Original Article

Three-dimensional Evaluation of Alveolar Bone Thickness of Mandibular Anterior Teeth in Different Dentofacial Types

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Abstract

Aim: The aim of this randomized study was to compare the alveolar bone thickness (ABT) of the mandibular incisor teeth of dental and skeletal Class I, II, and III adult patients at labial and lingual aspects of the bone and develop recommendations for the associated movements of teeth in this region, taking vertical facial type into consideration. **Material and Methods**: Sixty-two Class I, 74 Class II, and 63 Class III patients - aged between 20 and 45 - were assigned to three subgroups – high (H), low (L), and normal (N) growth patterns. On the axial slices of computerized tomographies, the measurements for the ABT on labial and lingual sides of the mandibular incisors were carried out at three levels. **Results:** In Class I group, at apex region, ABT of subgroups N and L were greater than H, at labial side. In Class II, ABT of subgroups N and L were greater than H, at apex at both sides and cervical lingual region. Similarly, ABT of subgroup L of Class III group was greater than H, at labial and lingual apex, mid-root regions. In Class II, the ABT of subgroup H was greater than L, at lingual cementoenamel junction. **Conclusions:** ABT of mandibular incisors of Class I patients is not affected from vertical pattern except for apical region. There is not a thick bone on the lingual side of the Class II, high-angle patients. The ABT of the Class III, high-angle patients is thin as a risk factor for proclination.

Date of Acceptance:
18-Jul-2017

Keywords: *Alveolar bone thickness, cone-beam computed tomography, lower incisors*

Introduction

To establish a balance in the anterior intermaxillary relation in various vertical facial patterns, a range of camouflage angulations of the mandibular anterior teeth may be seen.[1-8] Previous studies showed that, gingival recessions, damages to the root surface and the alveolar bone might occur with the proclination or retroclination of the mandibular incisors.[9] In the review of Borzabadi-Farahani,[12] it was concluded that the orthodontic treatment need indices should be revalidated under the means of pathologic boundaries of gingival recession. The labial bone thickness and crestal labial soft tissue thickness are mostly affected in the anterior region.[11] However, very few studied the alveolar bone support of the mandibular incisors by taking the vertical facial pattern into consideration.[12-14]

When two-dimensional dental radiographic views are not sufficient for diagnosis, cone-beam computed tomography (CBCT) images may be used for evaluation of the bone three-dimensionally without the effect of head orientation, image superimpositions, or distortions, and they have high accuracy and reliability for assessing the alveolar structure and relatively low radiation dose.[15-19]

Therefore, the purpose of the present study was to evaluate the alveolar bone thickness (ABT) of mandibular incisors on CBCTs considering the different vertical facial patterns of adult patients.

Access this article online	
Quick Response Code:	Website: www.njcponline.com
	DOI: 10.4103/njcp.njcp_90_17

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How to cite this article: Eraydın F, Germec-Cakan D, Tozlu M, Ozdemir FI. Three-dimensional evaluation of alveolar bone thickness of mandibular anterior teeth in different dentofacial types. Niger J Clin Pract 2018;21:519-24.

Material and Methods

This retrospective study was conducted on the CBCTs from the archives of Yeditepe University Dental School. The study sample was selected from 320 patients who were referred to oral radiology department. Only 199 of the CBCTs met the inclusion criteria of this study. The inclusion criteria were as follows: age between 20 and 45 years who had crowding of <3 mm in the mandibular arch, no excessive facial asymmetries, no diagnosed systemic diseases, no severe craniofacial dysmorphology, no metal prosthesis that could generate artifact, no periodontal disease with alveolar bone loss, no spacing or tooth shape anomaly as well as no missing teeth in the measurement area. Only the CBCTs of patients who did not have orthodontic treatment were included. Ethical approval was obtained from the institutional review board of Yeditepe University.

Patient data were handled according to the requirements and recommendations of the Declaration of Helsinki. The CBCT images were obtained using ILUMA™ (IMTEC Imaging, Ardmore, OK, USA) unit (120 kVp, 3.8 mA). The scan time was 40s, focal spot was 3.3 mm, and voxel size was 0.093 mm.

Measurements

For S-N/N-Me, <27° indicated low facial height, between 27° and 37° normal facial height, and more than 37° indicated increased facial height.[21,22] There were 66 high-angle growth pattern (35 men, 31 women), 69 normal growth pattern (23 men, 36 women), and 64 low-angle growth pattern (33 men, 31 women) patients with the mean age 27.2 ± 2.3 years. Sagittal grouping was done according to the Angle's classification and also an ANB angle <0° indicated a Class III, between 0° and 4° indicated a Class I, and more than 4° indicated a Class II jaw relationship.[23] In the high-angle group, there were skeletal and dental 18 Class I, 24 Class II, and 24 Class III patients. In the normal group, there were dentally 24 Class I, 27 Class II, and 18 Class III patients. In the low-angle group, there were dentally 20 Class I, 23 Class II, and 21 Class III patients. After all inclusion criteria were applied, CBCT images of 199 patients were evaluated.

The definitions of the reference points and measurements are described in Tables 1 and 2. On the sagittal slice, three measurement points on the labial and lingual sides were defined as three mm apical to the cementoenamel junction (CEJ),[24,25] middle region of the root, and the root apex [Figure 1] so that six alveolar bone measurements were done from the surface of root to the outer surface of the alveolar cortex perpendicular to the long axis of the tooth. On the axial slices, these

Table 1: Definitions of reference points used in the study

Reference points and lines	Definition of the points and lines
1	Incisal edge of lower incisor
2	Root apex of the lower incisor
3	Long axis of the lower incisor
4	Cemento-enamel junction (CEJ) on the labial side
5	CEJ on the lingual side
6	The line which passes through the points 3 mm apical to the CEJ on labial and lingual sides of the tooth
7	Intersection point of the line 6 with the labial contour of alveolar bone
8	Intersection point of the line 6 with the labial contour of the tooth root surface
9	Intersection point of the line 6 with the lingual contour of the tooth root surface
10	Intersection point of the line 6 with the lingual contour of the symphysis surface
11	The line perpendicular to the long axis of the tooth which passes through the mid-root region
12	Intersection point of the line 11 with the labial contour of symphysis
13	Intersection point of the line 11 with the labial contour of root surface
14	Intersection point of the line 11 with the lingual contour of root surface
15	Intersection point of the line 11 with the lingual contour of symphysis
16	The line perpendicular to the long axis of the tooth on the apex level
17	Intersection point of the line 16 with the labial contour of symphysis
18	Intersection point of the line 6 with the lingual contour of symphysis

Table 2: Definitions of the measurements used in the study

Measurement	Definition of the measurements
LC	Alveolar bone thickness at the cervical region of the labial side; distance between points 7 and 8, measured on line 6
LC'	Alveolar bone thickness at the cervical region of the lingual side; distance between points 9 and 10, measured on line 6
LM	Alveolar bone thickness at the middle region of the labial side; distance between points 12 and 13, measured on line 11
LM'	Alveolar bone thickness at the middle region of the lingual side; distance between points 14 and 15, measured on line 11
LA	Alveolar bone thickness at the apex of the labial side; distance between points 17 and 2, measured on line 16
LA'	Alveolar bone thickness at the apex region of the lingual side; distance between points 18 and 2, measured on line 16

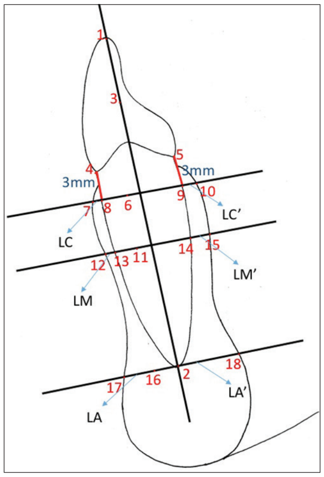

Figure 1: Reference points and measurements used in the study

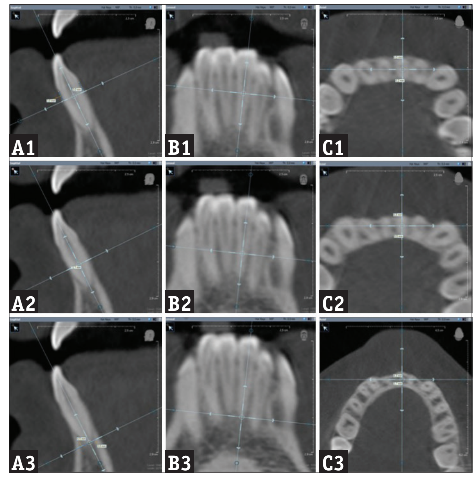

Figure 2: Measurement of cortical bone thickness on a sagittal (A1), coronal (B1), and axial (C1) image using the transversal reference plane at the vertical level of 3 mm from the cementoenamel junction, at mid-root (A2), (B2), (C2), and at apex (A3), (B3), (C3)

were recorded as horizontal ABT at 3 mm apical to the CEJ, at the middle region of the root, and at the root apex [Figure 2].

The measurements were performed by one examiner (F. U.). Twenty images were selected randomly and measurements were repeated 10 days after the first set of measurements by the same examiner for evaluation of the intraexaminer reliability.

Statistical analysis

Statistical analyses were carried out with NCSS 2007 software (NCSS LLC, Kaysville, UT, USA) for Windows. Besides descriptive statistics (mean and standard deviation), in the groups showing normal distribution, Kruskal–Wallis test was used. Since the study was retrospective, *post hoc* power analysis was applied by G* power for statistically significant comparisons. Subgroup comparisons were performed with Dunn's multiple comparison test. For the two group comparisons, Mann–Whitney U-test was utilized. The results were evaluated at $P < 0.05$ significance level. The examiner was consistent in the repeated measurements; the intraclass correlation coefficients were between 0.881 and 0.992.

Results

The *post hoc* power analysis for comparisons which were statistically significant was above 99%. There was no statistically significant difference between the groups for gender distributions. The results of the Mann–Whitney U-test showed that there was no statistically significant difference between male and female patients or the left and right sides in all measurements of the ABT ($P > 0.05$), and the data were combined for further tests.

Amount of alveolar bone thickness at 3 mm apical to the cementoenamel junction

In Class I, the mean value for ABT of the labial and lingual side did not show statistically significant difference, regarding the H, L, and N growth patterns.

In Class II, for the lateral tooth, the mean value of the ABT was greater for Group N and L than Group H for the lingual side.

In Class III, on the lingual side, the mean values of the ABT of Group H were greater than Group L [Table 3].

Alveolar bone thickness at the mid-root

In Class I, the mean values of the ABT at the middle region of the labial and lingual side did not have statistically significant difference.

In Class II, at the middle of the lingual side and at the mandibular central tooth, the mean value of the ABT of Group N was greater than Group H.

In Class III, at the middle region of the labial side, the mean values of the ABT had statistically significant difference. On the lingual side, the mean values of the ABT of the lateral were greater for Group N than Group H [Table 4].

Alveolar bone thickness at the apex region

In Class I, at the apex region, on the labial side, the mean values of the ABT of the Groups L and N were greater than Group H for the mandibular central and lateral incisor [Table 5].

In Class II, at the apex of the labial and lingual side of the mandibular incisors, the mean values of the ABT of Group H were lower than Groups N and L at both sides.

Table 3: The alveolar bone thickness at 3 mm apical to CEJ region of the skeletally Class I, Class II and Class III patients who have normal, low or high angle vertical growth pattern

Side	Tooth	Normal	Low angle	High angle	*P*
Class I					
Labial	Central	0.19±0.38	0.29±0.61	0.42±0.69	0.601
	Lateral	0.39±0.57	0.59±0.69	0.66±0.61	0.362
Lingual	Central	0.18±0.38	0.37±0.55	0.12±0.33	0.241
	Lateral	0.51±0.48	0.63±0.53	0.31±0.46	0.156
Class II					
Labial	Central	0.42±0.57	0.35±0.5	0.21±0.43	0.304
	Lateral	0.74±0.58	0.59±0.55	0.47±0.61	0.23
Lingual	Central	0.52±0.58[a]	0.27±0.42[a,b]	0.06±0.19[b]	0.001
	Lateral	0.75±0.57[a]	0.55±0.46[a]	0.23±0.38[b]	0.001
Class III					
Labial	Central	4.39±3.93	3.92±2.99	5.84±3.49	0.08
	Lateral	5.03±4.3	3.95±3.1	5.71±3.79	0.096
Lingual	Central	4.73±3.86[a,b]	4.49±3.7[a]	7.23±4.25[b]	0.024
	Lateral	4.82±4.55[a,b]	4.11±3.73[a]	7.87±4.56[b]	0.011

[a,b]Same superscript letters indicate no significant difference. Values are presented as mean and standard deviation

Table 4: The alveolar bone thickness at the middle region of the skeletally Class I, Class II and Class III patients who have normal, low or high angle growth pattern

Side	Tooth	Normal	Low angle	High angle	*P*
Class I					
Labial	Central	0.35±0.5	0.25±0.54	0.55±0.66	0.254
	Lateral	0.25±0.5	0.22±0.47	0.23±0.51	0.969
Lingual	Central	0.78±0.53	0.85±0.86	0.55±0.62	0.401
	Lateral	1.13±0.57	1.23±1.02	0.91±0.63	0.501
Class II					
Labial	Central	0.44±0.56	0.23±0.45	0.49±0.69	0.209
	Lateral	0.24±0.4	0.21±0.44	0.44±0.63	0.269
Lingual	Central	1.09±0.69[a]	0.91±0.68[a,b]	0.5±0.58[b]	0.003
	Lateral	1.61±0.74[a]	1.56±0.73[a]	1.05±0.71[b]	0.015
Class III					
Labial	Central	0.03±0.13[a]	0.46±0.7[b]	0.06±0.23[a]	0.007
	Lateral	0.06±0.25[a]	0.55±0.91[b]	0.12±0.31[a]	0.035
Lingual	Central	0.77±1.17	0.63±0.75	0.28±0.54	0.189
	Lateral	0.86±0.97[a]	0.65±0.92[b]	0.17±0.42[a]	0.032

[a,b]Same superscript letters indicate no significant difference. Values are presented as mean and standard deviation

In Class III, at the apex region of the labial side, the mean values of the ABT were greater for Group L than Group H. On the lingual side, the mean values of the alveolar bone were greater for Group H than Group L.

Discussion

When the mandibular incisor movements are planned, besides the ABT and quality, the position and inclination of the mandibular incisors on the sagittal plane and the periodontal status of the region are diagnostic measures.[10]

Table 5: The alveolar bone thickness at apex region of the skeletally Class I, Class II and Class III patients who have normal, low or high angle growth pattern

Side	Tooth	Normal	Low angle	High angle	*P*
Class I					
Labial	Central	4.21±1.36[a]	4.08±0.81[a]	2.54±0.85[b]	0.0001
	Lateral	4.27±1.64[a]	4.13±1.21[a]	2.92±0.68[b]	0.002
Lingual	Central	2.95±0.69	3.1±1.54	3.04±0.87	0.672
	Lateral	3.19±0.76	3.23±1.36	3.48±0.56	0.409
Class II					
Labial	Central	4.16±1.11[a]	4.01±1.35[a]	2.55±0.91[b]	0.0001
	Lateral	3.98±1.06[a]	4.23±1.62[a]	2.74±1.2[b]	0.001
Lingual	Central	3.18±1.26[a]	3.22±1.11[a]	2.28±1.42[b]	0.013
	Lateral	3.64±0.96[a]	3.57±1.36[a]	2.24±1.38[b]	0.0001
Class III					
Labial	Central	4.37±1.27[a,b]	5.41±2[a]	3.74±1.4[b]	0.002
	Lateral	4.37±1.24[a]	5.97±2.01[b]	3.59±1.14[a]	0.0001
Lingual	Central	2.91±1.22[a,b]	3.21±1.23[a]	2.25±0.83[b]	0.01
	Lateral	2.96±1.76[a,b]	3.09±1.34[a]	2.2±0.85[b]	0.026

[a,b]Same superscript letters indicate no significant difference. Values are presented as mean and standard deviation

There was no gender-related difference in the ABT. This finding was in concordance with the results of the other studies.[20,26]

It should be noted that the labial ABT at the apex seems thinner than lingual side in high-angle patients; if the mandibular anterior teeth are going to be retracted, mechanics for torque control should be preferred not to have uncontrolled tipping. In Class I, light orthodontic forces should be applied using elastic arch wires, and time must be allowed for the remodeling and healing of the alveolar bone in these patient groups not to lose marginal bone.

Yagci *et al*.[27] detected dehiscence and fenestration on the CBCTs of sagittally Class I, II, and III presenting normal vertical growth pattern. They reported that there was less restriction for moving the mandibular incisors in the labiolingual direction, and tooth tipping should be preferred to bodily movement in Class II patients; whereas, in our study, similar patient group presented <1 mm of bone thickness on the CEJ and mid-root regions.

On the contrary to Class II, Class III with high-angle growth pattern presents a thicker lingual cervical ABT than low and normal growth pattern patients, which is good news for compensation treatment of Class III. Torque control is needed to inhibit uncontrolled tipping of the mandibular incisors and keep the apex in the bony corridor in these patients. In midarea, there would be a great risk of fenestration with both compensation and decompensation tooth movements. Similarly, Kook *et al*.[28] studied the ABT between normal occlusion and Class III anterior open bite patients. For Class III treatment, we may recommend leveling with rectangular superelastic archwires as an option for root torque control of mandibular incisors. In Class III, decompensation of the mandibular incisors with excessive forward movement to catch the ideal mandibular incisor angle was reported to force the incisors out of the alveolar bone.[4] Grafting of the buccal area[29] use of light orthodontic forces, allowing time for remodeling, and providing torque control may be carried out for support of the treatment.

We found that ABT of low angles at apex region is greater than the other groups in almost all sagittal patterns. This result is similar with the results of the study of Gracco *et al*.,[14] where the authors correlated the morphology of the mandibular symphysis to various vertical facial patterns. In their CT study, they showed that the total and labial bone thickness on the mandibular anterior region of the low-angle growth pattern patients were greater than high-angle growth pattern patients. Their results were in agreement with Siciliani *et al*.[30] who made the bone thickness measurements on the lateral cephalograms and found out that the total thickness of the symphysis was greater in low-angle growth patterns than high-angle growth pattern patients. Handelman[22] measured the distance between the root apex and the external surface of the mandibular anterior cortical bone on lateral cephalograms. He concluded that narrow alveolus was found around mandibular incisors in high-angle Class III patients; which supports our results.

On the contrary, Nair *et al*.[31] found that the thickness of labial bone plate was thinner than the lingual bone and there was no difference between the different vertical facial patterns. Without any information on the sagittal relationship, only vertical facial characteristics were grouped in their study; therefore, the results may not show a difference between the vertical growth patterns due to the measurement of compound groups.

For age-related factors, the ABT variety as a result of different functional capacity, bite forces due to the muscle size and activity are known factors.[32,33] In the present study, only the CBCTs of the adult patients were included. Since the two dimensional images such as lateral cephalometric radiographs show superimposing on curved surfaces, which means that the original curvature of the symphysis or the labial alveolar bone of the mandibular incisor might be thinner than the curvature on the image.[30,34] CBCT images are reliable and accurate tools among diagnostic records with their minimum distortion and low radiation dose qualities. They enable the orthodontists to evaluate bone levels in three dimensions.

To avoid undesired fenestrations or dehiscences on the labial ABT, the clinician should be precautious about excessive tooth movement in all dentofacial types.

Conclusions

1. In all dentofacial types, gingival recessions or dehiscences may occur on the labial alveolar bone of Class I and Class II
2. In all dentofacial types, fenestrations may be detached on the labial alveolar bone of Class I, II, or III
3. There is poor bone thickness on the labial or lingual side of all Class II with either vertical facial type.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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