Original Article

Relationship between different skeletal facial types and anterior alveolar bone thickness with cone-beam computed tomography in an Asian population

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Background: To investigate the relationship between different skeletal facial types and anterior alveolar bone thickness with cone-beam computed tomography (CBCT) in an Asian population.

Methods: A total of 130 patients with 1,560 healthy anterior teeth were enrolled. On three-dimensional reconstructed images, Frankfurt-mandibular plane angle (FMA) value and angle formed by subspinale, nasion, and supramental (ANB) value were measured, and subjects were categorized into different groups based on their vertical skeletal patterns as well as sagittal jaw relationships. For each tooth, the thickness of alveolar bone was measured at three locations: 1, 3, and 5 mm apical to alveolar bone crest. Descriptive statistics were used. Kruskal-Wallis test, one-way ANOVA, and independent-samples *t*-test were used for further analysis.

Results: Men's maxillary anterior teeth's lingual alveolar bone thickness was significantly greater than women's ($P<0.05$). Strong correlations were found between vertical skeletal patterns and lingual alveolar bone thickness of maxillary/mandibular anterior teeth ($R^2=0.302$, $P<0.01$ in the maxilla; $R^2=0.311$, $P<0.01$ in the mandible). However, no significant difference was shown in the alveolar bone thickness among people with different sagittal bone profiles.

Conclusions: The lingual alveolar bone of the maxillary anterior teeth is thicker in males than in females. With the increase of FMA, the anterior alveolar bone gradually became thinner.

Keywords: Skeletal facial type; alveolar bone; thickness; cone-beam computed tomography (CBCT)

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Introduction

Anterior tooth movement plays an important role in orthodontic diagnosis, treatment planning and outcomes (1). Although orthodontic treatment has a well-established system, it still has many uncontrollable potential risks (2,3). The extent of orthodontic tooth movement is related to the magnitude and duration of the applied force, and depends on the response ability of the periodontal bone (4). Under the action of orthodontic forces, teeth on cancellous bone undergoing alveolar bone remodeling can be easily moved. However, when teeth are moved to the cortical bone at the edge of the alveolar ridge, further movement becomes difficult. It carries risks such as root resorption and dehiscence of the bone (5,6). Sheng *et al.* studied 21 patients with 252 anterior teeth before and after orthodontic treatment (7). They found that the alveolar bone on the lingual surface of the maxillary and mandibular anterior teeth was significantly more likely to be detected as dehiscence. And the thinner the alveolar bone is, the more likely bone defect will occur. In addition, if the underlying alveolar bone below is too thin, there could be an increased risk of soft tissue recession (8). Therefore, orthodontists need to make a preliminary judgment on the range of tooth movement and alveolar bone thickness before orthodontic treatment. The initial physiological morphology of alveolar bone is an important factor limiting the anterior tooth movement in orthodontic treatment (9).

Alveolar bone morphology is related to many factors, such as skeletal type, muscle, age, gender, etc. (10-12). Baysal *et al.* reported that the labial alveolar bones of the mandibular incisors in the skeletal class I group were thicker than that in the class II group (6). But Molina-Berlanga's study found that the alveolar bones in the lower incisors area were thinner in class I group patients (13). In the vertical direction, Sadek *et al.* found that the high-angle group had thinner alveolar bones in the middle and apex areas of the root of maxillary anterior teeth by using cone-beam computed tomography (CBCT) (14). Similar results have been reported in related studies (15,16). In addition, Do's research indicated that the palatal alveolar bone is thicker in men than women (17). However, Ohiomoba's study showed no gender differences in alveolar bone thickness, despite women having higher alveolar bone density (18).

The above researches showed some contradicted results, which need expanded samples to validate. However, establishing defensible guidelines for alveolar bone thickness, cannot be inferred from such studies. Given that the strength of masticatory muscles is closely related to the vertical and sagittal skeletal patterns, we hypothesized that the alveolar bone thickness should vary among people with different skeletal types. In this study, the labial and lingual alveolar bone thickness of anterior teeth among Asian populations with different skeletal types were assessed using CBCT, which gives the guide to predict the anterior alveolar bone thickness according to the skeletal types. We present the following article in accordance with the MDAR reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-935/rc).

Methods

Patient selection

This study was approved by the Ethics Committee of the Nanjing Stomatological Hospital (No. KY-2021NL-26), and was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was obtained from all patients. The samples measured in this study were obtained from patients in Nanjing Stomatological Hospital and obtained authorization from all patients. A total of 130 CBCT images were included. These CBCT scans are from patients aged 18 to 40 years, and the criteria for inclusion were a full complement of erupted permanent teeth (with or without third molars). Patients were excluded according to the following criteria: (I) orthodontic experience; (II) missing, impacted, or redundant anterior teeth; (III) anterior tooth crowding more than 4 mm; (IV) periodontitis; (V) temporomandibular joint disease; (VI) cleft lip and palate or other craniofacial deformities; (VII) jaw cyst or tumor; (VIII) history of facial trauma or orthognathic surgery. Finally, 130 participants were included in this study, including 48 males and 82 females with an average age of 22.86.

CBCT and graphical measurement

CBCT images were obtained from a NewTom VG scanner (QR Srl, Verona, Italy). The operation was carried out according to the manufacturer's instructions with 110 kV, 5 mA, 0.125 mm voxel size, 1.8 s exposure time, and the scope of the image was 160×160×150 cubic mm. We scanned CBCT images to generate image data in a standard file format called digital imaging and communications in medicine (DICOM). The collected CBCT data were 3D reconstructed and evaluated by the built-in software NNT 5.3 (J Morita Manufacturing Corp, Kyoto, Japan). All operations were performed on a 29.7-inch RadiForce MX300 W (Eizo Nanao Corporation, Hakusan, Japan) screen with 2,560×1,600 pixels resolution.

The measurement markers were defined on the reconstructed CBCT image (*Figure 1A,1B*). According to the value of Frankfurt-mandibular plane angle (FMA), these patients' vertical facial patterns were divided into three types: high-angle facial pattern (FMA >32°), average-angle facial pattern (FMA ranging from 22° to 32°), and low-angle facial pattern (FMA <22°). In the sagittal direction, according to the value of angle formed by subspinale, nasion, and supramental (ANB), patients were divided into class I (ANB ranging from 0° to 4°), class II (ANB >4°), and class III (ANB <0°).

To find the best section for measuring the thickness of alveolar bone, we selected the layer with the largest cross-

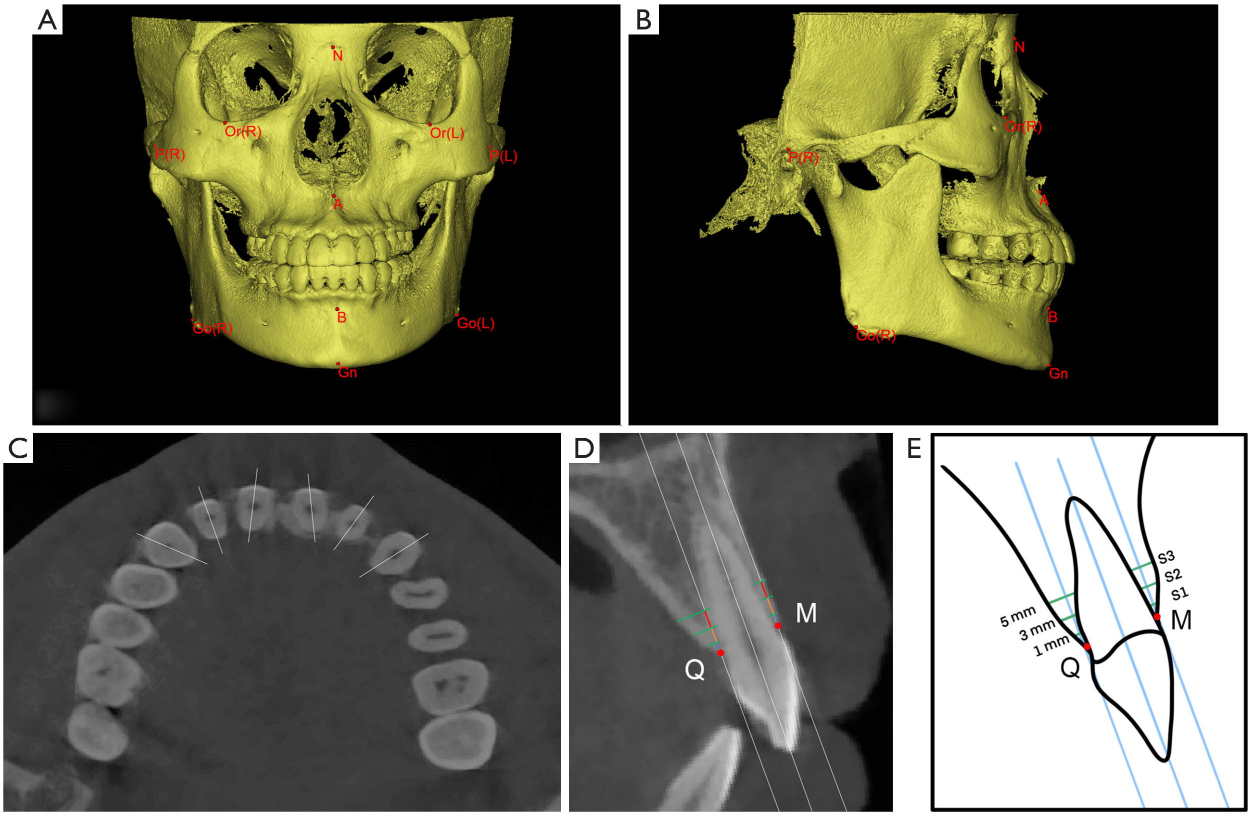

Figure 1 Method and location for measuring alveolar bone thickness. (A and B) Determining the landmarks used for cephalometric measurement; (C) the horizontal section with the largest cross-sectional area of anterior teeth; (D) the longitudinal section of anterior tooth with markers for measuring alveolar bone thickness; (E) schematic diagram of markers for measuring alveolar bone thickness. Landmarks in cephalometry: P, porion; Or, orbitale; N, nasion; A, subspinale; B, supramental; Go, gonion; Gn, gnathion; M, alveolar bone crest on the labial side; Q, alveolar bone crest on the lingual side.

sectional anterior tooth area in the horizontal section of the CBCT (*Figure 1C*). Then we connected the most protruding points on the lingual and labial sides of the tooth, and made a vertical section with this line as the measuring plane of the tooth (*Figure 1D*). By making a line parallel to the axis of the teeth through the alveolar bone crest (M point on the labial side, Q point on the lingual side), we measured the width of the alveolar bone wall at three locations: 1, 3, and 5 mm apical to M/Q point (S1, S2, S3, as shown in *Figure 1D,1E*).

All image data were measured independently by two observers (orthodontists with more than 5 years of practice). Ten samples were randomly selected and measured simultaneously by two observers. In addition, ten samples that had already been measured were randomly selected and measured again by the same observers one week later. Intra-group correlation coefficients (ICC) were used to evaluate the consistency of measurement between the two observers and the consistency of measurement of one observer at different times. The results of each test were higher than 90%.

Statistical analyses

The data were statistically analyzed by the Statistical Package for Social Sciences (SPSS, version 19.0, IBM Corp., Armonk, NY, USA). The relationship between anterior alveolar bone thickness and gender, and vertical and sagittal facial types were explored. The difference of alveolar bone thickness between different genders was analyzed by independent-samples *t*-test. One-way ANOVA and Kruskal-Wallis test were used for analyzing the correlation between anterior alveolar bone thickness and different vertical and sagittal bone types. The Pearson correlation coefficient was used to analyze the relationship between FMA, ANB and alveolar bone thickness. The results were considered statistically significant when $P<0.05$.

Results

The alveolar bone thickness of male maxillary anterior teeth was significantly greater than that of female maxillary anterior teeth

After confirming that there was no significant difference in alveolar bone thickness between the left and right sides ($P>0.05$), we used the average value to represent the data of teeth in the same position on the left and right.

As shown in *Table 1*, the mean thickness of anterior alveolar bone varies from 0.68 to 3.30 at different points. The lingual alveolar bone of the maxillary anterior teeth is the thickest, followed by the lingual alveolar bone of the mandibular anterior teeth and the labial bone of the maxillary anterior teeth. The thinnest one is the alveolar bone on the buccal side of the mandibular anterior teeth.

Alveolar bone thickness varied with sexes. Men's maxillary anterior teeth's lingual alveolar bone thickness was significantly greater than women's ($P<0.05$, *Table 1*, *Figure 2*). There were no statistically significant differences between males and females in other anterior tooth regions ($P>0.05$, *Table 1*).

There were significant differences in the lingual alveolar bone thickness of the anterior teeth among people with different skeletal types

The relationship between alveolar bone thickness and different vertical and sagittal skeletal types was examined. The lingual alveolar bone thickness of the three types of vertical bone profiles showed a significant difference ($P<0.01$, *Table 2*). The alveolar bone thickness of the anterior teeth of high-angle patients was the thinnest at most sites on the lingual side, while these positions in low-angle patients were the thickest (*Figure 3*). The exception was the lingual S1 of the maxillary lateral incisors, of which the alveolar bone thickness in the average-angle group was even greater than in the low-angle group. However, on the buccal side of these teeth, only few sites showed significant differences among the three types of patients (*Table 2*).

As for the sagittal bone profile, the alveolar bone thickness at most sites had no significant difference among skeletal class I, class II, and class III patients (Table S1).

The lingual alveolar bone thickness of anterior teeth was significantly correlated with the FMA

Since the lingual alveolar bone thickness only significantly varied in different vertical bone types rather than sagittal ones, we focused on the relationship between FMA and bone thickness at these sites. As expected, bone thickness at the lingual side of anterior teeth was correlated with FMA at all sites ($P<0.05$), and most of them were significantly correlated ($P<0.001$, *Table 2*). The correlation coefficient between all of these sites and FMA was negative, indicating that the thickness of alveolar bone decreased with the increase of FMA. The regression equation of mean alveolar bone thickness and FMA in the maxilla and mandible was developed. As shown in *Figure 4*, The linear relationship between the mean lingual alveolar bone thickness in maxilla and FMA can be summarized as $y = -0.037x + 3.114$ ($R^2=0.302$, $P<0.01$). The corresponding formula in the mandible is $y = -0.031x + 2.259$ ($R^2=0.311$, $P<0.01$).

Discussion

The alveolar bone condition plays an important role in orthodontic tooth movement, especially the thickness of alveolar bone. In this study, we measured the alveolar bone thickness of the anterior teeth in 130 patients and compared them in three dimensions: gender, vertical bone profile, and sagittal bone profile. Our goal is to identify reliable predictors of anterior alveolar bone thickness to help dentists reduce complications during orthodontic alignment. The subjects included in this study were all in the range of 18–40 years old. This is because that minors may still be in the growth stage and their alveolar bone thickness and jawbone morphology are still changing. After several years of stabilization, however, alveolar bone resorption occurs to varying degrees as the prevalence of periodontal disease increases significantly (19,20).

The relationship between gender and alveolar bone thickness is an important aspect of our study. Our measurements showed that the alveolar bone thickness was significantly greater in males at different levels on the lingual side of the maxillary anterior teeth. The result was in line with Do's study (17). The gender difference in the alveolar bone thickness may be related to chewing strength. The bite force is reported to be 190 N for men and 50 N for women, and this difference may lead to varying degrees of compensatory bone remodeling (21). Our result suggests that more attention should be paid to alveolar bone changes

Table 1 Correlation between anterior alveolar bone thickness (mm) and gender

Tooth	Site	Mean	SD	Male (n=48)		Female (n=82)		Significance (P)
				Mean	SD	Mean	SD	
Lingual								
U1	S1	1.44	0.44	1.56	0.47	1.37	0.41	0.020*
	S2	2.37	0.84	2.71	1.01	2.17	0.64	0.000*
	S3	3.30	1.25	3.82	1.44	3.00	1.01	0.000*
U2	S1	1.24	0.33	1.32	0.34	1.20	0.31	0.032*
	S2	1.91	0.64	2.14	0.72	1.77	0.54	0.001*
	S3	2.71	0.95	3.14	1.02	2.45	0.82	0.000*
U3	S1	1.31	0.39	1.48	0.36	1.22	0.38	0.000*
	S2	2.02	0.73	2.28	0.85	1.86	0.60	0.001*
	S3	3.01	1.19	3.36	1.34	2.80	1.05	0.009*
L1	S1	0.82	0.26	0.87	0.28	0.79	0.24	0.089
	S2	1.22	0.49	1.24	0.58	1.20	0.43	0.701
	S3	1.64	0.78	1.69	0.90	1.62	0.70	0.674
L2	S1	0.90	0.28	0.89	0.31	0.90	0.26	0.926
	S2	1.40	0.53	1.48	0.64	1.36	0.45	0.237
	S3	1.80	0.78	1.91	0.96	1.73	0.65	0.253
L3	S1	1.02	0.35	1.02	0.42	1.02	0.30	0.975
	S2	1.75	0.70	1.81	0.85	1.71	0.59	0.482
	S3	2.36	1.00	2.49	1.23	2.29	0.84	0.322
Buccal								
U1	S1	1.31	0.29	1.27	0.32	1.34	0.27	0.180
	S2	1.26	0.31	1.23	0.32	1.28	0.31	0.372
	S3	1.14	0.29	1.12	0.30	1.14	0.29	0.662
U2	S1	1.26	0.43	1.27	0.40	1.26	0.44	0.961
	S2	1.07	0.48	1.03	0.40	1.09	0.52	0.435
	S3	0.79	0.38	0.74	0.29	0.83	0.42	0.208
U3	S1	1.23	0.35	1.16	0.35	1.27	0.34	0.105
	S2	1.14	0.45	1.14	0.39	1.15	0.48	0.896
	S3	0.92	0.42	0.92	0.37	0.93	0.45	0.869
L1	S1	0.94	0.32	0.94	0.36	0.94	0.30	0.993
	S2	0.79	0.29	0.82	0.36	0.78	0.24	0.461
	S3	0.87	0.32	0.90	0.38	0.85	0.28	0.409
L2	S1	0.99	0.37	1.00	0.39	0.98	0.36	0.853
	S2	0.78	0.39	0.77	0.38	0.79	0.40	0.794
	S3	0.68	0.25	0.68	0.26	0.68	0.25	0.980
L3	S1	0.88	0.32	0.91	0.34	0.86	0.30	0.365
	S2	0.72	0.28	0.76	0.34	0.69	0.25	0.187
	S3	0.71	0.26	0.74	0.28	0.69	0.24	0.332

*, $P<0.05$. U1, maxillary central incisor; U2, maxillary lateral incisor; U3, maxillary canine; L1, mandibular central incisor; L2, mandibular lateral incisor; L3, mandibular canine.

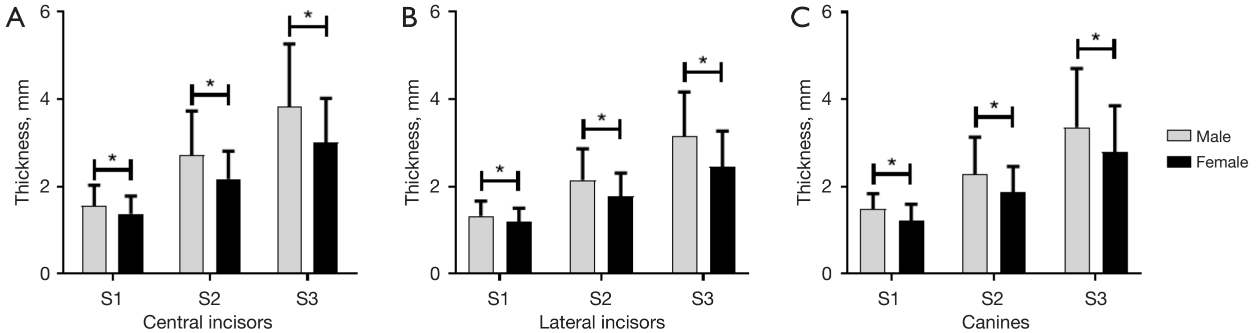

Figure 2 The lingual alveolar bone thickness of maxillary anterior teeth in males and females. Independent-samples *t*-test was used to compare differences between the two groups. *, P<0.05.

in the movement of anterior teeth to the lingual side in female patients.

There was no significant difference in the alveolar bone thickness at almost all sites among the three sagittal bone profile groups, indicating that the sagittal profile had little effect on the thickness of the anterior alveolar bone. This is not consistent with the previous studies (6,13). We speculate that this discrepancy is because that individuals from different parts of the world present different skeletal patterns. A systematic review showed that geographic environment was an effective modifier that explained the reason for up to 87% of alveolar bone thickness heterogeneity. Asians have thinner anterior alveolar bones than Europeans (22). The thinner alveolar bones of Asian populations made the difference between these three groups not detectable.

As for the vertical bone profile, there are differences in the alveolar bone thickness among three different groups. This study found that the differences among three different vertical groups are mainly manifested in the lingual/palatal alveolar bone—the thinnest in the high-angle group and the thickest in the low-angle group. There was no significant difference among the three groups in labial alveolar bone. This is a deviation from the previous studies which suggested that the alveolar bones in the high-angle group were thinner in both directions (14,15). The vertical bone morphology could interact with the soft tissues such as muscles, thus leading to different degrees of alveolar bone remodeling (23,24). In the high-angle group, the mandible rotates backwards and downwards, resulting in a shallow anterior overbite. In this case, there is a smaller bite force in the front teeth. In the low-angle group, by contrast, the mandible showed a tendency of forward and upward rotation. These people will have deeper anterior overbites and greater bite forces (25,26). According to Mavropoulos *et al.*, the increased bite force will increase bone deposition of alveolar bone (27,28). This suggests a smaller range of anterior tooth movement in high-angle patients. Specifically, the width of lingual alveolar bone at 1mm apical to alveolar bone crest of the maxillary lateral incisors in the average-angle group was even thicker than in the low-angle group. This may be due to the high incidence of morphological anomalies in maxillary lateral incisors (29). Furthermore, there was a negative correlation between FMA and lingual alveolar bone thickness of maxillary and mandibular anterior teeth. This means that the thickness of the lingual alveolar bone in the anterior area gradually becomes lesser as the bone profile extends vertically. The parameter slope in the linear regression equation (−0.037 for maxilla and −0.031 for mandible) gives us a clear picture of the effect of vertical bone profile on lingual/palatal alveolar bone thickness of anterior teeth. The R^2 (coefficient of determination) of 0.302 for the maxilla and 0.311 for the mandible means that FMA explains about 30% of the alveolar bone thickness.

Limitations of the study

The samples in different skeletal types were not individually matched for age; however, all subjects were at craniofacial maturity, rendering anatomic differences in the jaws or alveolar bone unlikely to have influenced the results. The ANB and FMA angle were used to differentiate the samples, neither of which may have been an ideal measure of sagittal or vertical discrepancy in all circumstances. A sample with a broader variety of malocclusions might yield different findings.

Table 2 The anterior alveolar bone thickness of different vertical bone types and their correlation with FMA

Tooth	Site	Low angle (n=45)		Average angle (n=46)		High angle (n=40)		Overall difference (P)	High-low difference (P)	High-average difference (P)	Low-average difference (P)	CC (with FMA)	Significance (P)
		Mean	SD	Mean	SD	Mean	SD						
Lingual													
U1	S1	1.54	0.49	1.47	0.34	1.29	0.45	0.027*	0.023*	0.155	0.666	−0.301	0.000*
	S2	2.67	1.10	2.42	0.56	1.98	0.61	0.001*	0.000*	0.031*	0.282	−0.444	0.000*
	S3	3.86	1.57	3.32	0.83	2.67	0.95	0.000*	0.000*	0.028*	0.078	−0.467	0.000*
U2	S1	1.33	0.33	1.34	0.30	1.04	0.26	0.000*	0.000*	0.000*	0.992	−0.377	0.000*
	S2	2.20	0.70	1.98	0.56	1.51	0.41	0.000*	0.000*	0.001*	0.162	−0.487	0.000*
	S3	3.21	1.02	2.78	0.74	2.06	0.71	0.000*	0.000*	0.000*	0.043*	−0.529	0.000*
U3	S1	1.46	0.44	1.32	0.30	1.14	0.36	0.001*	0.000	0.060	0.195	−0.366	0.000*
	S2	2.34	0.89	1.96	0.52	1.73	0.62	0.001*	0.000	0.273	0.031*	−0.374	0.000*
	S3	3.55	1.26	2.92	1.13	2.50	0.94	0.000*	0.000	0.193	0.024*	−0.379	0.000*
L1	S1	0.96	0.29	0.78	0.16	0.71	0.25	0.000*	0.000*	0.333	0.002*	−0.421	0.000*
	S2	1.58	0.56	1.10	0.30	0.93	0.28	0.000*	0.000*	0.141	0.000*	−0.564	0.000*
	S3	2.25	0.85	1.43	0.50	1.20	0.47	0.000*	0.000*	0.243	0.000*	−0.578	0.000*
L2	S1	1.03	0.31	0.91	0.24	0.74	0.19	0.000*	0.000*	0.006*	0.055	−0.408	0.000*
	S2	1.73	0.54	1.33	0.44	1.13	0.43	0.000*	0.000*	0.130	0.000*	−0.494	0.000*
	S3	2.31	0.77	1.65	0.63	1.40	0.65	0.000*	0.000*	0.218	0.000*	−0.522	0.000*
L3	S1	1.18	0.41	1.02	0.28	0.84	0.27	0.000*	0.000*	0.032*	0.058	−0.365	0.000*
	S2	2.17	0.75	1.67	0.53	1.37	0.55	0.000*	0.000*	0.069	0.001*	−0.466	0.000*
	S3	2.90	1.03	2.31	0.81	1.83	0.87	0.000*	0.000*	0.040*	0.008*	−0.424	0.000*
Buccal													
U1	S1	1.30	0.28	1.34	0.29	1.30	0.31	0.799				−0.011	0.904
	S2	1.18	0.27	1.28	0.36	1.33	0.29	0.072				0.168	0.056
	S3	1.09	0.31	1.15	0.31	1.17	0.25	0.379				0.103	0.247
U2	S1	1.31	0.41	1.27	0.41	1.21	0.47	0.557				−0.114	0.198
	S2	0.96	0.41	1.11	0.45	1.14	0.55	0.161				0.128	0.146
	S3	0.69	0.20	0.78	0.35	0.92	0.52	0.075				0.196	0.025*
U3	S1	1.20	0.28	1.32	0.37	1.16	0.37	0.086				−0.045	0.608
	S2	1.05	0.30	1.22	0.55	1.17	0.45	0.507				0.158	0.073
	S3	0.85	0.27	0.93	0.50	1.01	0.45	0.468				0.218	0.013*
L1	S1	0.96	0.28	1.00	0.35	0.85	0.30	0.091				−0.091	0.308
	S2	0.76	0.24	0.82	0.38	0.78	0.22	0.609				0.032	0.720
	S3	0.99	0.42	0.83	0.26	0.79	0.21	0.037*	0.010*	0.773	0.049*	−0.281	0.001*
L2	S1	1.02	0.42	1.04	0.32	0.89	0.36	0.160				−0.112	0.211
	S2	0.79	0.44	0.80	0.40	0.75	0.31	0.852				0.022	0.804
	S3	0.76	0.28	0.65	0.27	0.65	0.16	0.070				−0.139	0.121
L3	S1	0.92	0.31	0.94	0.33	0.76	0.28	0.014*	0.047*	0.019*	0.941	−0.164	0.063
	S2	0.73	0.27	0.73	0.35	0.68	0.20	0.700				−0.040	0.655
	S3	0.75	0.24	0.64	0.24	0.74	0.28	0.081				0.015	0.866

*, P<0.05. FMA, Frankfurt-mandibular plane angle; U1, maxillary central incisor; U2, maxillary lateral incisor; U3, maxillary canine; L1, mandibular central incisor; L2, mandibular lateral incisor; L3, mandibular canine.

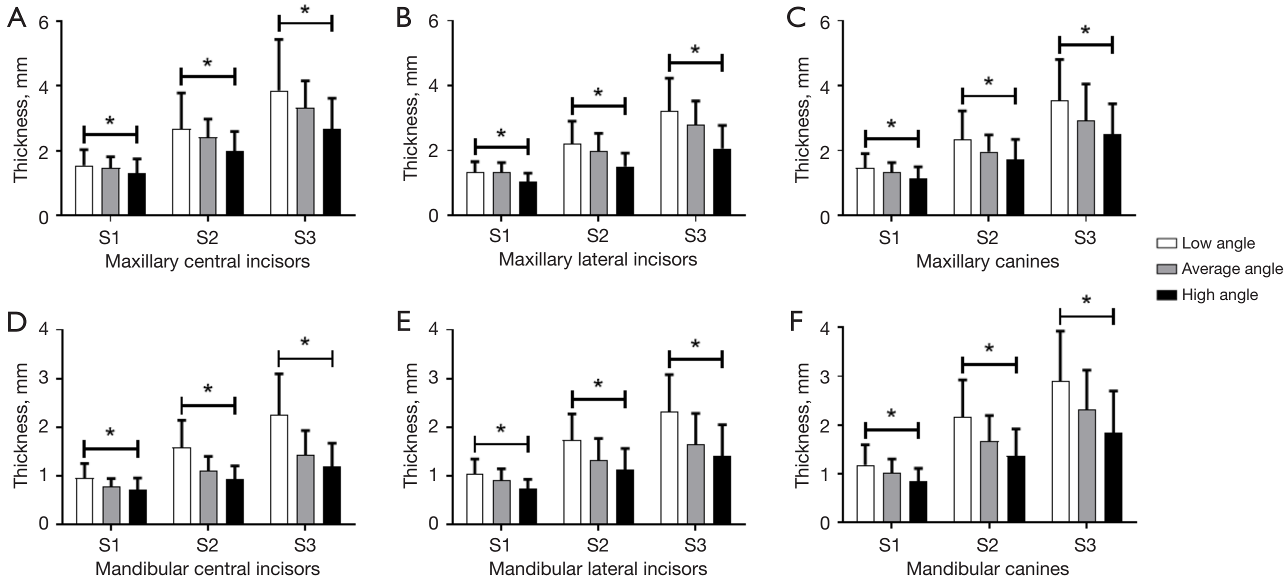

Figure 3 The thickness of lingual alveolar bone among the three vertical bone profiles. One-way ANOVA was used to analyze values for different groups. *, P<0.05.

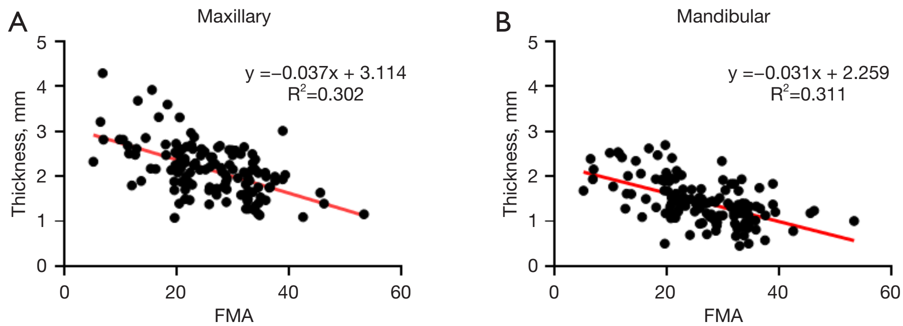

Figure 4 Regression equation between lingual bone thickness of anterior teeth and FMA. FMA, Frankfurt-mandibular plane angle.

Conclusions

Although the factors affecting the morphology of alveolar bone are complex, we can find some clues to make a preliminary judgment of the thickness of alveolar bone in Asian patients as follows:

(I) The lingual alveolar bone of male maxillary anterior teeth was significantly thicker than that of females.

(II) The alveolar bone thickness of the maxillary and mandibular anterior teeth was related to the vertical bone types. Sagittal bone types had no obvious relation with alveolar bone thickness.

(III) The lingual alveolar bone thickness of maxillary and mandibular anterior teeth was negatively correlated with the FMA value.

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Footnote

Reporting Checklist: The authors have completed the MDAR reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-935/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-935/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Nanjing Stomatological Hospital (No. KY-2021NL-26), and informed consent was obtained from all patients.

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Supplementary

Table S1 The anterior alveolar bone thickness of different sagittal bone types

Tooth	Site	Class I (n=41)		Class II (n=47)		Class III (n=42)		Overall difference (P)	Class I–II difference (P)	Class I–III difference (P)	Class I–III difference (P)
		Mean	SD	Mean	SD	Mean	SD				
U1 buccal	S1	1.32	0.33	1.30	0.31	1.33	0.24	0.861			
	S2	1.30	0.33	1.23	0.30	1.26	0.32	0.628			
	S3	1.15	0.29	1.06	0.28	1.20	0.31	0.092			
U1 lingual	S1	1.39	0.33	1.43	0.45	1.50	0.52	0.521			
	S2	2.34	0.56	2.46	1.10	2.30	0.73	0.788			
	S3	3.25	0.98	3.60	1.62	3.03	0.92	0.273			
U2 buccal	S1	1.23	0.31	1.18	0.31	1.39	0.59	0.202			
	S2	1.07	0.43	1.01	0.31	1.14	0.64	0.989			
	S3	0.75	0.34	0.76	0.27	0.87	0.50	0.306			
U2 lingual	S1	1.28	0.29	1.20	0.33	1.25	0.35	0.491			
	S2	2.02	0.52	1.93	0.75	1.77	0.58	0.206			
	S3	2.82	0.88	2.81	1.12	2.49	0.80	0.192			
U3 buccal	S1	1.25	0.40	1.26	0.33	1.18	0.31	0.370			
	S2	1.13	0.52	1.24	0.44	1.05	0.36	0.143			
	S3	0.91	0.49	0.97	0.43	0.89	0.33	0.611			
U3 lingual	S1	1.32	0.34	1.33	0.38	1.30	0.46	0.931			
	S2	2.00	0.58	2.20	0.88	1.83	0.63	0.063			
	S3	3.00	1.11	3.39	1.44	2.58	0.77	0.005**	0.247	0.227	0.003**
L1 buccal	S1	0.98	0.27	0.99	0.36	0.84	0.29	0.066			
	S2	0.81	0.28	0.84	0.35	0.72	0.21	0.185			
	S3	0.93	0.35	0.90	0.31	0.78	0.29	0.098			
L1 lingual	S1	0.81	0.25	0.82	0.25	0.83	0.29	0.960			
	S2	1.22	0.48	1.27	0.46	1.14	0.53	0.455			
	S3	1.73	0.74	1.69	0.73	1.51	0.86	0.383			
L2 buccal	S1	1.01	0.33	1.05	0.48	0.89	0.23	0.234			
	S2	0.79	0.46	0.87	0.45	0.67	0.16	0.403			
	S3	0.69	0.33	0.68	0.23	0.68	0.19	0.953			
L2 lingual	S1	0.94	0.30	0.91	0.25	0.84	0.29	0.249			
	S2	1.47	0.52	1.49	0.49	1.24	0.57	0.058			
	S3	1.92	0.74	1.89	0.72	1.58	0.85	0.079			
L3 buccal	S1	0.90	0.33	0.92	0.36	0.81	0.24	0.226			
	S2	0.73	0.29	0.70	0.34	0.71	0.19	0.220			
	S3	0.76	0.30	0.68	0.24	0.69	0.23	0.298			
L3 lingual	S1	1.06	0.36	1.08	0.37	0.92	0.30	0.071			
	S2	1.81	0.74	1.85	0.63	1.57	0.71	0.133			
	S3	2.44	1.02	2.51	0.91	2.13	1.05	0.167			

**, $P<0.01$. U1, maxillary central incisor; U2, maxillary lateral incisor; U3, maxillary canine; L1, mandibular central incisor; L2, mandibular lateral incisor; L3, mandibular canine.

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