *I,* group I; *ND,* nondeviated side of group III (asymmetry); *S,* group III (symmetry).
$^*P < 0.05$; $^†P < 0.01$.

addition, the maxillary first molar and second premolar tended to show thinner buccolingual alveolar width with decreased ANB value ($P < 0.05$; Table XIII). No significant correlation was noted between lingual alveolar bone thickness and ANB value ($P > 0.05$; Table XIII).

On the deviated side of patients with asymmetrical skeletal Class III malocclusion, buccal alveolar bone thickness of maxillary posterior teeth showed no significant difference with that in patients with symmetrical skeletal Class III malocclusion but were smaller than that of patients with skeletal Class I malocclusion ($P < 0.05$; Table X).

On the deviated side of patients with asymmetrical skeletal Class III malocclusion and in patients with symmetrical skeletal Class III malocclusion, maxillary posterior teeth were 7.8° and 5.9°, more buccally inclined when compared with patients with skeletal Class I malocclusion ($P < 0.01$; Table VIII). Considering the thinner buccal alveolar bone on deviated side of patients with asymmetrical skeletal Class III and in patients with symmetrical skeletal Class III malocclusion, decompensation of the buccally inclined maxillary posterior teeth should be more cautious with high risk of swinging the buccal root to the edge of cortical bone with lingual inclination movement of the teeth in Class III subjects. In addition, when the thin buccal alveolar bone of these positions hinders transverse expansion of maxillary arch, extractions in the maxillary arch of these subjects should be considered for presurgical orthodontic treatment in order to provide space retracting compensatory proclined maxillary anterior teeth and buccally inclined maxillary posterior teeth, leveling maxillary Spee curve without overpowering the thin buccal alveolar bone of maxillary posterior teeth.[30]

Maxillary first molar on nondeviated side of patients with asymmetrical skeletal Class III malocclusion had buccal alveolar bone thickness similar to that in patients with skeletal Class I malocclusion and showed positive correlation with mandibular deviation, which might be related with compensatory translocation of teeth toward deviated side but needed further investigation ($P < 0.01$, Table XII).

A few studies have reported alveolar bone thickness of maxillary posterior teeth. In maxilla, the first premolar and mesiobuccal root of first molar tend to present thinner buccal alveolar bone thickness compared with the second premolar in both patients with skeletal Class I and Class III malocclusion, which is consistent with our study.[12,31] In Sendky et al,[12] buccal alveolar bone thickness of the maxillary first premolar, second premolar, and mesiobuccal root of maxillary first molar was 0.4 mm, 0.6 mm, and 0.5 mm in patients with skeletal Class III malocclusion, respectively; and 0.7 mm, 1.3 mm, and 1.0 mm in patients with skeletal Class I malocclusion measured at 3 mm from cementoenamel junction.[12] In Temple et al,[31] the geometric mean values were 0.719 mm, 1.239 mm, and 0.766 mm, respectively, in a large sample size without distinguishing skeletal

Table XII. Correlations between mandibular deviation and measurements of maxillary posterior teeth in patients with skeletal Class III malocclusion (n = 69)

Variable/tooth	*Spearman correlation coefficient*	P
Buccolingual inclination of teeth on deviated side (°)		
Maxillary first molar	0.004	0.972
Maxillary second premolar	0.297	0.013*
Maxillary first premolar	0.399	0.001‡
Buccolingual inclination of teeth on nondeviated side (°)		
Maxillary first molar	−0.489	0.000‡
Maxillary second premolar	−0.197	0.105
Maxillary first premolar	−0.262	0.030*
Buccal alveolar bone thickness of teeth on deviated side (mm)		
Maxillary first molar	0.071	0.561
Maxillary second premolar	−0.022	0.858
Maxillary first premolar	−0.052	0.669
Buccal alveolar bone thickness of teeth on nondeviated side (mm)		
Maxillary first molar	0.307	0.010†
Maxillary second premolar	0.121	0.322
Maxillary first premolar	0.053	0.663
Lingual alveolar bone thickness of teeth on deviated side (mm)		
Maxillary first molar	0.170	0.162
Maxillary second premolar	0.233	0.054
Maxillary first premolar	0.072	0.554
Lingual alveolar bone thickness of teeth on nondeviated side (mm)		
Maxillary first molar	−0.023	0.854
Maxillary second premolar	−0.170	0.164
Maxillary first premolar	−0.077	0.527

*$P < 0.05$; †$P < 0.01$; ‡$P < 0.001$.

Table XIII. Correlations between ANB value and measurements of maxillary posterior teeth in patients with symmetrical skeletal Class III and skeletal Class I malocclusion (n = 60)

Variable/tooth	*Spearman correlation coefficient*	P
Buccolingual inclination of teeth (°)		
Maxillary first molar	−0.687	0.000***
Maxillary second premolar	−0.485	0.000***
Maxillary first premolar	−0.506	0.000***
Buccal alveolar bone thickness of teeth (mm)		
Maxillary first molar	0.479	0.000***
Maxillary second premolar	0.145	0.270
Maxillary first premolar	0.257	0.047*
Lingual alveolar bone thickness of teeth (mm)		
Maxillary first molar	0.215	0.100
Maxillary second premolar	−0.103	0.434
Maxillary first premolar	−0.189	0.148
Buccolingual alveolar width of teeth (mm)		
Maxillary first molar	0.414	0.001**
Maxillary second premolar	0.295	0.022*
Maxillary first premolar	0.244	0.060

*$P<0.05$; **$P<0.01$; ***$P<0.001$.

patterns measured at 3 mm apical to the alveolar crest.[31] Reported disparities with buccal alveolar bone thickness could be explained by variations in measurement levels, race, and inclusion criteria. In our study, buccal alveolar bone thickness of maxillary posterior teeth in both patients with asymmetrical and symmetrical skeletal Class III malocclusionwas about 0.35 mm thinner, on average, compared with patients with skeletal Class I malocclusion, which equivalently accounted for over 25% of buccal alveolar bone thickness of patients with skeletal Class III malocclusion.

On the nondeviated side of patients with asymmetrical skeletal Class III malocclusion, lingual alveolar bone of maxillary first molar was about 0.4 mm thinner than that of patients with skeletal Class I malocclusions ($P < 0.05$; Table XI), which suggested that the upright of maxillary posterior teeth in patients with asymmetrical skeletal Class III malocclusion might have the potential risk of swinging the palatal root to touch the edge of cortical bone.

Some limitations remained in this study. Buccal and lingual alveolar bone thickness was only measured at furcation level of maxillary first molar in this study. Further measurement on apical level or other planes of the maxillary posterior teeth, as well as measurement of buccolingual inclination and alveolar bone thickness of mandibular posterior teeth, may help bring more information for a better understanding of the periodontal condition of the teeth. In addition, sexual dimorphism should be considered with larger sample sizes in future studies.

CONCLUSIONS

1. With increasing severity of skeletal Class III pattern, maxillary posterior teeth were more likely to incline buccally.
2. Maxillary posterior teeth were buccally inclined on the deviated side and upright on the nondeviated side in patients with skeletal Class III malocclusion with mandibular asymmetry.
3. In patients with skeletal Class III malocclusion with mandibular asymmetry, buccal alveolar bone of maxillary posterior teeth was thinner on the

deviated side while lingual alveolar bone was thinner on the nondeviated side.

4. In skeletal symmetrical patients, a decreased ANB value correlated with thinner buccal alveolar bone of maxillary first molar and first premolar.
5. Decompensation of buccally inclined posterior teeth in patients with skeletal Class III malocclusion should be more cautious to avoid a high risk of fenestration and dehiscence.

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