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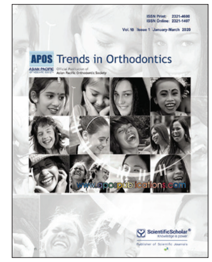

Original Article

Cone-beam computed tomography-based quantitative analysis of the thickness of mandibular alveolar bone in adult females with different vertical facial patterns

Tomomi Sakaguchi-Kuma[1], Yuji Ishida[1], Shuji Oishi[1], Tohru Kurabayashi[2], Takashi Ono[1]

Departments of [1]Orthodontic Science and [2]Oral and Maxillofacial Radiology, Tokyo Medical and Dental University (TMDU), Yushima, Bunkyo-ku, Tokyo, Japan.

***Corresponding author:**
Yuji Ishida,
Department of Orthodontic Science,Tokyo Medical and Dental University,
1-5-45 Yushima, Bunkyo-ku, 113-8549, Tokyo, Japan.

yjis.orts@tmd.ac.jp

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ABSTRACT

Objectives: The objectives of the study were to investigate the relationship between the thicknesses of the mandibular alveolar bone in the incisor, canine, premolar, and molar areas in adult female patients with different vertical skeletal patterns using cone-beam computed tomography (CBCT).

Materials and Methods: CBCT images of 50 adult female patients before orthodontic treatment were analyzed. Based on the mandibular plane angle, they were divided into three groups: Low, average, and high-angle. The thicknesses of the alveolar and cancellous bones of the mandible were measured at the apices of the incisor, canine, first premolar, and first molar on both sides.

Results: The thicknesses of the alveolar and cancellous bones were significantly larger in the low-angle group than in the high-angle group in all areas. At the incisal and canine areas, the thicknesses of the alveolar and cancellous bones were significantly larger in the average angle group than in the high-angle group. In the canine and first premolar areas, the thickness of the alveolar bone was larger in the low-angle group than in the average angle group.

Conclusions: Vertical facial pattern is a significant factor in the width of the mandibular alveolar bone, especially in the incisor and canine areas. For planning labiobuccal movement in mandibular canines and incisors, information about the mandibular morphology is thought to be important, particularly in high-angle cases.

Keywords: Cone-beam computed tomography, Vertical facial pattern, Mandibular morphology, Mandibular alveolar bone, Mandibular cancellous bone

INTRODUCTION

During orthodontic treatment, unwanted complications such as root resorption, gingival recession, and perforation of alveolar bone have been reported.[1-3] These complications occur when the root is moved too close to the cortical bone.[4-7] Planning of orthodontic treatment should consider anatomical limitations to avoid the occurrence of problems in the mandible.

Facial patterns are an important factor in orthodontic treatment because it influences treatment goals. Several studies, in an effort to understand the relationship between the shape of symphysis and facial patterns, have examined the incisal position in the alveolar bone and shape of symphysis before orthodontic treatment using a lateral cephalometric radiograph, which is conventionally used for two-dimensional analysis.[6,8] However, the information gained from cephalograms is limited and sometimes inaccurate. Therefore, evaluations of three-dimensional (3D) data by computed tomography (CT) scanners have been reported for orthodontic diagnosis.[9-12]

Since CT scanners pose a problem of radiation exposure, studies on mandibular morphology using 3D data by dental cone-beam CT (CBCT) have been recently reported.[13-17] However, there have been few investigations with regard to detailed 3D configurations of mandibular alveolar bone in orthodontic patients. Therefore, the aim of this study was to examine the thicknesses of mandibular alveolar and cancellous bones in multiple areas of the mandibular dentition and investigate the relationship between the thickness and skeletal patterns, using CBCT data of adult female patients, before orthodontic treatment.

MATERIALS AND METHODS

Subjects

The sample included 50 Japanese female patients who visited the Tokyo Medical and Dental University (TMDU) Dental Hospital between 2015 and 2017 and needed a CBCT scan before orthodontic treatment. The study was approved by the Institutional Ethical Committee of the Tokyo Medical and Dental University (approval numbers: 846 and 1254) and conducted in accordance with the tenets of the Declaration of Helsinki. After explaining the aim and design of the study, written consent was obtained from all patients.

The inclusion criteria were nongrowing female subjects with (1) no history of orthodontic treatment before the initial CBCT scan; (2) no missing teeth; (3) a midline deviation of the mandible ≤3 mm from the facial midline; (4) a maxillary occlusal cant ≤2°; (5) no history of systemic disease; and (6) no pathology or therapy that may significantly affect bone properties. Based on the inclusion criteria, 50 female subjects (mean age of 24.4 ± 5.8 years and age range of 18–39 years) were selected for this study. The sample size was calculated by a priori power analysis using G*Power Version 3.1 (Heinrich-Heine-Universität, Düsseldorf, Germany) according to the following assumptions: $f = 0.25$, $\alpha = 0.05$, and $1 - \beta = 0.8$.[18]

Lateral cephalometric radiographs were taken for all subjects for pre-treatment orthodontic diagnosis. Angular measurements, including SNA, SNB, ANB, and Frankfort-mandibular plane angle (FMA) were performed on these images. Based on the value of the FMA angle, the subjects were divided into three groups: Low-angle (mandibular plane angle ≤23.5°), average angle (23.6°–33.9°), and high-angle (≥34°).

CBCT

CBCT images were recorded using a CBCT scanner (FineCube; Yoshida Dental MFG. Co., Tokyo, Japan). The detailed settings of the CBCT scanner were as follows: Normal mode (16.8°s, 4.10 mGy, 90 kV, and 4 mA); slice thickness: 0.147 mm; field of view: 81 × 74 mm; and voxel size: 0.146 mm. All data were saved as digital imaging and communication in medicine (DICOM) files. Using image analysis software (OsiriX; Pixmeo SARL, Switzerland), the horizontal slice parallel to the occlusal plane was taken [Figures 1a and b]. From the horizontal slice, several slices perpendicular to the mandibular arch were taken at the center of the lower incisor, canine, first premolar, and the mesial root of the first molar on both sides. From these slices, the thicknesses of the alveolar and cancellous bones of the mandible were measured at the root apex of the incisor, canine, first premolar, and at the mesial root apex of the first molar [Figures 2a and b]. The measurements were performed by a trained investigator and repeated after 2 months by the same investigator. According to the previous study, the Dahlberg formula was used for calculating the measurement error.[19]

Statistical analysis

The mean and standard deviation (SD) were calculated for all measurements, including demographic parameters and angular measurements from lateral cephalometric radiographs. A paired *t*-test was used for comparisons between the two repeated measurements. A one-way analysis of variance (ANOVA) was used for comparisons of the demographic parameters and morphometric parameters from lateral cephalometric radiographs among the three

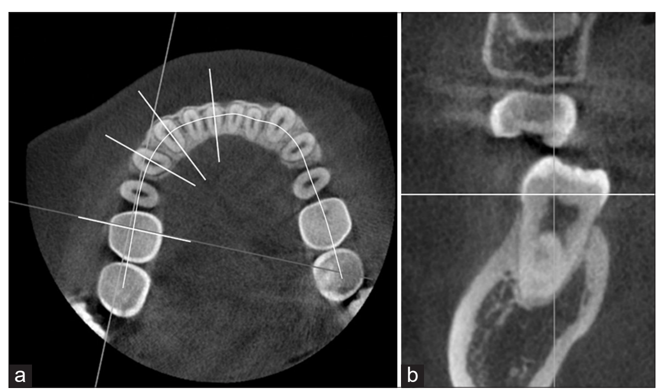

Figure 1: Cone-beam computed tomography images. (a) A horizontal view of the mandible. This plane is parallel to the occlusal plane. The mandibular arch is indicated by the curved line. The white lines perpendicular to the mandibular arch are taken at the center of the incisor, canine, first premolar, and at the mesial root of the first molar. (b) A representative slice for measurement in the view perpendicular to the occlusal plane and the mandibular arch. This picture shows the slice at the mesial root of the right first molar.

groups. When there was a significant difference by ANOVA, a *post hoc* Turkey-Kramer test was used for comparisons between groups. In addition, a Tukey-Kramer test was used to compare the thicknesses of the alveolar and cancellous bones at each area among the low, average, and high-angle groups. The significance level for all analyses was set at $P < 0.05$. All statistical analyses were carried out by the computer software SPSS 22.0 (IBM, Armonk, NY, USA).

RESULTS

Table 1 shows the demographic and morphometric parameters among the three groups. Only FMA in the average angle group was significantly larger than in the low-angle group. Likewise, FMA in the high-angle group was significantly larger than in both the low- and average-angle groups. There were no significant differences in the other parameters among the groups.

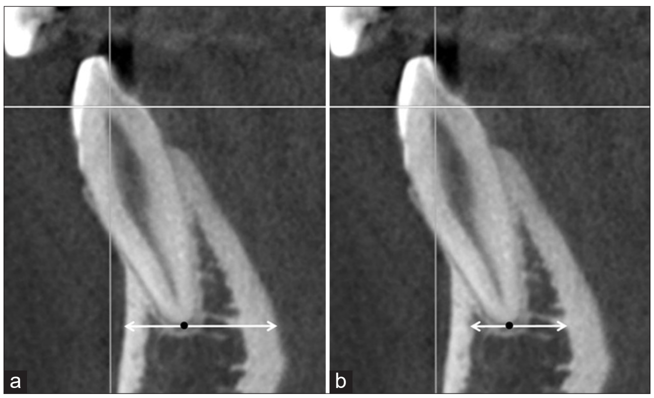

Figure 2: (a) Cone-beam computed tomography images of mandibular alveolar bone in the right incisor region. The black circles indicate the root apices. The lines through the root apices were drawn parallel to the occlusal plane. (a) The white arrow indicates the thicknesses of the alveolar bone. (b) The white arrow indicates the thickness of cancellous bone.

The measurement error of the thicknesses of the alveolar and cancellous bones ranged from between −0.25 and 0.24 mm to between −0.22 and 0.28 mm. The thicknesses of the alveolar and cancellous bones were 0.066 mm and 0.057 mm, respectively, based on Dahlberg's formula. The small difference between repeated measurements indicated the reproducibility of the method. In addition, the *t*-test showed that this difference was not statistically significant.

All measurements of the thicknesses of the alveolar and cancellous bones among the three groups are presented in Table 2. Statistical comparisons of the thickness of the alveolar bone in each area among the three groups are shown in Figure 3. The thickness of the alveolar bone was significantly larger in the low-angle group than in the high-angle group in all areas. Moreover, in the incisal and canine areas, the thickness of the alveolar bone in the average angle group was significantly larger than in the high-angle group. In the canine and first premolar areas, the thickness of the alveolar bone in the low-angle group was significantly larger than in the average angle group.

Figure 4 shows the statistical area comparison of the thickness of the cancellous bone among the three groups. The thickness of the cancellous bone in the low-angle group was significantly larger than in the high-angle group in all areas. Moreover, in the incisal and canine areas, the thickness of the

Table 1: Demographic and morphometric parameters of the low-, average-, and high-angle groups.

Group	Number of patients	Age (year)	SNA (°)	SNB (°)	ANB (°)	FMA (°)
Low-angle	15	26.5±8.22	82.3±4.15	78.4±3.82	3.91±3.54	20.7±1.82
Average angle	22	23.9±4.83	81.6±3.46	78.1±4.57	3.50±4.25	27.6±2.62[#]
High-angle	13	22.9±3.28	81.2±3.81	76.8±4.76	4.40±4.29	36.7±2.20[$,§]

The data are presented as mean±standard deviation. There was no significant difference in the parameters among groups except for the FMA: The average angle group was significantly larger (#) than the low-angle group, while the high-angle group was significantly larger than both the low-($) and average-(§) angle groups. ($P<0.05$) FMA: Frankfort-mandibular plane angle.

Table 2: Alveolar and cancellous bone thickness in each area among the low-, average-, and high-angle groups.

Area	Alveolar bone thickness (mm)			Cancellous bone thickness (mm)		
	Low-angle	Average angle	High-angle	Low-angle	Average angle	High-angle
Central incisor	8.31±1.60	7.49±1.97	6.13±2.12	5.18±1.69	4.83±1.57	3.46±1.47
Canine	10.04±1.39	8.80±2.12	7.48±2.29	6.26±1.52	5.45±1.54	4.39±1.81
First premolar	11.13±1.41	9.85±1.83	8.82±2.48	7.03±1.33	6.21±1.42	5.66±2.01
First molar	13.93±1.65	12.98±2.18	12.03±2.31	9.27±1.74	8.76±1.54	8.07±1.87

The data are presented as mean±standard deviation.

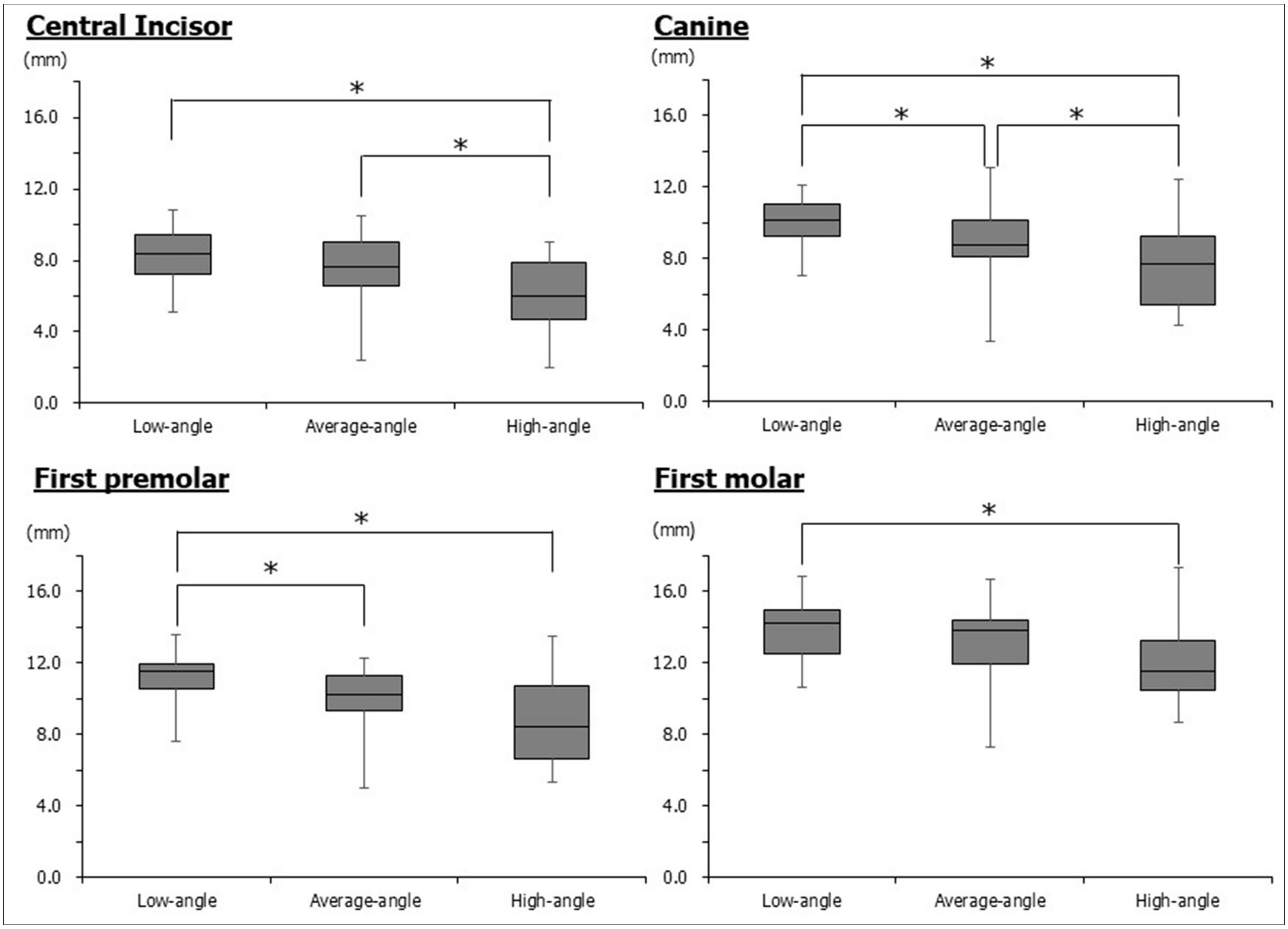

Figure 3: Statistical comparisons of the thickness of the alveolar bone in the low, average and high-angle groups. The edges of the boxes represent the upper and lower quantiles, the middle lines in the boxes represent the medium values, and the whiskers represent the maximum and minimum values. *p.

cancellous bone in the average angle group was significantly larger than in the high-angle group. These results were in alignment with the results of the alveolar bone. Unlike the alveolar bone, the thickness of the cancellous bone was not statistically different between the low-angle group and the average angle group in the canine and first premolar areas.

DISCUSSION

Short-faced patients have been known to present a thicker mandibular symphysis compared to average and long-faced patients.[20,21] In addition, a thinner symphysis was seen in long-faced patients compared to patients with other facial patterns.[6] These studies using cephalograms only focused on mandibular symphyses. In contrast, our study has demonstrated that more detailed and accurate information can be gathered not only of the mandibular incisor but also of the canine, first premolar, and first molar, with the advantages of the 3D imaging modality. In this study, the thicknesses of both the mandibular alveolar and cancellous bones were significantly larger in the low-angle group than in the high-angle group in all areas. This finding supports the previous studies regarding the relationship between the thickness of the mandibular symphysis and facial patterns. In a recent CBCT study, Lee *et al*. showed that lower incisor buccolingual alveolar bone width was significantly thinner in Class III high-angle patients than in Class III low and normal-angle patients except in the buccal region from the cementoenamel junction to the 0 and 3 mm apical level and the lingual region to the 9 mm apical level.[22] They also reported that the mandibular plane angle was negatively correlated with mandibular anterior alveolar bone thickness in Class III subjects.[22] The results of this study in the incisal area corresponded with those of Lee *et al*. We also obtained the same results for the lower incisor mandibular cancellous bone. This study is of importance in that it showed that the fact that mandibular plane angle correlates with lower incisor mandibular alveolar bone thickness is not limited to Class III subjects.

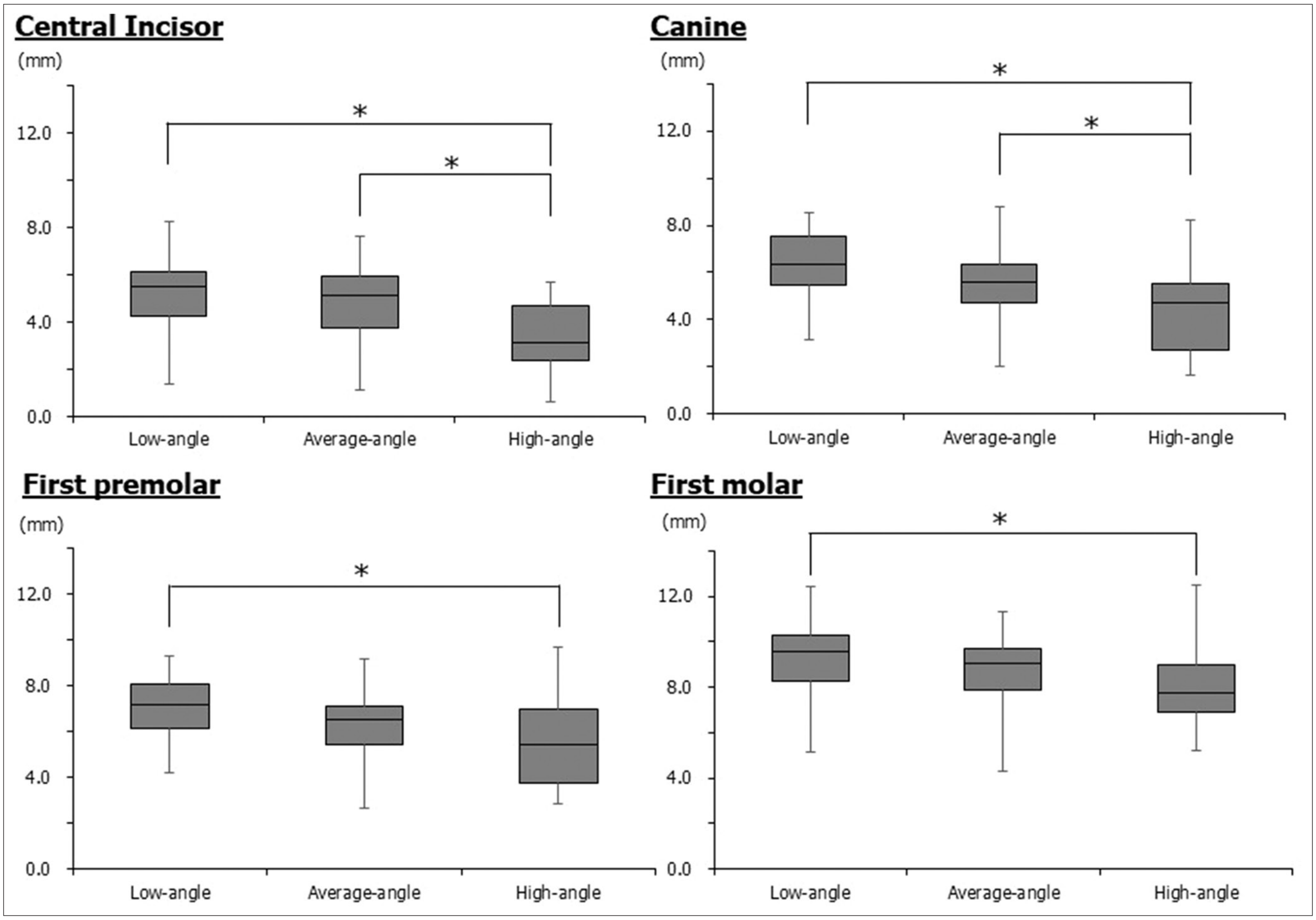

Figure 4: Statistical comparisons of the thickness of the cancellous bone in the low, average and high-angle groups. The edges of the boxes represent the upper and lower quantiles, the middle lines in the boxes represent the medium values, and the whiskers represent the maximum and minimum values. *p.

In addition, the CBCT study by Hoang *et al*. found that the low-angle group had significantly wider anterior alveolar bone at the root apex than both the average and high-angle groups, although the difference between the average and high-angle groups was not significant.[23] Findings from our study, between the low-angle and average angle groups, and the average angle and high-angle groups did not correspond with those of their study. The discrepancy may be due to the difference in the definition of the alveolar thickness at the apex of the mandibular incisor, which was perpendicular to the long axis of the incisor in Hoang's study[23] and parallel to the occlusal plane in our study.The alveolar thickness at the root apex, measured in tangent to the long axis of the incisor, is larger when the incisor inclination is large. We also speculate that the discrepancy is affected by gender and racial differences.[24]

According to the literature, the facial type is related to the bite force. Patients with a large bite force had a relatively short lower anterior facial height.[25] On the contrary, it was demonstrated that high-angle patients showed a light bite force.[26] An animal model study also suggested that bite force would have an influence on the shape and structure of the mandible because the bone adapts to the loads by remodeling.[27] Sella-Tunis *et al*. have reported that people with a large bite force have a wider ramus, a more rectangular mandibular body, and a curved basal arch, whereas people with a light bite force have a tall and narrow ramus, a triangular mandibular body, and a more triangular basal arch.[28] In our study, there were significant differences in the mandibular alveolar bone widths in all areas between the low and high-angle groups. This suggests that the influence on the mandibular structure by bite force would be great between these groups. Furthermore, differences in the alveolar bone widths among the three groups were inconsistent in each area in this study, which suggests that the influence of the masticatory muscle activity on mandibular growth is complicated and requires further investigation.

When the thicknesses between the alveolar and the cancellous bones in all mandibular areas were compared, there was a difference only in the canine and premolar regions. When comparing the low-angle group to the average angle group, there was a significant difference in both areas in the thickness of the alveolar bone but not in the thickness of the cancellous bone. This indicated that the thickness of the cortical bone would be larger in the low-angle group than in the average angle group. This new finding of this study about the difference between the alveolar and cortical bones would help in understanding relationships between maxillofacial morphology and the internal structure of mandible. A previous study about the mandibular tori, which is mainly composed of cortical bone and stimulated by masticatory stress, indicated that it was most frequently found below the first premolar.[29] The effect of masticatory muscle activity on the width of the cortical bone is strongly seen in the premolar region.

In this study, mandibular thickness in the canine area was significantly thinner in the high-angle group than in the other groups. The root resorption was exhibited most frequently in the maxillary incisors, followed by the mandibular incisors and the canines.[30] These facts suggest that root resorption, caused by root contact with the cortical bone, must be managed not only in the incisal area but also in the canine area. Furthermore, during the retention period, relapse of crowding and incisor irregularity increased more frequently in the mandible than in the maxilla.[31] The previous reports have demonstrated that severe relapse of crowding in the mandibular anterior area was noted in the group receiving treatment for expansion of the dental arch.[31,32] The anatomical limitations of the mandible could be related to these unfavorable outcomes. From the findings with regard to the thicknesses of the alveolar and cancellous bones in this study, in planning orthodontic treatment, excessive inter-canine expansion in the mandible should be avoided, especially in high-angle patients, when considering root resorption and future relapse. However, the shape of the mandible could be altered during orthodontic treatment. Therefore, further studies with regard to the pre- and post-treatment assessment of the thickness of the mandible are required.

CONCLUSIONS

Vertical skeletal pattern was a significant factor in the width of the mandible, especially in the incisal and canine areas.

The thicknesses of the alveolar and cancellous bones were significantly thinner in the high-angle group than in the low-angle group.

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Declaration of patient consent

Patient’s consent not required as patient's identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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