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Original Article

Morphological difference of symphysis according to various skeletal types using cone-beam computed tomography

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Purpose: The aim of this study was to investigate differences between the morphology of the mandibular symphysis and four facial skeletal types. **Materials and Methods:** 40 cone-beam computed tomographies were selected and classified in to 4 groups according to their vertical and anterior-posterior skeletal patterns. The bone volume (mm^3) of the symphysis, the cross sectional area corresponding to the 4 mandibular incisors' axis: the cross sectional area of total bone (mm^2), the area of the cancellous bone (mm^2) and the thickness (mm) of labial and lingual alveolar bone at 2 mm, 3 mm under the cemento-enamel junction (CEJ) were measured. General linear model (GLM), Kruskal-Wallis test and Tukey honestly significant difference (HSD) test were subsequently used for statistical analysis. **Results:** The lingual cortical bone thickness of the lateral incisors at 2, 3 mm under CEJ was greater in the Class I low angle group than the other 3 groups ($P < 0.05$). There were no statistically significant differences in the volume of the mandibular incisor bony support, cross-sectional area of total bone and cancellous bone at the mandibular incisor' axis. **Conclusion:** Patients in Class I, low angle group have a thicker lingual mandibular symphysis than Class I, high angle patients. **(J Dent Rehabil Appl Sci 2014;30(3):215-22)**

Key words: facial skeletal type; mandibular symphysis; CBCT; volume of mandibular symphysis

Introduction

Symphysis in which the mandibular incisor is located becomes the anatomical limits[1] of tooth movement. When excessive force is applied during orthodontic treatment, teeth can touch the cortical plate of alveolus which causes resorption of cortical bone, fenestration, dehiscence, root exposure, external root resorption, and gingival recession.[2,3] It has been reported that they have occurred in almost all adults that underwent orthodontic treatment.[4] In general, Class I bi-dentoalveolar protrusive patients who need premolar extraction with maximum retraction of the incisors, bone defects must be observed carefully before orthodontic treatment and anatomical characteristics must be considered when planning tooth movements. Particularly for symphysis which is a thin narrow part, special care must be taken for the lingual movement of mandibular incisor.[5] Excessive lingual movement of mandibular incisors bring about irreversible resorption of the lingual alveolar bone, which results in permanent recession of the lingual alveolar bone.[3,6] After 4-month retention period with penetrated cortical plate, it was insufficient to completely cover the root, and the perforation site of the bone could be repaired only by its relapse to original position.[7]

Because the conventional two-dimensional lateral

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cephalometric images cannot accurately provide the thickness of the alveolar bone and bone density, expresses at least 5% enlargement,[8] and does not show the concave surface of symphysis properly, the actual symphysis is narrower than the image.[3] To solve these limits of 2D images, the use of Cone-beam CT (Cone-beam computed tomography, CBCT) is increasing in dental treatment these days.[9,10]

Previous studies on shapes of symphysis according to skeletal pattern were mostly done by 2D cephalometrcis having limitations. Therefore, this study intended to examine any differences in mandibular shapes by measuring the sectional area, thickness, and volume of symphysis according to Class I Class II skeletal patterns and vertical (high, low) facial skeleton types.

Materials and Methods

1. Materials

The subjects of this study were 658 patients who visited the orthodontic department of Ewha Womans University Mokdong Hospital between February 2011 and April 2012 and took CBCT. Patients who were 18 years old or younger, who had received orthodontic treatment, who had severe crowding in the mandibular incisor (Little's irregularity ≥ 6),[11] whose number of teeth was abnormal (supernumerary or missing teeth), who had abnormal shapes of teeth (giant or dwarf teeth), or whose IMPA was out of the average range (90 < IMPA < 102)[12] were excluded. The subjects were divided into Class I (0°-4°) or Class II (4° or greater) based on ANB angle[13] and into low angle (25 - 32°) or high angle (38 - 49°) based on the SN-MP angle.[14] Thus, they were classified into four groups (Class I low angle, Class I high angle, Class II low angle and Class II high angle). As a result, a total of 40 subjects (7 males, 33 females) were chosen (Table 1). This study was approved by the Institutional Review Board of Ewha Womans University Medical School Mokdong Hospital (ECT 11-24-01).

2. Methods

1) CBCT data

The images taken with CBCT (Dinnova™, Willmed, Seoul, Korea, 9 mA, 80 kV, 24 s, 20 cm × 15 cm field of view) were saved as DICOM (digital imaging and communication in medicine) files. Lateral cephalometric images were obtained using the X-ray Generation Module of OnDemand 3D™ (Cybermed Inc., Seoul, Korea). They were saved as DICOM files and the facial skeletons were analyzed through cephalometric radiography analysis program (V-ceph™ 5.5, OSSTEM Inc., Seoul, Korea).

The volume (mm^3), sectional areas (total sectional area and the sectional area of cancellous bone; mm^2), and thickness (mm) of the alveolar bone were measured. The DICOM file was reoriented so that the mandibular central incisor would be perpendicular to the horizontal plane (Fig. 1A). The mandible was cut in such a way that it was perpendicular to the

Table 1. General characteristics of subjects in four subgroups (Mean ± SD)

	Class I		Class II	
	Low	High	Low	High
Number of subjects (M/F)	10 (2/8)	10 (2/8)	10 (1/9)	10 (2/8)
Age (year)	25.30 ± 5.42	24.60 ± 8.76	30.90 ± 7.25	23.50 ± 5.50
IMPA (°)	98.21 ± 4.37	93.13 ± 2.64	99.67 ± 3.00	95.92 ± 4.11
ANB (°)	2.17 ± 1.18	3.00 ± 0.73	5.67 ± 1.56	6.74 ± 1.66
SN-MP (°)	28.21 ± 2.15	41.26 ± 1.66	28.65 ± 2.06	43.15 ± 2.96

Class I, angle's Class I (0° < ANB <4°); Class II, angle's Class II (ANB > 4°), Low, low angle (25° < sella-nasion to mandibular plan angle < 32°); High, high angle (38 < sella-nasion to mandibular plan angle < 49°).
SD, standard deviation; IMPA, lower incisor to mandibular plane angle; ANB, A point - Nasion - B point angle; SN-MP, angle between sella-nasion line and mandibular plane.

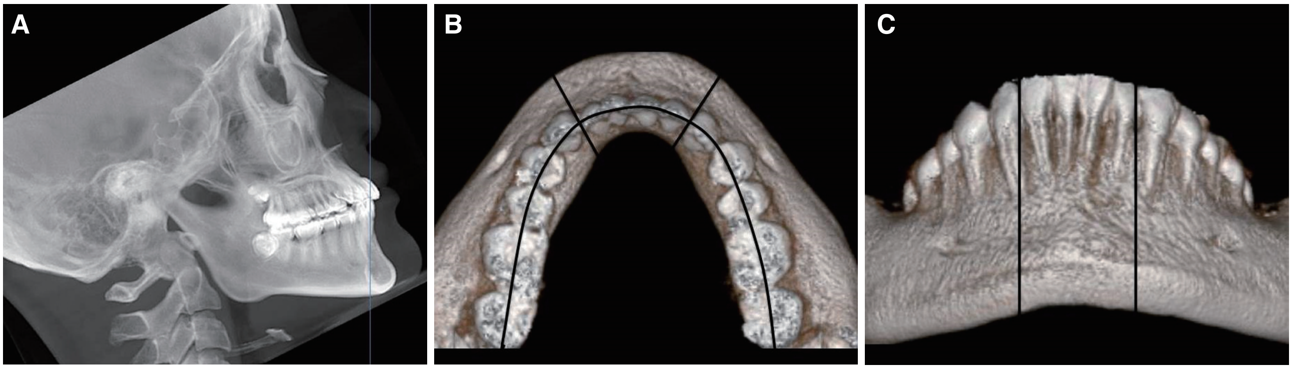

Fig. 1. Measuring volume of mandibular symphysis. (A) CT image was re-oriented to make the axis of the mandibular central incisor perpendicular to the horizontal plane, (B) Symphysis was sectioned in the direction that was vertical to the re-oriented horizontal plane and to the mandibular dental arch and passing by the distal side of lateral incisors, (C) Frontal view.

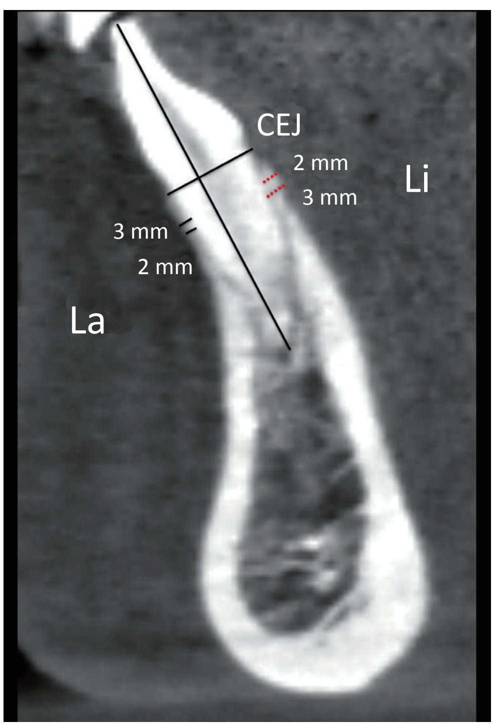

Fig. 2. Measurement of the alveolar bone thickness (mm) and dimension (mm^2) on the sagittal section. La (labial side, thick black lines): thickness of mandibular alveolar bone at 2, 3 mm under CEJ, Li (lingual side, thick red dotted lines): thickness of mandibular alveolar bone at 2, 3 mm under CEJ. Area of total alveolar bone, cancellous bone.
La, labial side of incisor; CEJ, cemento-enamel junction; Li, lingual side of incisor.

reoriented plane and the mandibular dental arch and it would pass through the center of both mandibular lateral incisors, and the volume (mm^3) of the alveolar bone of the mandibular incisor was measured (Fig. 1B, 1C) The total sectional area (mm^2) of the alveolar bone was measured from a plane based on the axis of each of the 4 mandibular incisors, and the sectional area of the cancellous bone (mm^2) excluding the cortical bone was measured. Furthermore, the thicknesses of the labial and lingual alveolar bones at 2 mm and 3 mm below CEJ (cemento-enamel junction) were measured (Fig. 2).

3. Intra-examiner reliability

To evaluate intra-examiner reliability, 10 of the 40 CBCT data were chosen and measured again with a week interval. An evaluation using ICC (Intraclass Correlation Coefficient) showed that the data were reliable at the confidence level of 0.994 (volume), 0.968 (total sectional area), 0.978 (sectional area of cancellous bone), and 0.939 (thickness).[15]

4. Statistical analysis

The collected data were analyzed for computer statistics with the PASW Statics 18 (SPSS Inc., Chicago, IL, USA) application. General linear model (GLM), Kruskal-Wallis test, and Tukey posteriori test were performed ($P < 0.05$). To examine differences of the four groups in symphysis volume, the sectional area of sagittal plane based on the axes of 4 mandibular incisors (total sectional area and sectional area of the cancellous bone), alveolar bone thicknesses (labial and lingual at 2 mm and 3 mm below CEJ), GLM was performed to adjust age, sex, and IMPA. To determine correlations, two-way ANOVA, Kruskal-Wallis test and Tukey post-hoc test were performed.

Results

The thicknesses of lingual alveolar bone at 2 mm and 3 mm below CEJ of the lateral incisor were significantly different, and the Class I low angle was thicker than other three groups ($P < 0.05$). The differences between the four groups in volume, sectional areas (total sectional area and sectional area of the cancellous bone), and the thicknesses of the buccal alveolar bone at 2 mm and 3 mm below CEJ were statistically insignificant ($P > 0.05$, Table 2, 3).

It was found that the differences in thicknesses of the lingual alveolar bone at 2 mm below CEJ of the left and right mandibular lateral incisors were significant ($P < 0.05$). The lingual alveolar bone at 3 mm below CEJ showed different significancy with different statistical methods, which could be interpreted as to have weaker effect by vertical or horizontal skeletal pattern. As a result of the post-hoc test, the thickness of the lingual alveolar bone at 2 mm below CEJ of the Class I low angle was thicker than other three groups ($P < 0.05$, Table 4), and the thickness of the lingual alveolar bone at 3 mm below CEJ of the Class I low angle was thicker than Class I high angle and Class II high angle ($P < 0.05$, Table 4).

Table 2. Volume (mm^3), cross sectional area of total bone (mm^2) and cancellous bone (mm^2) at the incisor's axis of mandibular symphysis according to facial types

	Class I		Class II		*P* value
	Low	High	Low	High	
Volume (mm^3)	8996.37 ± 2033.94	8006.37 ± 1951.2	9887.71 ± 2959.31	7498.47 ± 1615.61	0.119
Total area (mm^2)	262.66 ± 39.45	252.24 ± 47.49	285.85 ± 47.52	247.51 ± 34.21	0.300
Cancellous area (mm^2)	124.59 ± 25.33	115.27 ± 28.05	139.44 ± 41.57	110.02 ± 26.68	0.218

Gender, age and IMPA adjusted.
Class I, angle's Class I (0° < ANB < 4°); Class II, angle's Class II (ANB > 4°), Low, low angle (25° < sella-nasion to mandibular plan angle < 32°); High, high angle (38 < sella-nasion to mandibular plan angle < 49°).

Table 3. Means and standard deviations of the alveolar bone thickness of mandibualr incisors under CEJ 2, 3 mm

Alveolar bone thickness			Class I		Class II		*P* value
			Low	High	Low	High	
Central incisor	La	2 mm	0.58 ± 0.38	0.50 ± 0.4	0.47 ± 0.52	0.57 ± 0.39	0.332
		3 mm	0.48 ± 0.30	0.57 ± 0.44	0.64 ± 0.51	0.56 ± 0.35	0.364
	Li	2 mm	0.67 ± 0.58	0.53 ± 0.39	0.36 ± 0.42	0.46 ± 0.30	0.210
		3 mm	0.90 ± 0.69	0.76 ± 0.37	0.64 ± 0.48	0.61 ± 0.46	0.636
Lateral incisor	La	2 mm	0.47 ± 0.32	0.50 ± 0.44	0.64 ± 0.57	0.44 ± 0.43	0.251
		3 mm	0.35 ± 0.28	0.65 ± 0.49	0.63 ± 0.45	0.56 ± 0.43	0.051
	Li	2 mm	1.33 ± 0.61[b]	0.43 ± 0.34[a]	0.48 ± 0.46[a]	0.56 ± 0.38[a]	0.000*
		3 mm	1.70 ±0.87[b]	0.73 ± 0.33[a]	0.98 ± 0.63[a]	0.72 ± 0.54[a]	0.012*

Gender, age and IMPA adjusted. *$P < 0.05$, Kruskal-Wallis test, Tukey post hoc test (a < b), Two-way anova, Values with the same alphabetical superscript are not statistically different.
Class I, angle's Class I (0° < ANB < 4°); Class II, angle's Class II (ANB > 4°), Low, low angle (25° < sella-nasion to mandibular plan angle < 32°); High, high angle (38° < sella-nasion to mandibular plan angle < 49°); La, labial surface of incisor; Li, lingual surface of incisor.

Table 4. Means and standard deviations of the alveolar bone thickness at 4 incisors (detailed by parts)

				Class I		Class II		*P* value
				Low	High	Low	High	
Central incisor	Rt	La	2 mm	0.61 ± 0.36	0.44 ± 0.43	0.36 ± 0.49	0.59 ± 0.35	0.131
			3 mm	0.55 ± 0.31	0.59 ± 0.48	0.68 ± 0.48	0.59 ± 0.36	0.651
		Li	2 mm	0.71 ± 0.49	0.54 ± 0.43	0.36 ± 0.41	0.54 ± 0.29	0.190
			3 mm	1.00 ± 0.61	0.75 ± 0.44	0.63 ± 0.46	0.66 ± 0.24	0.346
	Lt	La	2 mm	0.56 ± 0.41	0.57 ± 0.39	0.58 ± 0.56	0.56 ± 0.44	0.920
			3 mm	0.41 ± 0.30	0.55 ± 0.42	0.58 ± 0.57	0.53 ± 0.36	0.463
		Li	2 mm	0.63 ± 0.68	0.52 ± 0.38	0.35 ± 0.47	0.39 ± 0.32	0.630
			3 mm	0.81 ± 0.79	0.77 ± 0.31	0.63 ± 0.56	0.56 ± 0.61	0.947
Lateral incisor	Rt	La	2 mm	0.45 ± 0.35	0.55 ± 0.48	0.59 ± 0.56	0.43 ± 0.39	0.359
			3 mm	0.36 ± 0.31	0.58 ± 0.55	0.61 ± 0.37	0.54 ± 0.37	0.270
		Li	2 mm	1.41 ± 0.67[b]	0.47 ± 0.36[a]	0.57 ± 0.53[a]	0.50 ± 0.40[a]	0.009**
			3 mm	1.88 ± 1.08[b]	0.75 ± 0.31[a]	1.03 ± 0.66[ab]	0.76 ± 0.61[a]	0.071
	Lt	La	2 mm	0.49 ± 0.31	0.45 ± 0.41	0.69 ± 0.61	0.46 ± 0.49	0.505
			3 mm	0.34 ± 0.26	0.66 ± 0.49	0.78 ± 0.51	0.58 ± 0.50	0.082
		Li	2 mm	1.25 ± 0.58[b]	0.48 ± 0.37[a]	0.44 ± 0.36[a]	0.61 ± 0.38[a]	0.001**
			3 mm	1.53 ± 0.58[b]	0.72 ± 0.37[a]	0.97 ± 0.62[ab]	0.69 ± 0.50[a]	0.120

Gender, age and IMPA adjusted.
$^*P < 0.05$, $^{**}P < 0.01$, Kruskal-Wallis test, Tukey post hoc test (a < b), Two-way anova, Values with the same alphabetical superscript are not statistically different. ab: There is no statistically difference with a and b.
Class I, angle's Class I (0° < ANB < 4°); Class II, angle's Class II (ANB > 4°), Low, low angle (25° < sella-nasion to mandibular plan angle < 32°); High, high angle (38° < sella-nasion to mandibular plan angle < 49°); Rt, right side; Lt, left side; La, labial surface of incisor; Li, lingual surface of incisor.

Discussion

This study investigated the differences in the shape of mandibular symphysis by Class I Class II skeletal patterns and the vertical facial skeletons in adult patients. There were no differences in the volume and sectional area of the alveolar bone of mandibular incisors, but the thickness of the lingual alveolar bone near CEJ varied. Among the 4 incisors, the lateral incisor showed a difference. The lingual alveolar bone of the low angle group was thicker than that of the high angle, which indicated that the symphysis thickness was more affected by the vertical skeleton rather than the horizontal skeleton in Class I Class II. The symphysis volume and sectional areas showed no significant difference of facial skeleton. It seems that the thin, long symphysis and the thick, short symphysis only changed their shapes maintaining their volume during growth. And seems that the alveolar bone thickness is more affected by vertical skeletal pattern in the more coronal part.

According to a study by Swasty et al.,[16] there were no differences in mandibular shape and alveolar bone thickness between genders, except for mandibular body height. However, in this study, the gender differences between the four groups were not statistically significant ($P > 0.05$).

Previous studies reported conflicting results of different alveolar bone thickness according to different age groups.[17,18] But because only adults were included in this study, no statistically differences in alveolar bone thickness were found according to ages ($P > 0.05$).

The differences in IMPA between groups were detected in this study. Since the plane for measuring volume was determined with mandibular incisors, the volume could be affected by IMPA. Thus, in this study, the IMPA values were controlled to certain levels and the results were analyzed with statistical adjustment.

Even though a few researchers insisted that there was no correlation between orthodontic tooth movement and gingival recession,[19,20] many studies reported that narrow symphysis was a major cause of fenestration and dehiscence.[6,21] Due to the compact labio-lingual alveolar bone around the roots of mandibular incisors, the movement of mandibular teeth are limited.[22,23] The alveolar bone condition must be evaluated when moving mandibular incisors to prevent gingival recession and bone fenestration.[23,24] Due to such anatomical limitations of the symphysis, the positions of mandibular incisors and the quantity of tooth movement planned are important factors.

Unlike other sites, symphysis has thicker lingual alveolar bone than the labial alveolar bone.[25] Handelman[1] investigated the correlations between facial form and symphysis thickness, and reported that the symphysis was thin in the long face for Class I and II and in all facial forms in Class III. Tsunori et al.[26] reported that patients with low angle exhibited thicker buccal alveolar bone, which was in contrast to this study showing differences in lingual alveolar bone thickness. This could be explained by including posterior teeth in investigating alveolar bone thickness which was not included in this study.

Cephalometric x-ray which is two-dimensional image is difficult to identify the adverse reactions of alveolar bone during or after tooth movement, and the symphysis thickness appears thicker than the actual thickness because the sagittal plane projected.[1] While conventional x-ray cannot evaluate the actual bone defects such as dehiscence and conventional CT has the burden of high radiologic dose and high price, Cone-beam CT can provide precise results for hard tissues in the craniofacial area without high exposure to radiation.[27]

Retraction of mandibular incisors has the risk of adverse reactions. More care should be taken in patients with narrow symphysis. Therefore, the volume and thickness of alveolar bone are important, but it is difficult to identify its shape through cephalometric x-ray or clinical intra-oral examination, CT can reveal them more clearly. The possibility of the resorption of alveolar bone must be explained to the patient, and the mandibular incisor retraction must be performed while paying attention to the thin symphysis for facial skeletons of Class II, high angle.

Conclusion

The differences in morphology of symphysis were examined according to vertical skeletal types and Class I and Class II facial patterns. It was found that Class I group and low angle had thicker lingual alveolar bone of mandibular incisor than that of Class II and high angle, respectively. Therefore, high angle patients are likely to have thin symphysis, extra care must be taken during retraction of the mandibular teeth.

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안면골격 유형에 따른 하악 전치 치조골의 형태 차이: Cone-beam CT를 이용한 정량적 평가

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목적: 본 연구는 수평적, 수직적 안면 골격 유형에 따른 하악 전치부 치조골의 형태학적 차이를 알아보기 위하여 시행하였다.
연구 재료 및 방법: 40명의 Cone-beam computed tomography (Cone-beam CT)를 선별하여, 4개 군으로 분류하였다. Cone-beam CT 자료를 이용하여 하악 전치부 치조골의 부피(mm^3), 하악 4절치 치축 기준 시상단면의 단면적(총 단면적, 해면골 단면적: mm^2), 백악법랑경계(cemento-enamel junction: CEJ) 2 mm, 3 mm 아래 순, 설측 치조골 두께를 측정하였다. 통계분석은 GLM, Kruskal-Wallis test and Tukey HSD를 사용하였다.
결과: 측절치의 백악법랑경계 2 mm, 3 mm 하방 설측 치조골 두께가, Class I low angle군이 나머지 3군 보다 두꺼웠다 ($P < 0.05$). 하악 전치 치조골의 부피, 전체 치조골 및 해면골의 단면에서의 통계적으로 유의한 차이는 없었다.
결론: Class I low angle군은 Class II high angle군에 비해 하악 전치 치조골의 설측 부위가 더 두껍다.

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주요어: 안면골격형태; 하악전치 치조골; CBCT; 설측치조골 부피

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