Evaluation of the infrazygomatic crest and mandibular buccal shelf in different sagittal skeletal patterns: a cone-beam computed tomography study

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Objectives: To compare bone thickness, bone height, and density in the infrazygomatic crest (IZC) and the mandibular buccal shelf (MBS) associated with different sagittal skeletal patterns.
Material and Methods: This retrospective study included three groups of which a Class I group consisted of 28 patients (24 female, 4 male, mean age: 26.46 ± 6.1), a Class II group comprised 31 patients (28 female, 3 male, mean age: 30.08 ± 5.9), and a Class III group included 26 patients (22 female, 4 male, mean age: 26.21 ± 5.3). Evaluations of bone characteristics were performed for both the IZC and MBS using cone-beam computed tomography (CBCT). Maxillary length and mandibular body length were also measured on lateral cephalograms. One-way ANOVA, chi-squared, and Spearman's correlation tests were applied for statistical analysis.
Results: The Class II group showed significantly greater bone thickness at the distal root level of the maxillary second molar in IZC ($p < 0.05$). While bone thickness showed no statistically significant difference in the MBS between the groups ($p > 0.05$), the Class II group showed significantly higher bone height values at the distal root level of the mandibular second molar in the MBS ($p < 0.05$). A statistically significant increase from the mesial aspect to the distal aspect was observed in total bone thickness in the Class I group and total bone thickness and height in the Class II and III groups in the MBS. The mandibular body length and SNB values were positively correlated with the total bone thickness and bone height of the MBS.
Conclusions: Bone thickness in the IZC and bone density in both the IZC and MBS were similar in the different sagittal skeletal patterns. Total bone thickness in the Class I and III groups and the total bone height in the Class II group showed a gradual increase from the mesial to the distal in the MBS. The length of the mandibular body may be a clinical clue to assist in the selection of the appropriate implantation area.
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Introduction

Mini-screws are frequently used to enhance anchorage during orthodontic treatment.[1] Although mini-screws are routinely placed in interradicular areas, in recent years, extra-alveolar sites such as the infrazygomatic crest (IZC) and the mandibular buccal shelf (MBS) have often been preferred by clinicians for the distalisation of the entire maxillary and mandibular arches or the flattening of the occlusal plane.[2,3] However, the stability of mini-screws remains a clinical challenge since they are often placed on movable mucosa overlying either the IZC or MBS.[4] Primary stability, which is a crucial factor governing the success of mini-screws, depends

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on the micro-architectural characteristics of bone tissue related to bone density and cortical bone thickness.[5]

Cone-beam computed tomography (CBCT) allows the evaluation of cortical bone thickness because of its ability to create high-resolution images.[6] In addition, CBCT provides three-dimensional volumetric data obtained using a relatively low radiation dose. An additional objective evaluation criterion for bone quality assessment is bone density, which is scored using Hounsfield units (gray scale) on CBCT images. The Hounsfield unit (HU) is a numerical value determined based on the ability of structures to absorb X-rays.[7]

Although previous studies have reported findings on bone quality for extra-alveolar sites in patients with different vertical facial anatomical variations,[8,9] there is little evidence regarding the evaluation of bone micro-architecture in individuals presenting with different sagittal facial patterns. The first aim of the present study was to determine bone thickness, bone height, and density in the IZC and MBS regions of individuals with different sagittal facial patterns. A second aim was to determine whether there was a correlation between either maxillary or mandibular base lengths and the quantitative-qualitative bone parameters. The null hypothesis was that the quantitative and qualitative bone parameters in the IZC and MBS are similar between the different sagittal skeletal patterns.

Materials and methods

This retrospective study was approved by the Local Ethics Committee of the Bezmialem Vakif University (Number: 20/370). A power analysis revealed that a sample size of 24 individuals for each group would provide more than 90% power to detect significant differences with an effect size of 0.80 and a significance level of $\alpha = 0.05$.

The CBCT images of 1060 patients taken from 2013 to 2020 were collected from the archives of the Bezmialem Vakif University Faculty of Dentistry Hospital by filtering according to the inclusion criteria. Informed consent forms were also obtained from the included patients.

The inclusion criteria were: (1) Individuals older than 18 years of age, (2) the presence of maxillary and mandibular first and second molars, (3) patients with third molars or congenitally missing third molars, (4) patients whose third molars had been extracted at least 6 months prior to the study, (5) no osseous pathology, (6) no local pathology related to tooth eruption, and (7) high-quality CBCT images.

Individuals with a history of craniofacial surgery, a craniofacial syndrome, or a cleft lip and palate, systemic diseases related to bone metabolism, or any history of trauma or periodontal disease, were excluded.

The cervical vertebral maturation method was used to evaluate skeletal maturity.[10] After applying the inclusion and exclusion criteria, the CBCT scans of 85 patients (11 male and 74 female) were selected for the study. The scans were captured using a Planmeca ProMax 3D Mid machine (Planmeca, Helsinki, Finland) at a voxel size of 200 μm. The sagittal skeletal patterns were determined based on the ANB angle[11] (the angle from point-A to nasion to point-B) which was measured on CBCT-generated lateral cephalograms. The patients were divided into three groups based on the ANB values as a Class I group (ANB angle = 0°–4°), a Class II group (ANB angle > 4°), and a Class III group (ANB angle < 0°). Table I presents the demographic characteristics of the groups. Maxillary length (the distance between anterior nasal spine and posterior nasal spine points) and mandibular body length (the distance between the gonion and menton points) were also measured.

Quantitative and qualitative bone analyses in the IZC and MBS regions were carried out using the Planmeca Romexis software (Planmeca Romexis version 3.8.3 R., 3D imaging software, PLANMECA OY, Helsinki, Finland). All measurements were performed by the same operator blinded to the types of sagittal skeletal relationships.

Bone thickness measurements in IZC

Cortical bone thickness values in the IZC region were measured using the methods described by Vargas et al.[8] and Nucera et al.[5]

The multiplanar views were oriented to standardise the images and enable thickness measurements in the IZC. The CBCT images were adjusted so that the occlusal plane was parallel to the ground. A vertical reference line was aligned to pass through the root of the molar to be measured. On this plane, a horizontal reference line was placed at the root apex of the same

Table I. Demographic data of the patients

	Class II	Class I	Class III		post-hoc *p*-value		
Variables	mean ± sd	mean ± sd	mean ± sd	*p*-value	I-II	II-III	I-III
Age	30.08 ± 5.9	26.46 ± 6.1	26.21 ± 5.3	0.18			
			Sex				
Female	28 (90.3 %)	24 (85.7 %)	22 (84.6 %)	0.63			
Male	3 (9.6 %)	4 (14.2 %)	4 (15.3 %)				
			Upper Third Molar				
Present	20	18	16	0.72			
Absent	11	10	10				
			Lower Third Molar				
Present	18	16	20	0.81			
Absent	13	12	6				
SNA°	82.7 ± 4.6	82.8 ± 5.6	79.3 ± 3.4	0.09			
SNB°	75.8 ± 4.6	80.6 ± 5.9	83.3 ± 3.5	0.001	0.04	0.001	NS
ANB°	6.8 ± 2.4	2.1 ± 1.1	-4 ± 3.5	<0.001	<0.001	<0.001	<0.001
SN-GoMe°	35.2 ± 7.5	31.2 ± 4.4	32.5 ± 5.5	0.26			

One way ANOVA with Bonferoni correction and chi-square tests were performed.

Sd, standard deviation.

molar. In the coronal plane, a vertical line was placed tangent to the maxillary buccal cortical bone. In the area at which the vertical and horizontal lines intersected, cortical bone thicknesses in the IZC were measured at 70° to the coronal plane (Figure 1A).

The measurements of cortical bone thickness were performed at four levels defined as the mesial root of the maxillary first molar (M1mr), the distal root of the maxillary first molar (M1dr), the mesial root of the maxillary second molar (M2mr), and the distal root of the maxillary second molar (M2dr) for both the right and left sides of the maxilla.

Bone thickness and bone height measurements in MBS

Total bone thickness and bone height in the MBS region were measured using the method described by Nucera et al.[5]

The multiplanar views were oriented to standardise the images and enable thickness measurements in the MBS. Firstly, the axial plane was positioned so that a vertical line would intersect with the root furcations of the mandibular molars. Subsequently, the sagittal plane was positioned so that a vertical line would pass through the long axis of the molar's root. Finally, the coronal plane was repositioned so that a vertical line would follow the long axis of the root identified for assessment.

The buccal cemento-enamel junction (CEJ) was identified on multiplanar views to standardise the images. The total bucco-lingual thicknesses of bone (cortical and cancellous bone) were measured on two different horizontal reference lines positioned apically at 6 mm (total thickness) and at 11 mm (total thickness) from the CEJ (Figure 1B). In addition, the total inciso-apical height of bone (cortical+cancellous) was measured on two different vertical reference lines buccally positioned at 4 mm (total height) and at 6 mm (total height) from the CEJ (Figure 1C). Four regions [mandibular first molar mesial root (M1mr), mandibular first molar distal root (M1dr), mandibular second molar mesial root (M2mr), and mandibular second molar distal root (M2dr) for both right and left mandibular sides], were identified, and total bone thickness and total bone height for these areas were measured on the coronal plane (Figure 1B, C).

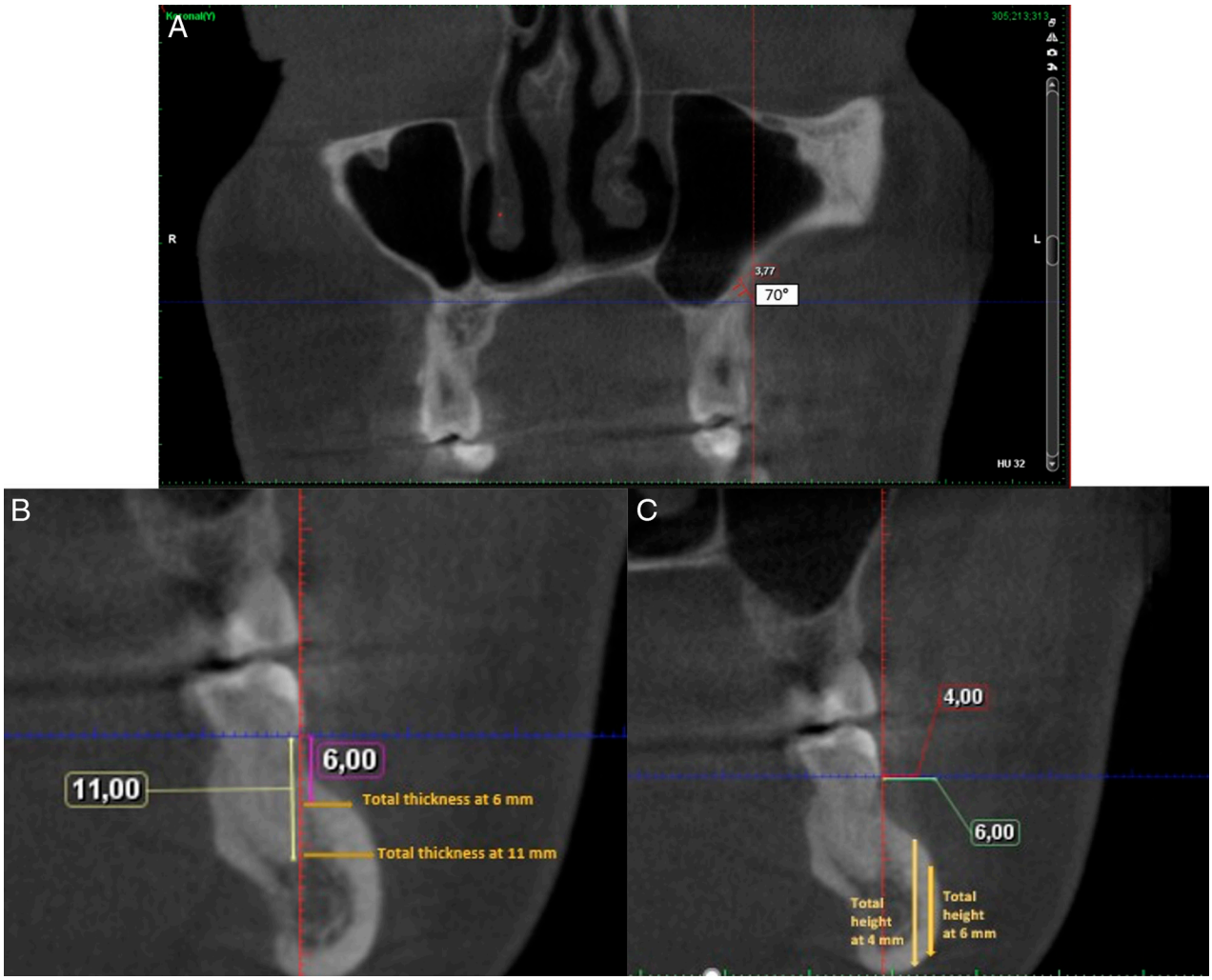


Figure 1. A, Bone thickness measurement in the infrazygomatic crest at the apex of the root at 70° angulation. B, Total bucco-lingual bone thickness measurement in the mandibular buccal shelf. Two different horizontal reference lines positioned apically at 6 mm and 11 mm from the cemento-enamel junction were used. Total thickness at 6 mm; bucco-lingual thicknesses of bone on a horizontal reference line positioned apically at 6 mm from the cemento-enamel junction, Total thickness at 11 mm; total bucco-lingual thicknesses of bone on horizontal reference lines positioned apically at 11 mm from the cemento-enamel junction. C, Total inciso-apical bone height measurement in the mandibular buccal shelf. Two different vertical reference lines buccally positioned at 4 mm and 6 mm from the cemento-enamel junction, were used. Total height at 4 mm; total inciso-apical height thicknesses of bone on vertical reference line buccally positioned at 4 mm from the cemento-enamel junction, Total height at 6 mm; total inciso-apical height thicknesses of bone on a vertical reference line buccally positioned at 6 mm from the cemento-enamel junction.

Bone Density measurements

The mean value of the Hounsfield units (HU) was used to describe bone density. HU values were automatically calculated using the Planmeca Romexis software (Planmeca Romexis 3D imaging software, PLANMECA OY, Helsinki, Finland). The most apical point of the distobuccal root of the first molar was selected as the target region. An isometric voxel of 2 × 2 mm was chosen from the cortical bone region, and the HU value on the outside of the selected region was calculated for the right and left sides of the maxilla and mandible and recorded as the output of the CBCT software (Figure 2).

Statistical analysis

The distribution of the data was analysed using the Shapiro–Wilk test. The total bone thickness and height values were normally distributed. Therefore, one-way ANOVA with Bonferroni correction and chi-squared tests were applied to compare the groups. Correlations between the maxillary length or mandibular body length and the bone thickness and height parameters were analysed using Spearman's correlation test due to

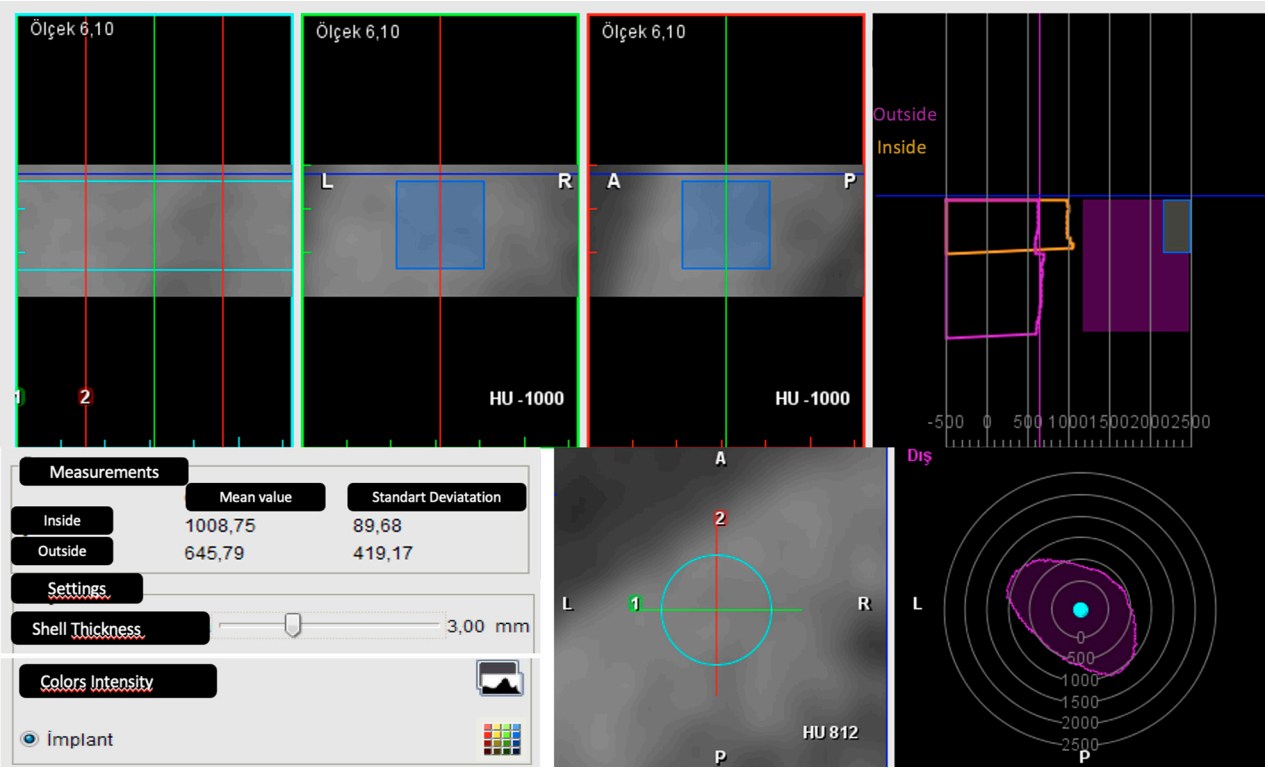


Figure 2. Bone density measurements (mean value of Hounsfield units-HU) from outside the 2 mm isometric voxel.

the non-normal distribution of the data. The results were evaluated based on a statistical significance level of $p < 0.05$. Furthermore, 12 CBCT images (four from each group) were randomly selected and re-measured after a 4-week interval to assess intra-examiner agreement. Bland–Altman plots and the intraclass correlation coefficient (ICC) were used to evaluate intra-observer reliability.[12]

Results

The results of the intraclass correlation test carried out to evaluate intra-examiner agreement showed high levels of agreement between the two measurements. The mean ICC value was 0.988 (0.970–0.992). The random error of the method was calculated by using the formula reported by Dahlberg.[13] The mean random error was 0.09 mm, with a range from 0.03 mm to 0.21 mm, without clinical significance. No systematic error was found.

The results showed no statistically significant differences related to gender, mean ages, and the presence or absence of third molars between the groups ($p > 0.05$). While there was no statistically significant difference in SNA values, there were statistically significant differences in SNB and ANB between the groups ($p < 0.05$, Table I).

Significantly lower cortical bone thickness values were observed in the mesial and distal root areas of the maxillary second molars at the IZC in the Class II group compared with the Class I group ($p > 0.05$, Table II).

While the total bone thicknesses measured at 6 mm and 11 mm below the CEJ showed no statistically significant differences ($p > 0.05$, Table II), the Class II group had significantly greater total bone height values measured at 4 mm and 6 mm in the area of the distal root of the maxillary second molar compared to the Class I and Class III groups ($p < 0.05$, Table II).

Moreover, no statistically significant difference was observed regarding the density (HU) values for any region between the groups ($p > 0.05$, Table II).

The results of the intragroup comparisons indicated no statistically significant differences in bone thickness values measured at 70° at the IZC between the first and second molars in any of the groups ($p > 0.05$,

Table II. Comparison of the quantitative bone characteristics in IZC and MBS among Class I, II and III groups

	M1mr				M1dr				M2mr							M2dr						
	Class II	Class I	Class III		Class II	Class I	Class III		Class II	Class I	Class III			post-hoc *p*-value			Class II	Class I	Class III		post-hoc *p*-value	
	mean ± sd	mean ± sd	mean ± sd	*p*-value	mean ± sd	mean ± sd	mean ± sd	*p*-value	mean ± sd	mean ± sd	mean ± sd	*p*-value	I-II	I-III	II-III	mean ± sd	mean ± sd	mean ± sd	*p*-value	I-II	I-III	II-III
IZC Thickness (mm)																						
Total_thick at 70°	2.5 ± 1.5	3.5 ± 1.9	3 ± 2.1	NS	2.6 ± 1.5	3.2 ± 1.7	2.9 ± 1.9	NS	2.2 ± 1.3	3.3 ± 1.8	3 ± 1.5	0.04	0.04	NS	NS	2.4 ± 1.5	3.7 ± 1.9	3.3 ± 1.9	0.04	0.03	NS	NS
MBS Thickness (mm)																						
Total thickness at 6 mm	4.2 ± 3.2	2.6 ± 2	2.8 ± 2	NS	5 ± 3.4	4 ± 3.1	4.4 ± 2.4	NS	6.5 ± 2.2	5.8 ± 2.3	7.1 ± 1.9	NS		7.5 ± 2.3	7.2 ± 2.3	8.5 ± 2	NS					
Total thickness at 11 mm	5.2 ± 2.6	4.2 ± 2.6	5 ± 2.6	NS	6.3 ± 3.1	6 ± 2.5	6.7 ± 1.8	NS	7.2 ± 1.9	6.6 ± 2.4	7.9 ± 1.6	NS		8 ± 2.2	7.4 ± 2.4	8.6 ± 1.9	NS					
Total height at 4 mm	18.4 ± 7.1	17.7 ± 9.7	17 ± 5.1	NS	19.9 ± 6.5	20 ± 7.7	19.6 ± 4	NS	22.7 ± 2.9	19.8 ± 7.3	20.1 ± 3.1	NS		23.8 ± 2.9	20.9 ± 6.1	20.4 ± 2.9	0.01	0.04	0.01	NS		
Total height at 6 mm	14.6 ± 7.4	15.3 ± 9.4	13.1 ± 6.7	NS	16.5 ± 6.4	17.2 ± 8.5	17 ± 5.1	NS	20.4 ± 3.6	17.6 ± 8.1	17.9 ± 3.9	NS		22.1 ± 3.7	19 ± 7.6	19.7 ± 3.8	0.04	0.01	NS	NS		
HU Value																						
	Class II	Class I	Class III																			
	mean ± sd	mean ± sd	mean ± sd	p-value																		
Maxilla	681.7 ± 221.3	676 ± 185.6	728 ± 127.8	NS																		
Mandible	1187.5 ± 400.6	902.2 ± 473.3	962.7 ± 294.5	NS																		

One Way ANOVA test with Bonferroni correction was performed.

HU value, mean value of Hounsfield Unit; IZC, infrazygomatic crest; L, left side; MBS, mandibular buccal shelf area; M1mr, first molar's mesial root, M1dr, first molar's distal root, M2mr, second molar's mesial root; M2dr, second molar's distal root; NS, nonsignificant; R, right side; Sd, standard deviation.

Table III). However, statistically significant increases were found in the total bone thickness measured at 6 mm and the total bone heights measured at 4 mm and 6 mm from the mesial to the distal in the Class II group ($p < 0.05$, Table III). Statistically significant increases were found in the total bone thickness values measured at 6 mm and 11 mm from the mesial to the distal in the Class I group, while no significant differences were found in total bone height values ($p < 0.05$, Table III). There were statistically significant increases in the total bone thickness values measured at 6 mm and 11 mm and the total bone height values measured at 4 mm and 6 mm from the mesial to the distal in the Class III group ($p < 0.05$, Table III).

The Spearman's correlation test revealed a positive association between the mandibular length and total bone thickness values and height in the MBS. Moreover, significant correlations were identified between the bone thickness and SNB values ($p < 0.05$, Table IV).

Discussion

The present study evaluated total bone thickness, height, and density in the IZC and MBS regions in individuals presenting with different sagittal skeletal patterns. Total bone thickness measurement methods described by Nucera et al.[5] and Vargas et al.,[8] were applied. Moreover, a linear relationship between HU and Gray Scale in CBCT was reported.[14,15] Previous studies have recommended the measurement of bone density in CBCT images because of the lower dose and cost compared to conventional computed tomography scans.[14] The present study is the first to compare HU values that were used to describe bone density between patients with different sagittal patterns. In many studies investigating bone quality in extra-alveolar regions, the lack of evaluation of bone density was noted as a limitation. In this respect, the present study makes a positive contribution to the literature.

The results of the present study revealed that the IZC cortical bone thickness values were similar for the intra- and inter-group comparisons in those patients with different sagittal skeletal patterns, except for the area of the distal root of the second molar. No significant relationship was found between cortical bone thickness values in the IZC region and the vertical or sagittal skeletal patterns of the jaws.[16,17] However, mandibular cortical bone thickness values were observed at the level of the maxillary second molar in the Class II patients. Oktay[18] reported that Class II individuals have larger maxillary sinuses. Therefore, this finding may be related to anatomical variability in the size and shape of the maxillary sinuses in adults and the maximal craniocaudal extension of the maxillary sinuses around the maxillary second molars.[19] Furthermore, no significant relationship was found between the cortical bone thickness values in the IZC and the position of the maxilla relative to the cranial base or maxillary length. These findings suggested that sagittal patterns may not be useful predictors of adequate bone availability for mini-screw placement.

Marquezan et al.[20] stated that bone density may be used as a parameter to evaluate the stability of mini-screws. In the present study, the HU values of neither the maxilla nor the mandible were affected by the sagittal skeletal patterns of the patients. However, differences emerged in the evaluations of cortical bone thickness in the MBS. The Class II group had higher total bone height values than the Class I and Class III groups. A Class II malocclusion is mostly associated with vertical parameters.[21] Considering that there is a negative correlation between the gonial angle and mandibular body length in the Class II group, greater total bone height in the distal root of the mandibular second molar, which is closer to the gonial region, may have been a result of the increased vertical dimension.[22]

In the present study, total bone thickness and bone height values tended to increase gradually from the anterior to the posterior in all groups. This finding has been corroborated by previous studies.[5,8,23] However, the increase in total bone thickness from the mesial to the distal was more striking at the coronal level (total thickness at 6 mm) in the Class I group. There was an increase in total bone thickness and total bone height from the mesial to the distal in the Class III patients in this study. However, in the Class II patients, the more striking increase in total bone height from the mesial to the distal (at both 4 mm and 6 mm levels) compared to total bone thickness was a noted finding.

Nucera et al.[5] reported a buccal bone thickness of 4 mm to be the minimum cut-off value for safe mini-screw placement in the MBS. The present study revealed that the best area to insert MBS mini-screws in Class I and Class III patients was

Table III. Comparison of the quantitative bone characteristics between different sites in IZC and MBS on right side for each group

	M1mr (I)	M1dr (II)	M2mr (III)	M2dr (IV)		post hoc *p*-value					
Class II	mean ± sd	mean ± sd	mean ± sd	mean ± sd	*p*-value	I-II	I-III	I-IV	II-III	II-IV	III-IV
				IZC (mm)							
Total thickness at 70°	2.5 ± 1.5	2.6 ± 1.5	2.2 ± 1.3	2.4 ± 1.5	0.85						
				MBS (mm)							
Total thickness at 6 mm	4.2 ± 3.2	5 ± 3.4	6.5 ± 2.2	7.5 ± 2.3	<0.001	NS	0.04	0.001	NS	0.01	NS
Total thickness at 11 mm	5.2 ± 2.9	6.3 ± 3.1	7.2 ± 1.9	8 ± 2.2	0.002	NS	0.04	0.002	NS	NS	NS
Total height at 4 mm	18.4 ± 7.1	19.9 ± 6.5	22.7 ± 2.9	23.8 ± 2.9	0.002	NS	0.03	0.003	NS	NS	NS
Total height at 6 mm	14.6 ± 7.4	16.5 ± 6.4	20.4 ± 3.6	22.1 ± 3.7	<0.001	NS	0.003	<0.001	NS	0.005	NS
				Class I							
				IZC (mm)							
Total thickness at 70°	3.5 ± 1.9	3.2 ± 1.7	3.3 ± 1.8	3.71 ± 1.9	0.75						
				MBS (mm)							
Total thickness at 6 mm	2.6 ± 2	4 ± 3.1	5.8 ± 2.3	7.2 ± 2.3	<0.001	NS	<0.001	<0.001	0.04	<0.001	NS
Total thickness at 11 mm	4.2 ± 2.6	6 ± 2.5	6.6 ± 2.4	7.4 ± 2.4	<0.001	0.03	0.002	<0.001	NS	NS	NS
Total height at 4 mm	17.7 ± 9.7	20 ± 7.7	19.8 ± 7.3	20.9 ± 6.1	0.46						
Total height at 6 mm	15.3 ± 9.4	17.2 ± 8.5	17.6 ± 8.1	19 ± 7.6	0.4						

				Class III							
				IZC (mm)							
Total thickness at 70°	3 ± 2.1	2.9 ± 1.9	3 ± 1.5	3.3 ± 1.9	0.89						
				MBS (mm)							
Total thickness at 6 mm	2.8 ± 2	4.4 ± 2.4	7.1 ± 1.9	8.5 ± 2	<0.001	0.03	<0.001	<0.001	<0.001	<0.001	NS
Total thickness at 11 mm	5 ± 2.6	6.7 ± 1.8	7.9 ± 1.6	8.6 ± 1.9	<0.001	0.01	<0.001	<0.001	NS	0.004	NS
Total height at 4 mm	17 ± 5.1	19.6 ± 4	20.1 ± 3.1	20.4 ± 2.9	0.007	NS	0.02	0.01	NS	NS	NS
Total height at 6 mm	13.1 ± 6.7	17 ± 5.1	17.9 ± 3.9	19.7 ± 3.8	<0.001	0.02	0.003	<0.001	NS	NS	NS

One way ANOVA test with Bonferroni correction was performed.

IZC, infrazygomatic crest; MBS, mandibular buccal shelf area; M1mr, first molar's mesial root; M1dr, first molar's distal root; M2mr, second molar's mesial root; M2dr, second molar's distal root; NS, nonsignificant; Sd, standard deviation.

Table IV. Correlation between cephalometric parameters and quantitative bone characteristics

	SNA		SNB		Maxillary Length		Mandibular Length	
	r	*p*-Value	*r*	*p*-Value	*r*	*p*-Value	*r*	*p*-Value
				M1mr				
Total thickness at 70°	0.070	0.66	0.048	0.76	-0.186	0.24	0.238	0.13
Total thickness at 6 mm	0.202	0.2	-0.034	0.83	0.295	0.06	0.207	0.19
Total thickness at 11 mm	0.301	0.05	0.328	0.03	0.212	0.18	0.331	0.03
Total height at 4 mm	0.174	0.27	0.140	0.38	0.124	0.44	0.440	0.004
Total height at 6 mm	0.284	0.07	0.246	0.12	0.220	0.16	0.357	0.02
				M1dr				
Total thickness at 70°	0.032	0.84	0.035	0.83	-0.120	0.45	0.267	0.09
Total thickness at 6 mm	0.131	0.41	0.031	0.84	0.164	0.3	0.268	0.09
Total thickness at 11 mm	0.293	0.06	0.346	0.02	0.030	0.85	0.375	0.01
Total height at 4 mm	0.028	0.86	0.059	0.71	0.018	0.90	0.504	0.001
Total height at 6 mm	0.139	0.38	0.211	0.18	0.087	0.58	0.450	0.003
				M2mr				
Total thickness at 70°	-0.088	0.58	0.089	0.57	-0.001	0.99	0.210	0.08
Total thickness at 6 mm	0.189	0.23	0.358	0.02	-0.059	0.71	0.508	0.001
Total thickness at 11 mm	0.085	0.59	0.358	0.02	-0.023	0.88	0.346	0.02
Total height at 4 mm	0.059	0.71	-0.092	0.56	0.155	0.33	0.384	0.01
Total height at 6 mm	0.089	0.57	0.002	0.99	0.124	0.44	0.508	0.001

	M2dr							
Total thickness at 70°	-0.190	0.23	-0.044	0.78	-0.069	0.66	0.233	0.14
Total thickness at 6 mm	0.042	0.79	0.355	0.02	-0.043	0.79	0.523	<0.001
Total thickness at 11 mm	0.150	0.34	0.281	0.07	0.051	0.73	0.431	0.005
Total height at 4 mm	0.035	0.82	-0.208	0.19	0.132	0.41	0.293	0.03
Total height at 6 mm	-0.012	0.94	-0.115	0.47	0.081	0.61	0.430	0.005

Pearson's correlation test was performed.

IZC, infrazygomatic crest; MBS, mandibular buccal shelf area; M1mr, first molar's mesial root; M1dr, first molar's distal root; M2mr, second molar's mesial root; M2dr, second molar's distal root; r, correlation coefficient.

the area of the mandibular second molar. Therefore, thicker mini-screws may be preferred for the MBS region from the mesial to the distal in these sagittal patterns. The vertical bone height of the MBS is also critical in the selection of the appropriate mini-screw length.[5] According to the results of the present study, in Class II and Class III patients, longer rather than thicker mini-screws may be preferred for the MBS region from the mesial to the distal. Furthermore, additional results of the present study showed a positive relationship between total bone thickness and total bone height and the mandibular length values. Therefore, the variability in the bone thickness values of different sagittal patterns might be explained by masticatory forces and biological adaptations.[23] The overall findings suggested that different sagittal skeletal patterns related to the variation in mandibular corpus lengths may be helpful in deciding on MBS mini-screw size and placement area.

The main limitation of the present study was the failure to include comparisons according to the vertical patterns and genders of the patients. In further studies, selected parameters that play a role in the success of mini-screw placement, such as the soft tissues, could also be evaluated in larger samples.

Conclusion

- Sagittal skeletal parameters did not have a significant effect on the thickness of the IZC.
- A gradual increase from the mesial to the distal of the mandibular molars for total bone thickness was noted in the Class I and Class III patients.
- The Class II and Class III patients showed a gradual increase from the mesial to the distal of the mandibular molars in total bone height values.
- The mandibular body length may be a clinical indicator to decide on the placement sites and dimensions of MBS mini-screws.

Conflict of interest

The authors declare that there is no conflict of interest.

Ethics

The protocol of this study was approved by the Bezmialem Vakif University Local Ethics Committee (Approval Number: 20/370).

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

EDS: Conceptualisation, Data curation, Investigation, Methodology, Validation, Visualisation, Writing, and review. EK and SS: Conceptualisation, Formal analysis, Investigation, Methodology,

Supervision, Validation, Visualisation, Writing—Review, and Editing. GK: Conceptualisation, Methodology, Supervision, Review, and editing.

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