Original article

Relationship between Symphysis Dimensions and Mandibular Incisors' Alveolar Bone Thickness in Different Vertical Skeletal Patterns

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Abstract

This study determined the relationship between symphysis dimensions and the alveolar bone thickness (ABT) at the mandibular incisors in different vertical skeletal patterns. 75 patients (average age 24.5 years) were divided into three groups according to their vertical skeletal pattern (skeletal deepbite, skeletal normal bite, and skeletal openbite). The labial and lingual ABTs at the mandibular incisors at the cervical, mid-root, and apical levels and the mandibular symphysis height and width were measured from cone-beam computed tomography images. The symphysis ratio was the ratio of symphysis width to symphysis height. One-way ANOVA was used to determine the differences in symphysis dimensions and ABT between the three groups and Pearson's correlation coefficient was used to determine the relationship between symphysis dimensions and ABTs at a 0.05 significance level. The symphysis dimensions and ABT were related in every skeletal pattern. Symphysis height negatively correlated with only labial apical ABT in skeletal normal bite patients. The relationship between symphysis width and ratio and ABT, mainly at the lingual surface, in skeletal openbite patients was the strongest, followed by skeletal normal bite and deepbite patients. The positive relationship between the mandibular symphysis width and symphysis ratio and ABT at the mandibular incisors was the strongest in skeletal openbite patients. The skeletal openbite patients with a taller symphysis had a stronger tendency to have a thinner lingual mid-root to apical ABT and total apical ABT compared with the other vertical skeletal patterns. The limited amount of mandibular incisor tooth movement in these patients should be considered.

Keywords: Alveolar bone thickness, Cone-beam computed tomography, Mandibular incisors, Mandibular symphysis, Vertical skeletal pattern

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Introduction

The alveolar bone is one of the periodontal tissues that support the teeth in the jaws. To achieve the ideal orthodontic tooth movement, orthodontists expect that the alveolar bone will adapt consistent with tooth movement. Thus, tooth movement should occur based on the treatment plan without causing any damage to the supporting bone. However, some deleterious consequences after orthodontic treatment, such as reduced alveolar bone thickness (ABT), bony dehiscences, and cortical plate perforations, have been reported, particularly at the anterior mandibular region[1-4] Moreover, the severity of alveolar bone loss after orthodontic treatment is related to the initial ABT.[5] Therefore, the thickness of the alveolar bone is considered as the boundary for tooth movement and violating this limit might negatively affect the bony support. Previous studies[6,7] revealed a very thin layer of labial and lingual alveolar bone in this area, especially at the upper-half root level. Not surprisingly, the mandibular anterior region is the most restricted for orthodontic tooth movement in the labio-lingual direction.[8]

Numerous studies have indicated that the factors related to the mandibular incisor's ABT include aging[9], amount of crowding and rotation[10], and skeletal relationship.[11-15] At the apical level, skeletal openbite (hyperdivergent) patients had thinner alveolar bone compared with skeletal normal and skeletal deepbite (hypodivergent) patients. However the ABTs at the cervical to mid-root level were similar between the three vertical facial types.[11-13] Although a skeletal openbite is strongly associated with thin alveolar bone, a very thin alveolus is present in every vertical skeletal pattern.[14,15]

The mandibular symphysis dimensions are other factors associated with the ABT in the anterior mandible. Severe alveolar bone loss at the mandibular incisors was found in orthodontic patients who had a narrow and tall symphysis.[4] Patients with a short and wide symphysis tended to have a thicker alveolar bone at the apical level.[16] However, the relationship between symphysis dimensions and the ABT at the mandibular anterior teeth with different vertical skeletal patterns has not been reported.

Cone-beam computed tomography (CBCT) is commonly used for three-dimensional structural examination in orthodontics. The data from CBCT images overcome some of the drawbacks of conventional lateral cephalometry (a two-dimensional image), such as structural overlapping and magnification error. The anterior mandible is a three-dimensional structure, consisting of four incisors. Therefore, the ABT of each tooth, which cannot be measured exactly using conventional lateral cephalometry, can be examined individually on CBCT images. Moreover the accuracy of the dimensional measurements from CBCT images corresponds with actual structure sizes, thus clinicians and researchers can get more accurate qualitative and quantitative data from CBCT images.[17,18]

The aim of this study was to evaluate the relationship between the ABT at the mandibular incisors at the cervical to apical levels and mandibular symphysis dimensions in different vertical skeletal patterns.

Materials and Methods

The study protocol was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2018-041). 75 Patients in the Faculty of Dentistry, Chulalongkorn University (36 males and 39 females) whose CBCT images were acquired from August 2013 to April 2018, were selected with the following inclusion criteria: age between 18 to 30 years, no previous orthodontic treatment, full permanent dentition without severe rotation or more than 3 mm crowding of the mandibular incisors, Class I sagittal skeletal relationship, no oral pathology or periodontal disease, and the landmarks used in this study were easily identified on the CBCT image. The sample size was calculated from a previous study[14] using the G* power program version 3.1.9.2. twenty five patients were determined to be required per group for a 0.05 significance level and 80 % power of the test.

The CBCT images were taken with a 3DX Accuitomo 170 machine (J. Morita, Kyoto, Japan) with 60-90 kVp, 1-10 mA, and 17.5 sec scanning time while the patients bit in maximum intercuspation. The CBCT image field of view was 8x8 cm with a 0.165 mm voxel size. The patients were divided into three groups (25 patients/group) based on vertical skeletal pattern (i.e. skeletal deepbite; 12 males 13 females, skeletal normal bite; 12 males 13 females, and skeletal openbite; 11 males 14 females). Lateral cephalograms constructed from the CBCT images using the maximum intensity projection method, were used for skeletal pattern identification. The sagittal skeletal relationship was identified using Wits appraisal (AO-BO).[19] Patients with a Class I skeletal relationship, based on Thai norms (AO-BO = -4.1-0.7 mm)[20], were recruited in this study. The palatal plane-mandibular plane (PP-MP) angle used to identify the vertical skeletal pattern was constructed in the palatal plane (ANS to PNS) and a line tangential to the lower border of the mandible as the mandibular plane and Thai norms of the palatal PP-MP angle[21] were used as standard values to categorize patients (skeletal deepbite < 21°, skeletal normal bite = 21°-29°, and skeletal openbite > 29°).

Infinitt proprietary software v.2 (Infinitt Co., Seoul, Republic of Korea) was used for examining and measuring the CBCT images by a single operator who had been trained and supervised by a board certified oral and maxillofacial radiologist. A 1 mm thick slice was used for the bone thickness measurement. The sagittal slice was set along the long axis of each tooth and aligned perpendicular to the alveolar ridge curvature. The labial and lingual ABTs at the four mandibular incisors were measured perpendicular to the long axis of each tooth from the root surface to the external limit of the mandibular labial and lingual cortical bones at 3 mm apical to the cemento-enamel junction, defined as the cervical level, 6 mm apical to the cemento-enamel junction, defined as the mid-root level, and at the root apices, defined as the apical level (Fig. 1). For the symphysis dimension measurements, the mandibular midline was used as the sagittal plane. The symphysis height was measured from the midpoint of the alveolar crest to Menton (Me). The symphysis width was measured from Pogonion (Pog) perpendicular to the symphysis height to the external limit of the lingual cortical bone. The symphysis ratio was calculated by dividing the symphysis width by symphysis height (Fig. 2). One month after the first measurement, 20 % of the patients were randomly selected. The same operator measured all variables again to determine the intra-rater reliability. An intra-class correlation coefficient (ICC) of 0.82-0.91 was found, showing excellent intra-rater reliability.

All statistical analyses were performed using SPSS v.22.00 (SPSS Inc., Chicago, IL, USA). The significance level was set at 0.05. The Kolomgorov-Smirnov test verified a normal distribution for all variables. The ABTs in the same subject were compared between the left and right teeth by the independent *t*-test. The result showed a nonsignificant difference in the ABTs between the left and right teeth, thus the data were combined for further statistical analysis. A comparison of all variables according to sex was performed using the independent *t*-test. No significant differences were found between the male and female variables; therefore, sex was not included as an independent variable in this study. One-way ANOVA and Tukey's post-hoc test were performed to determine the differences in age, sagittal skeletal relationship, ABTs, and symphysis dimensions of the mandibular incisors between the three vertical skeletal patterns. Pearson correlation coefficients were used to evaluate the relationship between the symphysis dimensions and ABTs at the mandibular incisors in the three vertical skeletal patterns.

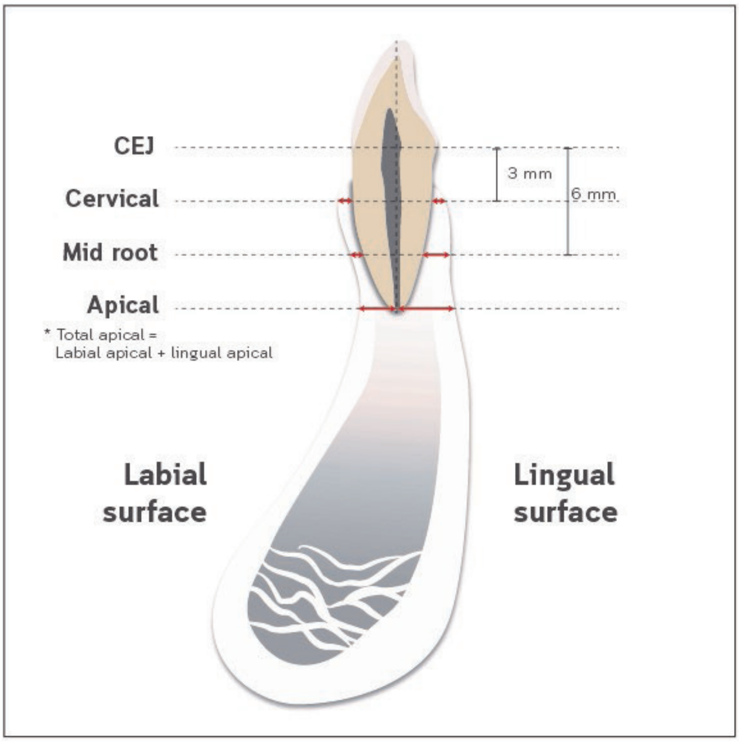

Figure 1 *The labial and lingual ABTs at the four mandibular incisors were measured perpendicular to the long axis of each tooth from the root surface to the external limit of the mandibular labial and lingual cortical bones.*

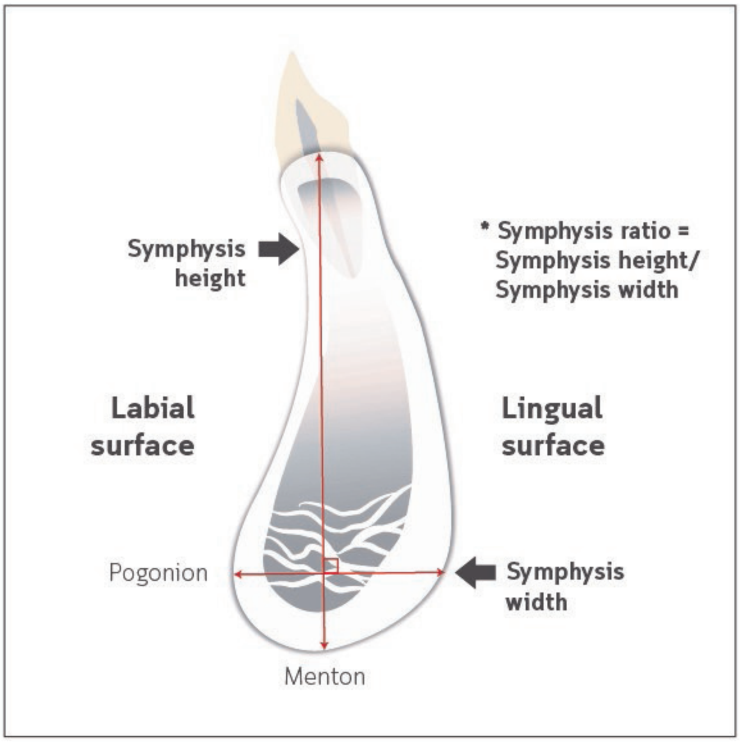

Figure 2 *Symphysis width and height were measured from an anteroposterior cross-section of the mandibular symphysis. The sym physis ratio was the ratio of the symphysis width to symphysis height.*

Results

The descriptive analytic summary of the subjects is presented in Table 1. There was no significant difference in age or Wits appraisal (sagittal skeletal relationship) between the three groups.

Table 1 Comparison of the means and standard deviations in the age, sagittal skeletal pattern, symphysis dimensions, and ABTs in the different vertical skeletal patterns

Measurement	Deepbite (D) (N = 25)	Normal bite (N) (N = 25)	Openbite (O) (N = 25)	ANOVA *p*-value	Tukey's tests Statistically different groups
Age (year)	23.47 ± 4.50	25.87 ± 5.60	24.33 ± 4.40	NS	-
Wit's appraisal (mm)	-1.29 ± 1.36	-1.34 ± 0.97	-1.35 ± 1.14	NS	-
Symphysis height (mm)	30.89 ± 2.07	32.71 ± 3.71	34.23 ± 3.79	0.012	D vs. O
Symphysis width (mm)	14.08 ± 1.58	13.41 ± 1.10	13.34 ± 1.87	NS	-
Symphysis ratio	0.45 ± 0.05	0.41 ± 0.05	0.40 ± 0.04	0.007	D vs O
Mandibular central incisor's ABT					
Labial-cervical	1.06 ± 0.36	0.83 ± 0.28	0.90 ± 0.32	NS	-
Labial-mid root	0.65 ± 0.25	0.48 ± 0.19	0.48 ± 0.29	NS	-
Labial-apical	3.94 ± 1.40	3.26 ± 1.21	2.94 ± 0.87	NS	-
Lingual-cervical	0.81 ± 0.29	0.82 ± 0.33	0.79 ± 0.25	NS	-
Lingual-mid root	1.65 ± 0.60	1.27 ± 0.45	1.19 ± 0.49	0.041	D vs O
Lingual-apical	5.36 ± 1.69	4.94 ± 0.92	4.42 ± 1.23	NS	-
total apical	9.29 ± 1.28	8.21 ± 1.38	7.37 ± 1.55	0.002	D vs O
Mandibular lateral incisor's ABT					
Labial-cervical	1.11 ± 0.41	0.89 ± 0.33	0.84 ± 0.37	NS	-
Labial-mid root	0.42 ± 0.17	0.35 ± 0.11	0.32 ± 0.17	NS	-
Labial-apical	4.22 ± 1.32	3.51 ± 1.16	3.33 ± 0.79	NS	-
Lingual-cervical	1.09 ± 0.30	0.93 ± 0.25	0.98 ± 0.32	NS	-
Lingual-mid root	2.27 ± 0.63	1.45 ± 0.42	1.39 ± 0.59	< 0.001	D vs O
Lingual-apical	5.40 ± 1.60	4.71 ± 0.62	4.55 ± 1.37	NS	-
total apical0	9.62 ± 1.29	8.22 ± 1.32	7.89 ± 1.58	0.004	D vs N, D vs O

**Values are presented as mean ± standard deviation*

The symphysis height in the skeletal openbite patients (34.23 ± 3.79 mm) was significantly higher compared with the skeletal deepbite patients (30.89 ± 2.07 mm). However, there was not a significant difference in symphysis width between the three groups. The symphysis ratio in the skeletal openbite patients (0.40 ± 0.04) was significantly lower than that of the skeletal deepbite patients (0.45 ± 0.05).

Our results demonstrated that the mean values of the lingual mid-root and total apical ABTs of the skeletal deepbite patients were significantly higher compared with the skeletal openbite patients. Moreover, the total apical ABT at the mandibular lateral incisors in the skeletal deepbite patients was also significantly higher compared with the skeletal normal bite patients.

Correlation between symphysis dimensions and Labial ABTs (Table 2)

The skeletal deepbite patients demonstrated only a weak positive relationship between symphysis width and the lateral incisors' labial cervical ABT. The results indicated that the skeletal normal bite patients had a weak negative correlation between symphysis height and the labial apical ABT at the lateral incisors. In addition, the symphysis width in the skeletal normal bite patients was weakly correlated with the labial cervical ABT at the lateral incisors and the symphysis ratio was moderately correlated with the labial apical ABT at the central incisors.

We found that the symphysis width in the skeletal openbite patients was weakly positively related to the central incisors' labial apical ABT and the lateral incisors' labial cervical ABT. The symphysis ratio in the skeletal openbite patients had a weak positive correlation with the labial apical ABT at the central incisors and had a moderate positive correlation with the labial apical ABT at the lateral incisors, (R = 0.492), which was the strongest relationship between labial ABT and symphysis dimensions.

Correlation between symphysis dimensions and lingual ABTs (Table 3)

The skeletal deepbite patients demonstrated a weak positive correlation between the symphysis width and the lingual apical ABT at the central and lateral incisors and between the symphysis ratio and lingual apical ABT at the central incisors.

The symphysis width of the skeletal normal bite patients was weakly positively correlated with the lingual mid-root ABT at the lateral incisors and was moderately positively correlated with the central incisors' lingual mid-root to apical ABTs and the lateral incisors' lingual cervical and apical ABTs. Moreover, the symphysis ratio had a weak positive correlation with the lingual apical ABT of the central incisors.

The skeletal openbite patients' symphysis width had a weak positive correlation with the lingual mid-root ABT at the central incisors and was moderately positively correlated with the central incisors' lingual apical ABT and the lateral incisors' lingual mid-root ABT. Additionally, we found that the symphysis width demonstrated a strong positive correlation, which was the strongest correlation found among the lingual ABTs, (R = 0.702), with the lingual apical ABT at the lateral incisors. The symphysis ratio had a weak positive correlation with the lingual mid-root ABT at the lateral incisors, and was moderately positively correlated with the lingual apical ABT at both teeth.

Correlation between symphysis dimensions and total apical ABT (Table 4)

The skeletal deepbite patients had only a weak positive relationship between the symphysis width and total apical ABT at the central incisors and between the symphysis ratio and total apical ABT at both teeth.

The symphysis width in the skeletal normal bite patients revealed a weak positive correlation with the total apical ABT at the central and lateral incisors. Furthermore, the symphysis ratio demonstrated a moderate positive correlation with the total apical ABT at both teeth.

A strong positive correlation between the symphysis width and the total apical ABT was found at the central and lateral incisors in the skeletal openbite patients. Moreover, the relationship between the symphysis width and total apical ABT at the lateral incisors demonstrated the strongest correlation (R = 0.719) in this study. The symphysis ratio was moderately positively correlated with the total apical ABT at the central and lateral incisors.

Table 2 Correlation between symphysis dimensions and mandibular incisors' labial alveolar bone thickness

Sites	Deepbite (N = 25)			Normal bite (N = 25)			Openbite (N = 25)		
	Symphysis Height	Symphysis Width	Symphysis Ratio	Symphysis Height	Symphysis Width	Symphysis Ratio	Symphysis Height	Symphysis Width	Symphysis Ratio
Central incisor									
Labial-cervical	0.220	0.320	0.130	0.286	0.110	-0.117	-0.038	0.149	0.264
Labial-mid root	-0.024	-0.022	0.005	0.031	0.320	**0.255**	-0.270	-0.085	-0.187
Labial-apical	-0.108	-0.040	0.031	-0.351	0.282	**0.442***	-0.177	**0.315***	**0.336***
Lateral incisor									
Labial-cervical	0.277	**0.352***	0.014	0.223	**0.332***	-0.018	0.165	**0.302***	0.127
Labial-mid root	-0.139	0.229	0.354	0.031	0.159	0.146	0.059	0.276	-0.023
Labial-apical	-0.281	0.053	0.177	**-0.376****	0.236	0.278	-0.242	0.225	**0.492****

*** Correlation is significant at the 0.01 level (2-tailed)*

** Correlation is significant at the 0.05 level (2-tailed)*

Table 3 Correlation between symphysis dimensions and mandibular incisors' lingual alveolar bone thickness

Sites	Deepbite (N = 25)			Normal bite (N = 25)			Openbite (N = 25)		
	Symphysis Height	Symphysis Width	Symphysis Ratio	Symphysis Height	Symphysis Width	Symphysis Ratio	Symphysis Height	Symphysis Width	Symphysis Ratio
Central incisor									
Labial-cervical	0.264	0.229	0.008	0.178	0.328	0.101	0.309	0.132	0.163
Labial-mid root	-0.025	-0.154	0.167	0.078	**0.409***	**0.232**	0.264	**0.379****	0.338
Labial-apical	0.131	**0.371****	**0.349***	-0.131	**0.489****	**0.385***	0.071	**0.569****	**0.520****
Lateral incisor									
Labial-cervical	0.082	0.318	0.160	0.129	**0.448****	0.227	0.149	0.318	0.090
Labial-mid root	0.032	0.319	0.226	0.347	**0.368***	0.294	0.162	**0.460***	**0.366***
Labial-apical	0.166	**0.313***	0.198	0.194	**0.568****	0.207	-0.114	**0.702****	**0.437****

*** Correlation is significant at the 0.01 level (2-tailed)*

** Correlation is significant at the 0.05 level (2-tailed)*

Table 4 Correlation between symphysis dimensions and mandibular incisors' total apical alveolar bone thickness

Sites	Deepbite (N = 25)			Normal bite (N = 25)			Openbite (N = 25)		
	Symphysis Height	Symphysis Width	Symphysis Ratio	Symphysis Height	Symphysis Width	Symphysis Ratio	Symphysis Height	Symphysis Width	Symphysis Ratio
Central incisor									
total apical	**0.028**	**0.308****	**0.356***	**-0.360**	**0.393***	**0.478***	**-0.260**	**0.679****	**0.462***
Lateral incisor									
total apical	0.075	0.184	0.370*	-0.293	0.328*	0.536**	-0.081	0.719**	0.590**

*** Correlation is significant at the 0.01 level (2-tailed)*

** Correlation is significant at the 0.05 level (2-tailed)*

Discussion

Vertical skeletal patterns and symphysis dimensions were the independent variables in the current study. However, other factors might be related to ABT. Koh *et al.*[9] reported that the alveolar bone level is reduced in an age-dependent manner. Older patients tend to have thinner alveolar bone; therefore, in the present study, we recruited only 18–30-year-old subjects. In addition, some types of malocclusion, such as crowding or rotation, impact the thickness of the alveolar plate.[10] Thus, based on our inclusion criteria, the subjects in our study had only mild crowding (0-3 mm). Moreover, the sagittal skeletal pattern is related to the mandibular incisor's ABT.[11,12,14] Based on this, only skeletal Class I relationship patients were recruited to eliminate this confounding factor.

The present study used lateral cephalograms constructed from CBCTs to identify the sagittal and vertical skeletal patterns. Previous studies[22,23] revealed that the reliability of lateral cephalograms constructed from CBCTs was comparable to conventional lateral cephalograms and valid for scientific research. Moreover, some landmarks; such as Menton, Pogonion, and the upper and the lower incisal edge and root apex, of the lateral cephalograms constructed from CBCTs had a significantly higher reliability compared with conventional lateral cephalograms.[23] The small field of view (FOV) (8x8 cm) of the CBCT images, which does not involve the cranial base, was used in this study. The palatal plane-mandibular plane (PP-MP) angle was selected to identify each subject's vertical skeletal pattern instead of the Sella to Nasion-mandibular plane (SN-MP) angle. Petchdachai[21] reported a high correspondence between the PP-MP angle and other parameters, e.g. Frankfurt's horizontal plane and SN-MP angle, which are commonly used to identify the vertical skeletal pattern. In addition, the small FOV CBCT images used in this study have a small voxel size and provide higher partial resolution and display structural details better. Because our study investigated the ABT of the mandibular incisors, which is very thin, the small voxel size (0.165 mm) results in more accurate measurements compared with the larger voxel size.

Previous studies[24,25] have found that the mandibular symphysis in hyperdivergent patients was taller and narrower compared with hypodivergent patients. These findings partly corresponded with ours. The results of our study indicated that the symphysis height in skeletal openbite patients was significantly higher compared with skeletal deepbite patients. However, we did not find a significant difference in symphysis width between the skeletal openbite and deepbite patients. Thus, these results suggest that the mandibular symphysis in hyperdivergent patients was higher, but not narrower, than that in hypodivergent patients. The different finding between our results and previous studies[24,25] may be due to using different types of radiographs. The previous studies used conventional lateral cephalograms for evaluating the symphysis dimensions, whereas our study used CBCT imaging. Therefore, our study measured the symphysis dimensions at the mid-sagittal plane without the involvement of adjacent structures.

The present study detected differences in the mandibular incisors' ABT between vertical skeletal patterns. Consistent with the results of other studies[12-14], the mandibular incisors' ABT at the root apex level in skeletal deepbite patients was significantly thicker compared with skeletal openbite patients. The thinner bony support of the skeletal openbite patients might be a consequence of dento-alveolar compensation, because the teeth and alveolar bone over-erupted to maintain the overbite for the increased vertical skeletal dimensions. Although previous studies [12-14] indicated that there was no difference in ABT at the upper half root level between vertical skeletal patterns, the current study found that the lingual alveolar bone at the mid-root level in skeletal deepbite patients was significantly thicker compared with the skeletal openbite patients. The different ethnicities of the subjects between our study and former studies might explain the disparate results.

The present study also found differences in the relationship between the symphysis dimensions and the ABT at the mandibular incisors between the labial and lingual plates, which was similar to the results of Foosiri *et al,*.[16] The labial alveolar bone had a weak to moderate relationship with the symphysis width at the cervical level and demonstrated a moderate relationship with the symphysis ratio at the apical level. However, the symphysis width and symphysis ratio had a weak to moderate positive relationship with all levels of the lateral incisor's lingual ABT and mid-root to apical level of the central incisor's ABT. Moreover, a strong positive correlation was found between the symphysis width and the lingual apical ABT at the lateral incisor. The total apical ABT at both teeth demonstrated a moderate positive relationship with the symphysis width and had strong positive relationship with the symphysis ratio. Studies of the postnatal growth of the mandibular symphyseal area[26,27] found that the lingual cortex of the anterior mandible, including the dento-alveolar process, and the protruding chin, underwent periosteal bone deposition during growth. In contrast, the labial side of the anterior mandible above the protruding chin exhibited an inconsistent pattern of periosteal bone resorption, with some patients demonstrating resorption only at the interdental area, while others had resorption over the entire surface. The similar bone remodeling activity at the protruding chin and lingual cortex of the anterior mandible and the different bone remodeling activity at the protruding chin and labial cortex, which is located above the protruding chin, might explain the stronger association between the lingual ABT and symphysis width and ratio, compared with the labial ABT.

Our study found a relationship between the symphysis dimensions and the mandibular incisors' ABTs in every vertical skeletal pattern. However, the number of ABTs that were significantly related to the symphysis dimensions and the degree of correlation coefficient were different in each vertical skeletal pattern. Thus, the relationship between symphysis dimensions and ABT was strongest in skeletal openbite patients and weakest in skeletal deepbite patients. The strongest correlation ($R = 0.68–0.72$) among the groups was found in skeletal openbite patients between symphysis width and total apical ABT of both teeth and between symphysis width and lingual apical ABT at the lateral incisors. Whereas the relationship between apical ABT and symphysis width and ratio in skeletal deepbite patients was only weakly positively correlated ($R = 0.31–0.37$). The overall result from our study and a previous study[16], which demonstrated that apical alveolar bone and lingual alveolar bone tended to be thicker in patients with a wide and short symphysis compared with those with a narrow and long symphysis, and this relationship was stronger in skeletal openbite patients, compared with skeletal deepbite patients. The difference in the amount of chin prominence between vertical skeletal patterns might explain these findings. A thick protruding chin area (protuberantia mentalia) was commonly found in hypo-divergent patients, and hyperdivergent patients naturally had a small protruding chin area. Moreover, there was a wider range in the protruding chin areas between hypo-divergent patients compared with the hyperdivergent patients, which had a narrow range.[28] Because our study defined symphysis width as a linear measurement from Pog point to the external lingual limit of the symphysis, the protruding chin area was involved in the measurement. Therefore, in skeletal openbite patients, the symphysis width was better correlated with the ABT of the mandibular incisors than that of skeletal deepbite patients.

Based on our results, the relationship between the symphysis dimensions and ABT was strongest in the skeletal openbite patients and weakest in the skeletal deepbite patients. Orthodontists should include the mandibular symphysis dimensions as a factor that is related to ABT, especially in skeletal openbite patients. This is because thin alveolar bone is associated with negative consequences after orthodontic treatment.[2-4] To prevent deleterious effects, such as alveolar bone loss or bony dehiscence and fenestration, the pre-treatment alveolar bone at the mandibular incisors should be considered the limit for orthodontic tooth movement, particularly in skeletal openbite patients, who have a tall and narrow symphysis. The type and amount of tooth movement should be initially planned based on the amount of bony support. In patients requiring lingual tooth movement, bodily tooth movement or controlled tipping should be selected rather than un-controlled tipping that can potentially move the root apex through the labial plate as the crown is moving lingually. Similarly, labial tooth movement should be achieved using controlled tipping with a rotation center at the root apex rather than bodily tooth movement. Importantly, clinicians should use a low force for orthodontic tooth movement and carefully monitor the existing labial and lingual alveolar bone at the mandibular incisors throughout the treatment period.

Hoang *et al*,.[15] hypothesized that the thin alveolar bone found in hyperdivegent patients resulted from vertical dental compensation, which maintained the overbite by over-eruption of dentoalveolar process. The overall results of our study, which indicated a negative relationship between symphysis height and apical ABT, supports this idea. However, skeletal normal bite patients were the only group that demonstrated this tendency; the skeletal openbite patients did not have this relationship. This finding may be due to an inadequate sample size per group, which is a limitation of our study. Future studies should increase the number of patients to better evaluate the relationship between symphysis dimensions and ABT in different vertical skeletal patterns.

Conclusion

The positive relationship between the mandibular symphysis width and symphysis ratio, which is the ratio of symphysis width to symphysis height, and the ABT at the mandibular incisors was strongest in the skeletal openbite patients. The skeletal openbite patients with a taller symphysis were more likely to have a thinner lingual mid-root to apical ABT and total apical ABT, compared with the other vertical dimension patients. The limited amount of mandibular incisor tooth movement that can take place in these patients should be carefully considered.

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