

Evaluation of the Relationship Between Morphology, Volume, and Density of the Mandible and Dentofacial Vertical Dimension Using Cone Beam Computed Tomography

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Academic Editors: Alessandro Leite Cavalcanti and Wilton Wilney Nascimento Padilha

Received: 12 April 2019 / Accepted: 01 August 2019 / Published: 16 August 2019

Abstract

Objective: To evaluate the relationship between mandibular shape, mandibular bone density, cortical bone thickness, and condylar volume and facial height using a cone-beam computed tomography (CBCT). **Material and Methods:** Fifteen female patients (16-25 years old) were included in this study. The following measurements were performed on CBCT radiographs; inter-canine and inter-molar width of the mandible at three vertical points (alveolar crest, apex and basal bone), mandibular cortical bone thickness in disto molar and canine sections, bone density of the mandibular body and condylar volume. Afterward, subjects were divided into short face, normal and long face groups according to the Frankfort-mandibular plane angle (FMA) measured on lateral cephalograms obtained from CBCTs. Data were analyzed using Pearson correlation, one-way ANOVA, and post-hoc analysis. **Results:** The inter-canine width of the mandible at the apical point in long face subjects was greater than in the other groups. Likewise, the cortical bone thickness was significantly higher in long face patients compared to the short face and normal subjects. There was no statistically significant difference in mandibular density or condylar volume between patients with various vertical heights ($p > 0.1$). **Conclusion:** Vertical growth pattern is correlated with mandibular morphology to some extent.

Keywords: Cone-Beam Computed Tomography; Vertical Dimension; Mandible.

Introduction

The morphology of the mandible may change as a result of the various loads exerted on it by forces from the attached muscles [1-4]. Several studies have proposed that mandibular morphology might be related to facial height, as the strength of forces loaded onto the mandible via attached muscles differs between patients with low, moderate or high facial height [5-9]. Assessment of mandibular morphology and condylar shape in orthodontic patients can be an efficient way to determine an appropriate treatment plan and predict the final result of therapy. In addition, mini implants are commonly used to provide appropriate anchorage, so the prediction of suitable sites for these implants with sufficient cortical bone thickness is critical for their fitness and stability [6,10].

Recently, cone-beam computed tomography (CBCT) has become popular in orthodontics as it provides a three-dimensional image of the craniofacial complex and its multidimensional reconstruction of the tooth-bone complex provides a comprehensive view on which the reliable measurements can be made [5,11]. Although CBCT has been used in several studies to evaluate mandibular morphology in recent years [5-7,12-14], the relationship between mandibular and condylar morphology with different facial types has not yet been clarified.

This study was conducted to clarify how mandibular cortical bone thickness, mandibular density, inter-canine and inter-molar width of the mandible, as well as condylar shape, vary in CBCT images of patients with different facial types.

Material and Methods

Study Design and Sample

This cross-sectional study was carried out on CBCT radiographs of patients referred to a private radiologic center in Mashhad, Iran. Inclusion criteria required female patients aged 16-25 with symmetric mandibles and complete permanent dentition. Subjects were excluded from the study if there was moderate or severe dental crowding in the mandible with respect to Little's Irregularity Index (LII), a previous history of orthognathic surgery or orthodontic treatment or the presence of an underlying disease that interfered with the proper function of the mandible and masticatory muscles such as rheumatoid arthritis or temporomandibular joint disorders. Moreover, low-quality images or those containing pathologic lesions in the mandible were excluded.

All CBCT scans were performed due to ENT (Ear-Nose-Throat) or orthodontic diagnostic purposes, including impacted canines, sinus evaluation, fractures, and septum deviations. CBCTs were obtained using a Planmeca Promax 3DMax (Planmeca Oy, Helsinki, Finland) and the radiation parameter was set at 80 kVp, 8 mA and 12 s per revolution. Consequently, images were created with a voxel size of 0.2 mm and a grey scale of 15 bits. Planmeca Romexis 3.1.1R software (Reconstruction with HPZ800 Workstation) was used for measurements on the CBCT images.

Measurements

Cross-sections of the mandible were obtained using Romexis Software (Planmeca OY, Helsinki, Finland) and variables were measured on each section as follows:

- Inter-canine and inter-molar width [15]: Inter-canine and inter-molar width of the mandible were measured in axial sections through the mandibular alveolar crest, the apical points of the canines and molars. Inter-canine width of the mandible was measured at the most mid-buccal tip of the tooth on axial sections passing through the mandibular alveolar crest and the apical point of the canines. In order to evaluate inter-canine width at the mandibular basal point through the coronal section passing through the center of the canines, the long axis of the canines was drawn and continued to the inferior border of the mandible, and the distance between the two points was measured. These widths were also measured at the mandibular basal points in coronal sections. The inter-molar width of the mandible was measured at the distobuccal tip of the tooth on axial sections passing through the mandibular alveolar crest and the apical point of the molar distal root. The measurement of the inter-molar width of the mandible at the mandibular basal point was similar to the inter-canine width.

- Thickness of cortical bone [16]: The thickness of cortical bone was measured on four coronal sections for each subject. These cross-sections were perpendicular to the alveolar arch and included sections passing through the distal surface of the left and right mandibular first molars and sections passing through the center of the right and left mandibular canines. In order to assess the cortical bone thickness at each section, a straight line was drawn perpendicular to the mandibular plane to define the alveolar height. Afterward, the two lines were extended at one third and two-thirds of the alveolar height perpendicular to the first line as they passed across the section (Figure 1A and 1B). The cortical bone was measured at the resulting two buccal points, two lingual points and one at the base of the section. The mean of these measurements was reported as cortical bone thickness at each section.

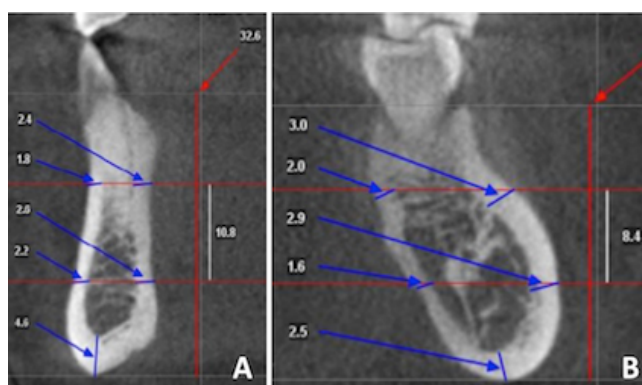


Figure 1. A: Measurements of the cortical bone thickness on a coronal section through the mandibular canine. B: Measurements of the cortical bone thickness on a coronal section through the distal surface of the mandibular first molar.

- Condylar volume [17]: To calculate the volume of each patient's condyle, using Romexis software (Planmeca OY, Helsinki, Finland), 100 axial sections were prepared from the sigmoid notch to the head of the condyle, and then the total areas of the cross-sections were calculated and were reported as condylar volume.

- Mandibular bone density [18]: Mandibular bone density was measured in the body of the mandible and reported based on the Hounsfield number. In this calculation, the body of the mandible was defined as the area between the line passing the posterior tooth apices above and the border of the mandible below. The dividing line of this area from the ramus was the confluence of the occlusal plane with the posterior border of the ramus. To assimilate the measured volume of the samples, a cylinder with a diameter of 10 mm and a height of 30 mm in the center of the defined area, as mentioned above, was considered by the software and the Hounsfield number of this volume was calculated.

- Category [19]: According to the cephalograms generated from CBCT radiographs by software (Romexis) and following the Frankfort-Mandibular angle (FMA), patients were divided into three facial types: seven were in the short face group ($FMA \leq 22$), five in the normal group ($22 < FMA < 28$) and three in the long face group ($FMA \geq 28$).

Statistical Analysis

Data were analyzed using Pearson correlation, one-way ANOVA, and post-hoc analysis. All analysis was performed with SPSS version 22 (IBM Corp., Armonk, New York, USA). According to the small sample size of this study (N=15), the significance level was set at $p < 0.1$.

Results

Inter-canine and inter-molar width of the mandible at each section were compared between participants with different facial types, as shown in Table 1. Inter-canine and inter-molar width at each section were higher in long face participants compared with short face or normal groups, but this difference was not statistically significant except for the inter-canine width at the apical point section ($p=0.039$). Inter-molar width at the basal bone sections was greater than at the other sections in all facial types but especially in long face patients.

Table 1. Mean and standard deviation (SD) of mandibular width at each section for each of facial type.

Variables	Short Face		Normal		Long Face		p-value
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	
Inter Canine Width							
Alveolar Crest	30.1	2.2	30	1.8	32.2	2.2	0.337
Apical Point	21.4	2.1	20.45	0.25	24.1	2.2	0.039
Basal	19.8	3.8	19.4	2.8	23.5	4.1	0.278
Inter Molar Width							
Alveolar Crest	53.8	2.4	52.9	3.6	53.9	2.9	0.456
Apical Point	53.7	2.6	53.5	4	56.7	4.3	0.418
Basal	63	4.2	61	4.2	68.4	5.1	0.187

Comparison by ANOVA of the average thickness of mandibular cortical bone between patients with different facial types revealed a significant difference between groups ($p < 0.1$; Table 2). Post-hoc analysis showed that long face participants had significantly higher values compared to

patients with normal or short facial types while the thinnest bone in all the sections was measured in patients with normal facial type.

Table 2. Mean and standard deviation (SD) of cortical bone thickness at each section for each of the facial types.

Tooth	Short Face		Normal		Long Face		p-value
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	
Right Molar	1.97	0.25	1.8	0.35	2.4	0.35	0.056
Left Molar	1.94	0.24	1.8	0.3	2.38	0.38	0.058
Right Canine	1.9	0.13	1.63	0.38	2.06	0.18	0.077
Left Canine	1.86	0.17	1.53	0.39	2.12	0.15	0.027

There was no statistically significant difference in mandibular basal bone density between patients with different facial heights on the left and right sides of the mandible ($p=0.78, 0.53$). The greatest mandibular basal bone density at the left side was measured in short face patients compared to the normal group, while the long face group exhibited the lowest density. The density of the right side of the mandibular basal bone followed a similar pattern in which short face patients had the highest values followed by the normal group, and the lowest density was again measured in the long face patients.

Table 3. Mean and SD of mandibular bone density at each section for each facial type.

Mandibular Bone Density	Short Face		Normal		Long Face		p-value
	Mean HU	SD	Mean HU	SD	Mean HU	SD	
Left Side	316.2	49.9	293.0	46.2	281.1	149.0	0.78
Right Side	321.4	48.6	283.9	28.5	274.7	130.7	0.53

HU: Hounsfield's units.

When the sum of the right and left condylar volume were compared between the three groups, no statistically significant difference was observed ($p \geq 0.1$), although condylar volume in long face patients was greater than in normal and short face groups.

Table 4. Mean and SD of condylar volume for each of facial type.

Condylar Volume	Short Face		Normal		Long Face		p-value
	Mean (mm ³)	SD	Mean (mm ³)	SD	Mean (mm ³)	SD	
Sum of Left and Right	246477	20000	239216	19584	265477	20852	0.233

Discussion

In the current study, there were no significant differences in the mandibular width of any of the measured sections among the subjects with different facial heights (except for the inter-canine width of the mandible in the apical section). These findings are similar to those of a previous study in which the difference between the widths of the mandibular bone of patients with different facial heights was not significant [5].

Our results also showed that the inter-molar widths of the mandible in all groups at the alveolar crest sections were less than its width at the basal bone sections and although this difference

in long face subjects was greater than in the other groups, it was not statistically significant. In this regard, it was reported that in long face patients, the upper third region of the mandible is narrower compared to average-face and short face subjects [7]. This difference in mandibular width might be due to clockwise rotation of the mandible that is observed in long face subjects which exerts forces on the mandible through the facial muscles, especially the buccinators, and leads to increased pressure at the alveolar crest region and consequently reduced width at this region of the mandible.

Since mini-implants can reduce or even eliminate the unpredictable anchorage losses, which occur during orthodontic treatments [20], increasing their success rate is an important issue for clinicians. As osseointegration does not occur around the inserted mini implants, their stability is dependent on a tight fit to the surrounding cortical bone. For this reason, previous studies reported the success rate of these mini implants to be directly related to the cortical bone thickness of the target site [21,22]. Consequently, the prediction of appropriate sites with sufficient thickness of cortical bone for insertion of mini implants is critical especially if this prediction could be performed by assessing the patient's facial type in order to save time and avoid extra exposure of the patients to radiation.

In the present study, the cortical bone thickness was measured four sites of the mandible for each subject, and in all sites, the highest average thickness of cortical bone was in long face subjects followed by normal patients, while the lowest cortical bone thickness was reported in short face subjects. In contrast, in several other studies, the cortical bone was thinner in patients with a vertical growth pattern compared to subjects with a horizontal growth pattern [5-7]. The age of patients has also been reported to have an effect on cortical bone thickness in some studies [23-25] as cortical bone thickness in younger patients was less than in elderly patients. Thus considering the lower age range of the participants in the current study compared with previous findings [5,6], this factor could also explain the origin of the antithetical finding of our study. Moreover, evaluations on cadavers or dry skulls, racial differences, and variations in the sites of cortical bone measurements might be the causes of diversity between studies [6].

There was no statistically significant difference in the density of the mandibular basal bone between subjects with various facial types. In spite of that, the average density was higher in the short face group compared to patients with normal facial height, while long face subjects had the lowest density. It has been demonstrated that cortical bone density significantly varied in relation to age [26].

Although our statistical analysis revealed no significant relationship between condylar volume and facial type, the average condylar volume was greater in the long face group than in the other groups. In contrast, a previous study revealed that condylar volume in low-angle subjects was significantly higher compared to normal and high-angle groups [27]. Muscular activity and genetic factors were mentioned as possible causes of this difference between the various facial types, but according to the transverse construction of their study, no absolute conclusion about the mechanism of the observed difference in condylar volume between subjects with various facial types could be

drawn [21]. Skeletal morphology and type of mastication were also reported to be related to condylar volume and morphology [27-29]. Previous authors found significant differences in condylar volume between side and sex [30]; however, this relation was not observed for age and occlusal support.

Conclusion

The vertical growth pattern is correlated with mandibular morphology to some extent. Further studies with a larger sample size are recommended to clarify this relationship.

Authors' Contributions: FF and SHHZ designed the study and performed the data analysis, MFM designed the study and data collection, AR contributed to data analysis and interpretation and wrote the paper. All authors declare that they contributed to the critical review of intellectual content and approval of the final version to be published.

Financial Support: Research Vice-Chancellor of Mashhad University of Medical Sciences (Grant Number 910407).

Conflict of Interest: The authors declare no conflicts of interest.

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