Cumhuriyet Dental Journal: 2018; 21(3)

Doi: 10.7126/cumudj.406846 *RESEARCH ARTICLES*

COMPARISON AND EVALUATION OF ALVEOLAR BONE AROUND LOWER CENTRAL INCISORS IN CLASS III AND CLASS I PATIENTS

İskeletsel Sınıf III ve Sınıf I Bireylerin Alt Santral Kesici Dişlerinin Etrafındaki Alveolar Kemiğin Karşılaştırılması ve Değerlendirilmesi

Ezgi ATİK, Hande GÖRÜCÜ COŞKUNER, Tülin TANER

Makale Kodu/Article Code *: 406846*

Makale Gönderilme Tarihi *: 16.03.2018*

Kabul Tarihi *: 26.07.2018*

ABSTRACT

Objectives: The aim was to evaluate and compare the alveolar bone support of mandibular central incisors in subjects with Class III and Class I skeletal patterns using cone-beam computed tomography (CBCT).

Materials and Methods: Group 1 included 20 patients (mean age=19.78±2.80) with Class III malocclusion (mean ANB°=-2.77±3.69), mesofacial growth pattern (FMA°=27.03 ±5.11) and lingual-inclined mandibular incisors (IMPA°<85). Group 2 included 20 patients (mean age=20.85±3.97) with Class I malocclusion (mean ANB°=2.94 ±1.46), mesofacial growth pattern (FMA°=25.67±6.83) and normal inclined mandibular incisors (85<IMPA°<95). Vertical alveolar bone level and alveolar bone thickness (ABT) of total 80 mandibular central incisors (40 from each group) were evaluated. Buccal, lingual and total ABT were measured at the crestal, midroot, and apical levels. Buccal (BACH) and lingual (LACH) alveolar crestal heights were also evaluated. Mann-Whitney U, independent samples-t-tests, and Pearson correlation analysis were applied for statistical analysis.

Results: The lingual ABT at the crestal and midroot level, buccal ABT at the apical level, and total ABT at all levels were significantly lower in Group 1 than Group 2 ($p<0.05$). There was a negative correlation between the buccal ($r=-0.324$; $p=0.042$) ABT at the apical level and mandibular plane angle. The change in mandibular incisor inclination was positively correlated with buccal ABT at the apical level ($r=0.463$; $p=0.003$) and lingual ABT at the crestal level ($r=0.550$; $p<0.001$). BACH was significantly higher in Group 1 (2.21±1.48 mm) compared to Group 2 (1.42±0.17 mm) ($p < 0.05$).

Conclusions: In subjects with Class III deformities, mandibular central incisors have less bone support especially at the buccal side of the alveolar bone at the apical level and lingual side of the alveolar bone at the crestal and midroot levels. Rate of change in mandibular incisor inclination and mandibular plane angle can be thought as significant factors that may influence alveolar bone thickness.

Key Words: Class III, alveolar bone, CBCT evaluation

ÖZ

Amaç: Bu çalışmanın amacı, konik ışınlı bilgisayarlı tomografi (KIBT) kullanılarak iskeletsel Sınıf III ve Sınıf I malokluzyonlu bireylerde mandibuler santral keserlerin etrafındaki alveolar kemik desteğini değerlendirmek ve karşılaştırmaktır.

Materyal ve Metod: Grup 1, İskeletsel Sınıf III malokluzyona (ortalama ANB°= -2,77±3,69), mezofasiyal büyüme yönüne (FMA°=27,03 ±5,11) ve linguale eğimli mandibuler keserlere (IMPA°<85) sahip olan 20 hastadan (ortalama yaş=19,78±2,80 yıl) oluşmaktadır. Grup 2, İskeletsel Sınıf I malokluzyona (ortalama ANB°= 2,94 ±1,46), mezofasiyal büyüme yönüne (FMA°=25,67±6,83) ve normal eğimli mandibuler keserlere (85<IMPA°<95) sahip olan 20 hastadan (ortalama yaş=20,85±3,97) oluşmaktadır. Toplam 80 mandibuler santral keser dişin (her bir gruptan 40 diş) görüntüleri kullanılarak vertikal alveolar kemik yüksekliği ve alveolar kemik kalınlığı (AKK) ölçülmüştür. Bukkal, lingual ve total AKK; krestal, kök ortası ve apikal seviyelerde ölçülmüştür. Bukkal (BAKY) ve lingual (LAKY) alveolar krestal yükseklikler de değerlendirilmiştir. İstatistiksel analiz için Mann-Whitney U, bağımsız örneklem-t-testleri ve Pearson korelasyon analizi uygulanmıştır.

Bulgular: Krestal ve orta kök seviyesinde lingual AKK; apikal seviyede bukkal AKK; ve tüm seviyelerde total AKK Grup 1'de Grup 2'ye göre anlamlı şekilde daha az bulunmuştur (p<0,05). Apikal seviyede bukkal AKK (r=-0,324; p=0,042) ve mandibuler düzlem açısı arasında negatif korelasyon bulunmuştur. Mandibuler keser eğimindeki değişim apikal seviyedeki bukkal AKK (r=0,463; p=0,003) ve krestal seviyedeki lingual AKK (r=0,550; p<0,001) ile pozitif korelasyon göstermiştir. BAKY, Grup 1'de (2,21±1,48 mm) Grup 2'ye (1,42±0,17 mm) göre anlamlı şekilde yüksek bulunmuştur (p<0,05).

Sonuçlar: Sınıf III deformitesi olan bireylerde, mandibuler santral keser dişler özellikle apikal seviyede alveolar kemiğin bukkal tarafında ve krestal ve kök orta seviyelerinde ise alveolar kemiğin lingual tarafında daha az kemik desteğine sahiptir. Mandibuler keser eğiminde ve mandibular düzlem açısındaki değişim oranı, alveoler kemik kalınlığını etkileyebilecek önemli faktörler olarak düşünülebilir.

Anahtar Kelimeler: Sınıf III, alveolar kemik, KIBT incelemesi

Department of Orthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.

INTRODUCTION

Adequate alveolar bone support is essential for both efficient tooth movement and stable tooth position. A detailed evaluation of maxillomandibular alveolar bone morphology is crucial in determining orthodontic tooth movement limits and exceeding this limit may cause undesirable iatrogenic side effects in periodontal tissues such as dehiscence and fenestration.[1] It has been emphasized by some authors that the morphology of alveolar bone structure may be related to the inclination of the teeth in the anteroposterior direction.[2,3] Surgical orthodontic treatment of Class III patients requires orthodontic decompensation including proclining the mandibular incisors to normal axial inclinations. With previous studies,[4-6] it was shown that the proclination of the incisors out of the alveolar envelope might be associated with gingival recessions. It has been indicated in a previous study[7] that the mandibular incisors had greater bone loss than the maxillary incisors in skeletal Class III patients. In Class III patients with thin symphysis structure, severe labial inclination of the incisors may also increase the alveolar bone loss.[8,9] More careful orthodontic planning is required to ensure that the above-mentioned dental decompensation movements do not cause iatrogenic side effects, since Class III individuals show a thinner alveolar bone structure, especially in the cervical area, compared to individuals with normal occlusion.[10]

Traditional radiographic images such as cephalograms, panoramic radiographs, or periapical radiographs are less accurate for the evaluation of bone structure.[11] The alveolar bone measurements may be overestimated with the traditional cephalometric radiographs.[1,12] Considering the high accuracy of cone-beam computed tomography (CBCT) without distortion or superimposition[13-15], it is the appropriate technique for precise evaluation of alveolar bone dimensions. The vertical height and buccolingual thickness of the alveolar bone in the anterior region of the mandible can be measured with the aid of the sections obtained from the CBCT images, and topographic location assessment can be performed showing the inclination of lower incisors in different planes.[16,17]

In the literature, there is a limited number of studies[10,18,19] evaluating the correlation of buccolingual tooth inclination with alveolar bone thickness in skeletal Class III deformities. Therefore, this study was performed to determine the alveolar bone thickness and height of the mandibular central incisors in subjects with Class III malocclusion and to compare the results with Class I normal occlusion. The null hypothesis was that there was no difference between the two different malocclusion groups.

MATERIALS AND METHODS

This study was a retrospective evaluation of patient records. Pre-treatment CBCT images of 40 non-growing individuals were obtained from the data archive of Hacettepe University, Faculty of Dentistry, and Department of Orthodontics. Ethical approval was obtained from the Hacettepe University Ethical Committee (institutional review board number: GO 16/591-23). CBCT scans were selected according to the following inclusion criteria: (1) CBCT scans taken for diagnostic purposes of multiple impacted teeth or severe facial asymmetry for Class I malocclusion, and pre-surgical evaluation for Class III malocclusion, (2) scans of patients older than 16 years, (3) IMPA degree lower than 85° for skeletal Class III group, and IMPA degree between 85° and 95° for skeletal Class I group. Exclusion criteria were as the following: (1) missing or unerupted mandibular permanent incisors, (2) history of trauma to the lower anterior teeth, (3) crowding more than 3 mm or spacing more than 1 mm in the mandibular anterior alveolar segment, (4) prosthetic crowns on the mandibular incisors, (5) previous orthodontic or surgical treatment.

Three-dimensional CBCT scans were previously taken with i-CAT Cone Beam 3D Imaging System (Imaging Sciences International, Hatfield, Pa) at maximum intercuspation. The scanning settings for the CBCT machine were: 23x17 cm field of view (voxel size, 0.30 mm), 120-kVp tube voltage, tube current of 2 mA, and 17.8 seconds scan time. The CBCT scans were divided into two groups on the basis of both malocclusion classification (Skeletal Class III or I) and IMPA (<85° or between 85° and 95°). The sample consisted of CBCT scans of totally 40 individuals. A total of 80 teeth were evaluated. Group 1 included the CBCT scans (40 mandibular central incisors) of 20 Skeletal Class III malocclusion patients (10 male, 10 female; mean age: 19.78±2.80 years; mean ANB°: -2.77°±3.69°), mesofacial growth pattern (FMA°: 27.03°±5.11°) with IMPA lower than 85° (mean IMPA°: 78.78°±6.32°) indicating lingually-inclined mandibular incisors according to Tweed analysis. Group 2 included the CBCT scans (40 mandibular central incisors) of 20 Skeletal Class I patients (10 male, 10 female; mean age: 20.85±3.97 years; mean ANB°: 2.94°±1.46°), mesofacial growth pattern (FMA°: 25.67°±6.83°) with IMPA between 85° and 95° (mean IMPA°: 91.92°±3.27°) indicating normally inclined mandibular incisors according to Tweed analysis (Figure 1).

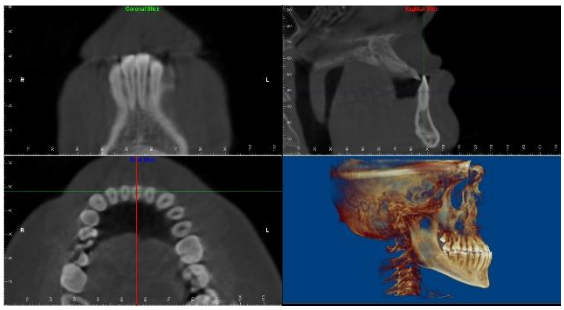

Figure 1. The orientation of all 3 planes of space of CBTC.

Measurements of alveolar bone were performed by importing the DICOM files into Dolphin software (Dolphin Imaging Systems, Chatsworth, Calif). Afterwards 3D reconstructions were obtained selecting the axial, coronal, and sagittal displays (Figure 2).

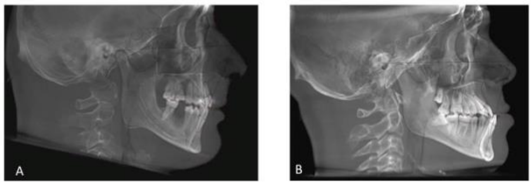

Figure 2. Representative images of two groups classified by different malocclusion and incisor inclination. A, Class I normal group; B, Class III lingual-inclined group.

The axial plane was selected to intersect with the crown of the interested tooth. The coronal and sagittal planes were adjusted to pass through the center of the crown and the root of the interested tooth with the sagittal plane perpendicular to the subject's arch in the axial view. On the sagittal cross section of the mandibular central incisors, buccal and lingual alveolar crestal heights (BACH and LACH) were measured from the most coronal level of the alveolar bone crest to the most apical portion of the cementoenamel junction (CEJ). Along the axis of the root of each tooth, alveolar bone width measurements were made along the sagittal reference plane at 3, 6, and 8 mm apically to the CEJ. Buccal and lingual bone thicknesses were measured from the most buccal and lingual aspects of the root to the most buccal and lingual aspects of the alveolar bone along the orientation of the sagittal plane (Figure 3).

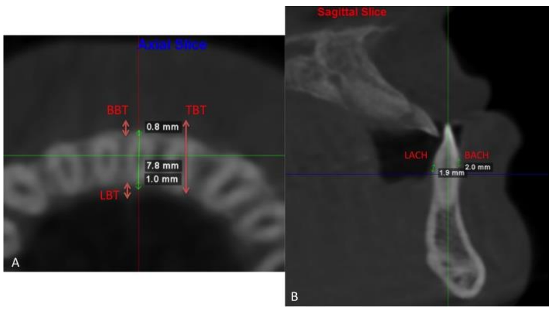

Figure 3. Measurements from CBCT; A, location of alveolar bone thickness measurements; B, vertical alveolar bone level measurement. BBT means buccal bone thickness, LBT means lingual bone thickness, BACH means buccal alveolar crestal height, LACH means lingual alveolar crestal height.

From the constructed lateral cephalograms, the incisor-mandibular plane angle (IMPA), formed by the intersection of the long axis of the mandibular incisor and the gonion-menton line, and mandibular plane angle (FMA) formed by the intersection of the Frankfurt horizontal plane and mandibular plane were measured. All measurements were made by 2 orthodontists (E.A. and H.G.C.) previously calibrated.

Statistical Analysis

Statistical calculations were performed by using IBM-SPSS for Windows version 21 (SPSS Inc., IL, USA). Shapiro-Wilks test was used to demonstrate whether the parameters were distributed normally or not. Independent samples t-test was used to compare the normally distributed variables, and Mann-Whitney U test was used to compare the variables that were not distributed normally between the groups. The significance level was established at $p < .05$. Pearson correlation analysis was used to analyze the relationship of alveolar bone measurements with IMPA and FMA.

The CBCT measurement error was assessed by calculating the intraclass correlation coefficient (ICC) based on a two-way mixed analysis of variance (ANOVA). 20 CBCT scans (ten from each skeletal pattern group) were measured by two calibrated orthodontists 2 weeks apart to test the reproducibility of the measurements. The ICC values were between 0.847 and 0.990 (Table 1). These values can be considered to be good and excellent.

Table 1. Reliability results of clinical measurements.

	Left tooth			Right Tooth		
	ICC	*95% Confidence Interval*		*ICC*	*95% Confidence Interval*	
		Lower	*Upper*		*Lower*	*Upper*
B-crestal (mm)	0.932	0.838	0.972	0.873	0.711	0.947
B-midroot (mm)	0.864	0.694	0.944	0.942	0.862	0.976
B-apical (mm)	0.957	0.896	0.983	0.951	0.882	0.980
L-crestal (mm)	0.963	0.911	0.985	0.931	0.837	0.972
L-midroot (mm)	0.957	0.897	0.983	0.971	0.930	0.988
L-apical (mm)	0.974	0.936	0.989	0.985	0.062	0.994
T-crestal (mm)	0.948	0.875	0.979	0.973	0.935	0.989
T-midroot (mm)	0.981	0.953	0.992	0.976	0.942	0.990
T-apical (mm)	0.990	0.975	0.996	0.989	0.972	0.995
BACH (mm)	0.982	0.956	0.993	0.989	0.974	0.996
LACH (mm)	0.847	0.658	0.936	0.946	0.871	0.978

ICC: Intraclass correlation coefficient.

RESULTS

Table 2 shows the demographic and clinical variables of the compared groups. The average age of the patients and the FMA angle showed no significant difference between the groups, on the other hand lower incisor inclination degree was significantly lower in Group 1 (mean IMPA°: 78.78°±6.32°) than Group 2 (mean IMPA°: 91.92°±3.27°) ($p<0.05$).

Table 2. Demographic and Clinical Characteristics of the Sample.

Variables	**Group 1 (Class III)**	**Group 2 (Class I)**	**p-value**
Number of subjects	20 (10 female, 10 male)	20 (10 female,10 male)	
Age (year)	19.78 ±2.80	20.85±3.97	0.565[a]
ANB (°)	-2.77±3.69	2.94±1.46	<0.001*[a]
IMPA (°)	78.78±6.32	91.92±3.27	<0.001*[a]
FMA (°)	27.03 ±5.11	25.67±6.83	0.480[b]

a: Mann-Whitney U test, b: Independent samples-t-test.

The results of the alveolar bone measurements of the mandibular central incisors are listed in Table 3. Statistically significant differences of total ABT between the groups were found at crestal, midroot and apical levels ($p<0.05$). At apical level, buccal ABT value (0.75±0.44 mm) in Group 1 was significantly lower than value in Group 2 (1.28±0.64 mm) ($p=0.004$). The lingual ABT values around the mandibular central incisors in Group 1 were also lower than in the other group at the crestal and midroot levels, and these differences were significant ($p\leq0.01$). There was no statistically significant difference in the ABT on the buccal side at the crestal and midroot levels between the groups. Considering the vertical alveolar bone level, BACH measurement was significantly higher in Group 1 (2.21±1.48 mm) than found in Group 2 (1.42±0.17 mm) ($p=0.010$). Considering the lingual surface, no significant difference was found between the groups in according with LACH ($p=0.091$).

Table 3. Comparison of alveolar bone measurements between the groups.

Variables	Group 1 (Class III)	Group 2 (Class I)	Mean difference	95% Confidence Interval of the Difference		1-2 (P)
				Lower	Upper	
B-crestal (mm)	0.55±0.29	0.63±0.26	-0.08	-0.26	0.96	0.354[b]
B-midroot (mm)	0.46±0.26	0.76±0.42	-0.30	-0.52	-0.08	0.072[a]
B-apical (mm)	0.75±0.44	1.28±0.64	-0.53	-0.88	-0.18	0.004*[b]
L-crestal (mm)	0.70±0.41	1.10±0.30	-0.39	-0.62	-0.16	0.001*[b]
L-midroot (mm)	0.94±0.83	1.27±0.47	-0.33	-0.76	0.10	0.010*[a]
L-apical (mm)	1.26±0.84	1.63±0.61	-0.37	-0.84	0.10	0.122[b]
T-crestal (mm)	6.50±0.93	7.04±0.47	-0.55	-1.02	-0.08	0.011*[a]
T-midroot (mm)	6.12±0.99	6.91±0.73	-0.79	-1.35	-0.23	0.007*[b]
T-apical (mm)	6.08±1.05	7.05±1.10	-0.97	-1.66	-0.28	0.007*[b]
BACH (mm)	2.21±1.48	1.42±0.17	0.78	0.11	1.46	0.010*[a]
LACH (mm)	2.57±2.64	1.51±0.26	1.05	-0.15	2.25	0.091[a]

a: Mann-Whitney U test, b: Independent samples-t-test, comparison of alveolar bone measurements between the groups, the significance level was $p<0,05$. *Statistically significant.
1-2, Group 1 and Group 2 comparison. B:Buccal, L:Lingual, T:Total.

Table 4 shows the Pearson correlation between each one of the variables of alveolar bone measurement and IMPA/FMA degrees for all teeth (n=80) studied.

Table 4. Correlation between cephalometric and alveolar bone measurements.

Variables	N	IMPA (°)	FMA (°)
		R (P)	**R (P)**
B-crestal (mm)	40	0.190 (0.239)	0.009 (0.955)
B-apical (mm)	40	0.463 (0.003)*	-0.324 (0.042)*
L-crestal (mm)	40	0.550 (0.000)*	-0.131 (0.419)
L-apical (mm)	40	0.395 (0.012)*	-0.170 (0.295)
BACH (mm)	40	-0.266 (0.098)	0.122 (0.454)
LACH (mm)	40	-0.155 (0.339)	0.017 (0.916)

Pearson correlation coefficent analysis. Values are presented as R (p) value.

There were no correlations between buccal crestal ABT and IMPA and/or FMA angles. BACH and LACH measurements were not statistically correlated with IMPA or FMA angles ($p>0.05$). Changes in IMPA angle were positively and moderately correlated with changes in buccal ABT at apical ($r=0.463$; $p=0.003$) and lingual ABT at crestal levels ($r=0.550$; $p<0.001$) indicating that as the incisor tipped labially, the cortical bone on the lingual aspect at the crestal level and the cortical bone on the buccal aspect at the apical level became thicker. A negative correlation existed between changes in FMA angle and changes in buccal ($r= -0.324$;$p=0.042$) ABT at the apical level. Lingual crestal and lingual apical ABT measurements were not correlated with changes in FMA angle.

DISCUSSION

The structure of the mandibular symphysis can limit the movement of the incisors since the alveolar bone thickness of the lower anterior teeth is thin and more susceptible to periodontal disease.[2,20] The determination of the structure of the mandibular symphysis especially in skeletal Class III patients who need orthognathic surgery is important, as the lower incisors are mostly inclined lingually as a result of dental compensation and need to move forward during the presurgical orthodontic treatment. It is known that as the mandibular incisors are proclined, it is more likely to see alveolar bone fenestration or recession of the gingiva.[21] With the advance of 3-dimensional CBCT images, it is possible to examine alveolar bone morphology with quality without distortion or overlap, and also to measure the alveolar bone thickness around the roots.[22-25] Therefore, this study focused on the alveolar bone amount around the lower central incisors in Skeletal Class III patients who had lingually inclined lower incisors, and compare the values with normally inclined lower incisors in Class I patients. Many cephalometric goals for the position of mandibular incisors have been advocated. In this study, we divided the initial CBCT scans of the patients on the basis of IMPA according to Tweed classification besides malocclusion classification (Class III or Class I). Tweed stated that the mandibular incisors should create an angle between 85° and 95° with the mandibular plane if the mandible plane to the Frankfurt plane angle falls in the 22° to 29° range.[26] IMPA for the scans selected for Group 1 were lower than 85° indicating lingual-inclined group, and for Group 2 were between 85° and 95° indicating the normal-inclined group.

In the present study, buccal and lingual alveolar bone thicknesses were evaluated at 3 distances which were respectively 3, 6, and 8 mm from the CEJ to represent respectively the cervical, midroot, and apical levels of the tooth.

Buccal ABT showed significantly lower values at only apical level on the other hand lingual ABT showed lower values at both crestal and midroot levels in Class III group compared to Class I group. This difference between the groups can be related to the significant lower IMPA value in Class III group, indicating lingual-inclined incisors, which makes the apex closer to the labial cortex. Yamada *et al.*[2] also reported that the central incisor root apex was closer to the internal labial cortical bone than the lingual cortical bone in adults with mandibular prognathism. Similar to our results, Kook *et al.*[18] found that alveolar bone thickness at the tooth apex was significantly lower in Class III patients than in normal occlusion sample. Sendyk *et al.*[10] compared the alveolar bone thickness in patients with Class III malocclusion from those with normal occlusion with CBCT. The results of the study showed that the average buccal and lingual alveolar thickness at 3mm (cervical portion) and 8 mm (apical region) from the CEJ were significantly lower in Class III group.

In the study of Tian *et al.*[27], the relationship between labiolingual inclination and the thickness of the alveolar bone in mandibular central incisors was investigated using CBCT, and the total and lingual alveolar bones were thinner in lingual inclination group than in labial inclination group. Similar to the findings of Tian *et al.*[27], the total bone thicknesses at all levels were significantly thinner in Group 1 (Class III, lingual-inclined incisors) compared to group 2 (Class I, normal-inclined incisors). Thin symphsis in Class III malocclusion presents a challenge during pre-surgical orthodontic treatment when labial proclination of the mandibular incisors is planned; so special attention should be paid by the orthodontists not to cause a risk of periodontal problem. The results of the study of Sarıkaya *et al.*[28] indicated a significant decrease in the thickness of lingual bone plate especially in the coronal and middle third of the root after the retraction of mandibular incisors. In the present study, the lingual crestal and midroot alveolar bone thicknesses were significantly lower in Class III patients when compared to Class I patients. Because of the risk of adverse effects after incisor retraction especially in the lingual alveolar region, it would be better to maintain the initial, and therefore natural incisor position of the mandibular incisors in Class III camouflage treatments instead of retracting the teeth.

The distance between the alveolar crest and the cementoenamel junction represents the extent of vertical alveolar bone loss. Besides, bone dehiscences can be described as an increase of the distance between the CEJ and the buccal or lingual alveolar bone crest.[29] CEJ-to-alveolar bone crest of 2 mm or less is considered normal with the studies.[30,31] With the experimental studies,[32,33] it was shown that mandibular incisor proclination could cause marginal bone loss. In the present study, considering the vertical alveolar bone level, BACH measurement was significantly higher in Group 1 (2.21±1.48 mm) than found in Group 2 (1.42±0.17 mm). Kook *et al.*[18] also indicated that Class III patients exhibited more vertical bone loss especially at the lingual alveolar plate than Class I patients. However in the present study, we found a significant difference related to vertical bone level especially at the buccal side.

We also intended to confirm whether dental inclination change effects the buccal and lingual ABT. According to the results of the present study, there was a relationship between the buccal ABT at apical and lingual ABT at crestal levels and lower incisor inclination. This result indicated that as the incisor tipped labially, the cortical bone on the lingual aspect at the crestal level and the cortical bone on the buccal aspect at the apical level became thicker. Yamada *et al.*[2] and Yu *et al.*[3] similarly suggested that the morphology of the alveolar bone was affected by tooth inclination. Yu *et al.*[3] concluded that the lower central incisor root apex was closer to the lingual alveolar crest when it was buccally inclined. Similary, Yamada *et al.*[2] found significant positive correlations between the labio-lingual inclination of the mandibular central incisors and the associated cancellous bone thickness. In related to their results, when the mandibular central incisor was more lingually inclined, the associated alveolar bone was more thinner. However Sendyk *et al.*[10] indicated in a recent study that in subjects with Class III deformities, there were weak and few significant correlations between inclination of mandibular central incisor and lingual alveolar thickness of central incisor at 6 mm, and emphasized the natural process of development to provide the stability to the thickness of the alveolar bone. Inconsistent with our finding, Lee *et al.*[19] found no significant correlation of the degree of incisor inclination with the extent of alveolar bone change. Because of the controversial results of the aforementioned studies[2,3,10,19], it may not be correct to establish a direct mathematical relationship between the degree of tooth inclination and the change in alveolar bone thickness.

It has been indicated that the growth facial pattern has an effect on the morphology of bucccal and lingual alveolar bone plates.[34,35] Also it has been stated that hyperdivergent patients present a thinner mandibular symphysis and alveolar ridge in the anterior region of the mandibula, when compared to other facial patterns.[1,36] In the present study two groups did not differ from each other with regards to growth pattern. However, the correlation of FMA with the alveolar bone measurements revealed a negative correlation between changes in FMA and changes in buccal ABT at the apical level. This result meant that when the FMA degree increased, bone thickness at apical level decreased. Under this perspective, it can be thought that, in patients who demonstrate hypodivergent pattern with Class III malocclusion, the orthodontic treatment planning may present less restriction for labio-lingual incisor movement mainly at the level of root apex.

Comparing the results of the 2 groups, Class III and Class I malocclusion, it has been shown that subjects with Class III malocclusion have thinner alveolar bone at the cervical, midroot and apical levels in different regions (buccal or lingual) than do those with normal occlusion. Using the Class I malocclusion samples in Group 2 gave us some information about the tissue amount around the roots of lower incisors and also the opportunity to compare with the Class III samples' bone values. Considering the results, orthodontists should be careful when planning the labio-lingual movements of the lower incisors, both in camouflage and surgical Class III patients in order to prevent dehiscence and fenestration in the alveolar bone. From the clinical perspective, alveolar bone measurement before beginning treatment with the help of CBCT evaluation can help the orthodontist to move the lower incisors within the alveolar bone housing to minimize the risk of alveolar bone loss during presurgical or camouflage orthodontic treatment.

The CBCT images used in the present study had a voxel size of 0.3 mm. As very small dimensions are studied to detect bone thickness and height, it may be impossible to accurately detect the changes less than 0.3mm of thickness with a voxel size of 0.3 mm.[37] In a recent study[38] the influence of voxel dimension on measurement accuracy and reproducibility was evaluated, and CBCT images demonstrated good accuracy for measuring the mandibular anterior teeth with 0.2 mm and 0.3 mm voxel sizes. In the present study to reduce the measurement error, half of the variables were repeatedly measured and correlation coefficients were at good and excellent. It would be better to carry out further studies including larger sample to enhance the statistical power and to rule out the possible type II errors.

CONCLUSIONS

1. In subjects with Class III malocclusion, mandibular incisors were more lingually inclined compared to the Class I group.

2. Thinner alveolar bone was observed on the buccal aspect at apical level, and on the lingual aspect at the crestal and midroot level of the central incisors in Class III group.

3. Total average alveolar bone thickness at all levels were statistically less in Class III subjects compared with subjects with Class I malocclusion.

4. Buccal alveolar crestal height was significantly higher in Class III group compared to Class I.

5. Significant correlations were found between mandibular incisor inclination and labial ABT at the apical level and palatal ABT at the crestal level.

6. A weak negative correlation existed between changes in FMA angle and changes in buccal ABT at the apical level.

REFERENCES

1. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. Angle Orthod 1996;66:95-109; discussion 109-110.

2. Yamada C, Kitai N, Kakimoto N, Murakami S, Furukawa S, Takada K. Spatial relationships between the mandibular central incisor and associated alveolar bone in adults with mandibular prognathism. Angle Orthod 2007;77:766-772.

3. Yu Q, Pan XG, Ji GP, Shen G. The association between lower incisal inclination and morphology of the supporting alveolar bone--a cone-beam CT study. Int J Oral Sci 2009;1:217-223.

4. Joss-Vassalli I, Grebenstein C, Topouzelis N, Sculean A, Katsaros C. Orthodontic therapy and gingival recession: a systematic review. Orthod Craniofac Res 2010;13:127-141.

5. Djeu G, Hayes C, Zawaideh S. Correlation between mandibular central incisor proclination and gingival recession during fixed appliance therapy. Angle Orthod 2002;72:238-245.

6. Yared KF, Zenobio EG, Pacheco W. Periodontal status of mandibular central incisors after orthodontic proclination in adults. Am J Orthod Dentofacial Orthop 2006;130:6 e1-8.

7. Kim Y, Park JU, Kook YA. Alveolar bone loss around incisors in surgical skeletal Class III patients. Angle Orthod 2009;79:676-682.

8. Melsen B, Allais D. Factors of importance for the development of dehiscences during labial movement of mandibular incisors: a retrospective study of adult orthodontic patients. Am J Orthod Dentofacial Orthop 2005;127:552-561; quiz 625.

9. Wainwright WM. Faciolingual tooth movement: its influence on the root and cortical plate. Am J Orthod 1973;64:278-302.

10. Sendyk M, de Paiva JB, Abrao J, Rino Neto J. Correlation between buccolingual tooth inclination and alveolar bone thickness in subjects with Class III dentofacial deformities. Am J Orthod Dentofacial Orthop 2017;152:66-79.

11. Lupi JE, Handelman CS, Sadowsky C. Prevalence and severity of apical root resorption and alveolar bone loss in orthodontically treated adults. Am J Orthod Dentofacial Orthop 1996;109:28-37.

12. Ten Hoeve A, Mulie RM. The effect of antero-postero incisor repositioning on the palatal cortex as studied with laminagraphy. J Clin Orthod 1976;10:804-822.

13. Leuzinger M, Dudic A, Giannopoulou C, Kiliaridis S. Root-contact evaluation by panoramic radiography and cone-beam computed tomography of super-high resolution. Am J Orthod Dentofacial Orthop 2010;137:389-392.

14. Zamora N, Llamas JM, Cibrian R, Gandia JL, Paredes V. Cephalometric measurements from 3D reconstructed images compared with conventional 2D images. Angle Orthod 2011;81:856-864.

15. Ganguly R, Ruprecht A, Vincent S, Hellstein J, Timmons S, Qian F. Accuracy of linear measurement in the Galileos cone beam computed tomography under simulated clinical conditions. Dentomaxillofac Radiol 2011;40:299-305.

16. Gahleitner A, Watzek G, Imhof H. Dental CT: imaging technique, anatomy, and pathologic conditions of the jaws. Eur Radiol 2003;13:366-376.

17. Gahleitner A, Podesser B, Schick S, Watzek G, Imhof H. Dental CT and orthodontic implants: imaging technique and assessment of available bone volume in the hard palate. Eur J Radiol 2004;51:257-262.

18. Kook YA, Kim G, Kim Y. Comparison of alveolar bone loss around incisors in normal occlusion samples and surgical skeletal class III patients. Angle Orthod 2012;82:645-652.

19. Lee KM, Kim YI, Park SB, Son WS. Alveolar bone loss around lower incisors during surgical orthodontic treatment in mandibular prognathism. Angle Orthod 2012;82:637-644.

20. Holmes PB, Wolf BJ, Zhou J. A CBCT atlas of buccal cortical bone thickness in interradicular spaces. Angle Orthod 2015;85:911-919.

21. Proffit W. Limitations, controversies and special problems. St Louis Mo: Mosby; 2007.

22. Hu KS, Kang MK, Kim TW, Kim KH, Kim HJ. Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation. Angle Orthod 2009;79:37-45.

23. Lee KJ, Joo E, Kim KD, Lee JS, Park YC, Yu HS. Computed tomographic analysis of tooth-bearing alveolar bone for orthodontic miniscrew placement. Am J Orthod Dentofacial Orthop 2009;135:486-494.

24. Park J, Cho HJ. Three-dimensional evaluation of interradicular spaces and cortical bone thickness for the placement and initial stability of microimplants in adults. Am J Orthod Dentofacial Orthop 2009;136:314 e311-312; discussion 314-315.

25. Timock AM, Cook V, McDonald T, Leo MC, Crowe J, Benninger BL et al. Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. Am J Orthod Dentofacial Orthop 2011;140:734-744.

26. Tweed C. Frankfort-mandibular incisor angle in orthodontic diagnosis, treatment planning and prognosis. Angle Orthod 1954;24:121-169.

27. Tian YL, Zhao ZJ, Han K, Lv P, Cao YM, Sun HJ et al. [The relationship between labial-lingual inclination and the thickness of the alveolar bone in the mandibular central incisors assessed with cone-beam computed tomography]. Shanghai Kou Qiang Yi Xue 2015;24:210-214.

28. Sarikaya S, Haydar B, Ciger S, Ariyurek M. Changes in alveolar bone thickness due to retraction of anterior teeth. Am J Orthod Dentofacial Orthop 2002;122:15-26.

29. Garib DG, Yatabe, M.S., Ozawa, T.O., da Silva Filho, O.M. Alveolar bone morphology under the perspective of the computed tomography: Defining the biological limits of tooth movement. Dental Press J Orthod 2010;15:192-205.

30. Newman MG, Takei, H.H., Klokkevoid, P.R., Carranza, F.A. Carranza's Clinical Periodontology. St Louis: Mo:Elseiver; 2006.

31. Kallestal C, Matsson L. Criteria for assessment of interproximal bone loss on bite-wing radiographs in adolescents. J Clin Periodontol 1989;16:300-304.

32. Steiner GG, Pearson JK, Ainamo J. Changes of the marginal periodontium as a result of labial tooth movement in monkeys. J Periodontol 1981;52:314-320.

33. Batenhorst KF, Bowers GM, Williams JE, Jr. Tissue changes resulting from facial tipping and extrusion of incisors in monkeys. J Periodontol 1974;45:660-668.

34. Gracco A, Lombardo L, Mancuso G, Gravina V, Siciliani G. Upper incisor position and bony support in untreated patients as seen on CBCT. Angle Orthod 2009;79:692-702.

35. Tsunori M, Mashita M, Kasai K. Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning. Angle Orthod 1998;68:557-562.

36. Beckmann SH, Kuitert RB, Prahl-Andersen B, Segner D, The RP, Tuinzing DB. Alveolar and skeletal dimensions associated with overbite. Am J Orthod Dentofacial Orthop 1998;113:443-452.

37. Sun Z, Smith T, Kortam S, Kim DG, Tee BC, Fields H. Effect of bone thickness on alveolar bone-height measurements from cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2011;139:e117-127.

38. Menezes CC, Janson G, da Silveira Massaro C, Cambiaghi L, Garib DG. Precision, reproducibility, and accuracy of bone crest level measurements of CBCT cross sections using different resolutions. Angle Orthod 2016;86:535-542.

Corresponding Author

Ezgi Atik, Assistant Professor,

Department of Orthodontics,

Faculty of Dentistry,

Hacettepe University,

Sıhhiye, 06100, Ankara, TURKEY

Tel **:** +90 312 3052290

Fax **:** +90 312 3091138,

E-mail : ezgibaytorun@hotmail.com