Comparison of alveolar bone thickness in anterior areas of maxilla and mandible between subjects with class I and class II malocclusions

Running title: Cephalometry and CBCT for bone measurement

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Abstract

This study aimed to compare alveolar bone thickness in anterior jaw regions in subjects with class I and class II malocclusions.

Fifty cone beam computed tomography (CBCT) scans of the upper jaw and 20 CBCT images of the lower jaw were selected from available records in a private radiology center. The images were divided into class I and class II malocclusions, according to ANB and Wits analysis. Bone thickness was measured in the anterior regions of the maxilla and mandible in three areas including apex, middle root and alveolar crest at both buccal and lingual sides. The values were compared between groups using independent samples t-test and Mann–Whitney U test.

In the upper jaw, bone thickness was significantly greater in class II than in class I patients in the palatal crest and buccal apex areas (P = 0.049 and P< 0.001, respectively). At the palatal side of the apex, the mean bone thickness was significantly lower in class II than in class I subjects (P = 0.001). Neither in other regions of the upper jaw nor at any part of the lower jaw, there was any significant difference in bone thickness between class I and class II patients (P > 0.05). The crest region of lower incisors was thin (<1mm) in both groups.
There are some differences in alveolar bone thickness between class I and class II patients in the upper jaw, which should be considered in orthodontic diagnosis and treatment planning.
Keywords—CBCT, alveolar bone thickness, class I malocclusion, class II malocclusion, dehiscence, fenestration, orthodontic treatment, periodontal disease

1. Introduction:

Dental malocclusion occurs with a high incidence in most populations. For instance, in Iran, a review by Eslamipour et al. (Eslamipour et al., 2018) found that 87% of individuals suffer from malocclusion, leaving only 13% with normal occlusion. Orthodontic treatment has been proven effective in enhancing esthetics, chewing function, and tooth alignment, finally leading to improved self-confidence and oral health-related quality of life (Tabrizi et al., 2013). Despite its benefits, orthodontic treatment is not without potential side effects. Dental caries, enamel attrition, pulpal reactions, and periodontal problems are some of the complications that may arise during or after the treatment (Sardana et al., 2023; Talic, 2011). Of particular concern are periodontal problems, including gingival recession, dehiscence, and fenestration, which tend to be more prevalent in elderly patients and the anterior mandible (Alani et al., 2016; Miyama et al., 2018).
During the orthodontic treatment process, bone resorption occurs in the direction of tooth movement. Excessive resorption at cortical surfaces of alveolar bone may lead to the destruction of periodontal support and the occurrence of fenestration and/or dehiscence in some areas (Karine Evangelista et al., 2010; Jepsen et al., 2023). Non-extraction cases are prone to devasting bone resorption if there is a significant difference between tooth volume and the available space within the dental arch. Another condition that may cause bone loss is camouflaging skeletal malocclusions by anterior-posterior movements of incisors or altering their labiolingual inclinations, as occurs in the treatment of class II or class III patients (Cao et al., 2011; Justus, 2015). It is important to pay attention to the morphology of the maxilla and mandible in the treatment planning of these cases to avoid periodontal sequelae after therapy.
Knowledge about bone thickness in various areas of the jaws holds great importance in orthodontic treatment planning and dental implant positioning. Bone thickness cannot be reliably diagnosed solely through clinical examination or two-dimensional

imaging. Cone-beam computed tomography (CBCT) stands out as the most reliable method for evaluating periodontal structures and bone thickness in areas of interest (Farzaneh Ahrari et al., 2023). CBCT offers the advantages of precise linear measurements in dental and skeletal structures without the limitations of two-dimensional imaging like distortion and superimposition, and at a far lower radiation dose and cost than that of computed tomography (CT) scans (Imanimoghaddam et al., 2019; Khojastepour et al., 2019; Khojastepour et al., 2023).

It is crucial to assess alveolar bone morphology in patients with different malocclusions to minimize complications arising from orthodontic interventions (Kim et al., 2010; Nahm et al., 2012; Song Hee Oh et al., 2020). Class II malocclusions may indicate some natural dental compensations that affect bone thickness around anterior teeth (Raber et al., 2019). To date, limited research exists on the comparison of alveolar bone thickness in different areas of the roots in subjects with various malocclusions. This study was conducted to compare alveolar bone thickness in the anterior regions of the upper and lower jaws in subjects with class I and class II malocclusions using CBCT imaging.

2. Materials and Methods:

The study protocol was approved by the ethics committee of Mashhad University of Medical Sciences (approval number IR.MUMS.DENTISTRY.REC.1400.010). This cross-sectional study included 50 cone beam computed tomography (CBCT) images of the upper jaw (25 males and 25 females with a mean age of 22.9 ± 5.4 years) and 20 CBCT images of the lower jaw (8 males and 12 females with a mean age of 21.9 ± 4.1 years). The images were taken in a private oral and maxillofacial radiology center for purposes other than this study such as diagnosis of impacted teeth. The informative consent form was taken from the patients. Inclusion criteria consisted of high-resolution images obtained from patients between the ages of 15 to 40 years. The patients presented with either class I or class II malocclusion, which was diagnosed based on the ANB (A point-Nasion-B point) and Wits analyses. Class I malocclusion was defined as having $0° < ANB < 4°$ and $-1 \leq Wits < 1$ mm, while class II malocclusion included patients with $ANB \geq 4°$ and $Wits \geq 1$ mm combined with overjet > 5 mm (Farzaneh Ahrari et al., 2022; F. Ahrari et al., 2015).

The exclusion criteria involved patients with cleft lip/palate or other craniofacial anomalies, a history of orthodontic treatment, the presence of internal or external root resorption, a history of root canal treatment or periodontal surgery in the region of interest, as well as the presence of deciduous, impacted, supernumerary, or missing teeth in the anterior parts of the jaws. The research was performed based on the guidelines presented in the Declaration of Helsinki. Informed consent was taken from patients at the time of image acquisition for the use of CBCT scans in future research.

CBCT scans were obtained using a Planmeca Promax 3D Max machine (Planmeca OY, Helsinki, Finland) with the following protocol settings: 88 kV power, 8 mA current intensity, 12 seconds exposure time, 200 µm voxel size, and a 90 × 90 mm field of view (FOV). Before taking the CBCT images, the head position of the patients was standardized concerning the horizontal and vertical reference lines. The images were stored in Digital Imaging and Communication in Medicine (DICOM) format and then reconstructed and analyzed by a multiplanar reformation software (Planmeca Romexis 5.3.4.39), using a 27-inch display monitor at a resolution of 1920 × 1080 pixels under dark lighting conditions.

For standardization, the right upper and lower central incisors were selected for measurements in all cases. The exception was when the tooth was rotated, in which the unrotated left central incisor was evaluated. After image reconstruction, the longitudinal axis of the right central incisor was delineated. Four reference lines (A, B, C, and D) were drawn perpendicular to the longitudinal axis of the central incisors. Line A was drawn at the cementoenamel junction (CEJ), while lines B, C, and D were placed 2.4 mm, 4.8 mm, and 7.2 mm apically to line A, respectively, to represent the crestal, middle and apex areas of the incisors (Fig. 1). The distance between the root surface and cortical bone boundary (bone thickness) was measured in the axial view at the specified levels (B, C, and D) at the buccal and palatal/lingual sides of the central incisors Fig. 2).

CBCT measurements were conducted by an experienced operator, who was not involved in the study protocol. The assessor underwent education and calibration by a radiologist before commencing the measurements. To assess intra-examiner reliability, 20% of the samples were randomly selected, and the measurements were repeated by the same evaluator one week later. Finally, the thickness of the alveolar bone was compared in different areas between class I and class II malocclusions.

2.1 Statistical Analysis

The reliability of measurements was assessed using the intraclass correlation coefficient (ICC). The normal distribution of the data was evaluated using the Kolmogorov-Smirnov test, which revealed that some data did not follow a normal distribution ($P > 0.05$). Therefore, bone thickness at different root areas was compared between the two groups using the independent samples t-test for data with normal distribution and the Mann-Whitney U test for data with non-normal distribution. To compare age and sex between class I and class II malocclusions, the independent samples t-test and the chi-square test were applied. The statistical analysis was conducted using SPSS (IBM SPSS Statistics, version 22.0; IBM Corp, Chicago, Il), with the significance level set at $P < 0.05$.

3. Results:

Table 1 presents the age and gender distribution of the patients in class I and class II groups. The statistical analysis revealed no significant difference in age and gender distribution between patients with class I and class II skeletal patterns ($p > 0.05$; Table 1). The mean intraclass correlation coefficient (ICC) was calculated to be 0.96 with values ranging from 0.89 to 1.0, indicating excellent intra-observer reliability.

None of the cases exhibited any sort of alveolar defects such as fenestration or dehiscence. Table 2 presents the mean and standard deviation of alveolar bone thickness at the buccal and lingual sides of the upper central incisor at the crest, middle, and apex areas between the study groups. The alveolar bone thickness was comparable between the two groups at the buccal side of the crest, and at the buccal and palatal sides of the middle root area ($P > 0.05$; Table 2). However, the maxillary bone thickness was significantly greater in class II than in class I patients in the palatal crest and buccal apex areas ($P = 0.049$ and $P< 0.001$, respectively; Table 2). At the palatal side of the apex, the mean bone thickness was significantly lower in class II than in class I subjects ($P = 0.001$; Table 2).

Table 3 presents descriptive statistics of mandibular bone thickness at the buccal and lingual sides of the crest, middle, and apex areas in patients with class I and class II malocclusions. Lower incisors showed less than 1.0 mm of bone thickness on the labial and lingual surfaces at the crest area in both groups. Comparison between the two groups revealed no significant difference in bone thickness at different root levels of mandibular incisors neither at the buccal nor at the lingual side ($p > 0.05$; Table 3).

4. Discussion:

This study compared the thickness of the alveolar bone overlying upper and lower incisors in patients with class I and class II skeletal patterns. The alveolar bone thickness was evaluated using CBCT imaging, which is the most accurate method for conducting alveolar bone measurements (Al-Khawaja et al., 2021). Factors such as age, sex, and race, which may influence bone thickness values, were comparable between the two groups to counteract their effects on the results.

In this study, facial bone thickness at the crest area of the upper incisors was measured to be 1.04 ± 0.55 mm and 1.16 ± 0.52 mm in class I and class II patients, respectively, while on the palatal side of the upper incisors, this value was measured to be 1.21 ± 0.41 mm and 1.42 ± 0.32 mm, respectively. In contrast, previous studies reported relatively lower buccal bone thickness at the upper incisor area. Lei et.al (Lei et al., 2022) compared alveolar bone thickness in patients with Angle class I and class III canine relationships. Regardless of the canine relationship, they reported a relatively thin buccal plate in the anterior maxilla when measured at the mid-root level (0.97 ± 0.32 mm). An observational study by Gluckman et.al (Gluckman et al., 2018) also reported that the majority of anterior maxillary teeth were surrounded by a thin facial plate (≤1mm) at the crest (83%) and the mid-root (92%) level. Similarly, Braut et.al. (Braut et al., 2011) documented a thin facial bone with less than 1 mm bone thickness at the crest (62.9%) and middle root (80.1%) of maxillary incisors. These disparities may be attributable to ethnical differences or various measurement methods between the studies.

The findings of this study demonstrated that bone thickness on the palatal side was consistently greater than that on the buccal side throughout all root areas. These results align with previous research by Oh et.al (S. H. Oh et al., 2020) who also observed greater alveolar bone thickness on the palatal/lingual side compared to the labial side of the jaws. In both malocclusion classes, palatal and buccal cortical thickness displayed an increasing pattern from the crest to root apex in the maxilla and mandible. Cassetta et.al (Cassetta et al., 2013) documented a significant linear increase of alveolar bone thickness from the alveolar crest to alveolar base; corroborating the findings of the current study.

Upon performing statistical analyses on the data, we found that Class II patients exhibited thicker alveolar bone at the palatal side of the crest area compared to Class I patients. Furthermore, the mean bone thickness at the buccal side of the apex was significantly greater in class II than in class I patients, while the palatal side of the apex exhibited significantly lower bone thickness in class II compared to class I patients. This suggests that class II patients with proclined upper anterior teeth may experience thinning of buccal bone in the crest area and palatal bone in the apex area of upper incisors, although the difference between the two groups was not significant at the buccal crest area. In contrast, Al-Khawaja et.al (Al-Khawaja et al., 2021) revealed that buccal bone thickness was greater in Class II patients compared to those with Class I malocclusion when measured at 2mm apical to the crest.

Orthodontic tooth movement can possibly lead to iatrogenic sequala on the periodontium (Justus, 2015; Ten Hoeve et al., 1976). Although no cases of alveolar defects were observed in the present study, clinicians should keep in mind that tooth movement can aggravate periodontal problems in cases with pre-existing fenestration prior to commencing orthodontic treatment and increase the risk for dehiscence development (Sheng et al., 2020). A CBCT study by Yagci et.al. (Yagci et al., 2012) found that Class II patients exhibited a significantly greater prevalence of fenestration compared to Class I and Class III subjects. Contrarily, Evangelista et al. (K. Evangelista et al., 2010) noticed a significantly greater prevalence of fenestration in patients with Class I malocclusion compared to those with Class II Division 1 malocclusion.

Focusing on the lower incisor area, we observed severe bone thinning at the cervical region of the lower anterior teeth, with alveolar bone thickness measuring 0.6 ± 0.29mm and 0.71± 0.39 mm on the buccal side, and 0.70 ± 0.36 mm and 0.79 ± 0.32 mm on the lingual side for Class I and Class II subjects, respectively. A study by Nayak Krishna et.al (Nayak Krishna et al., 2013) also observed labial bone thinning at the coronal level of mandibular incisors after lingual movement of these teeth. This emphasizes the importance of closely monitoring the supporting bone of lower anterior teeth to prevent potential periodontal complications during or after orthodontic treatment.

Comparison of bone thickness between buccal and lingual areas of the lower jaw revealed no significant differences in the crest, middle, and apex areas between class I and class II patients. However, it is essential to acknowledge that this lack of significant difference may be related to the relatively small sample size in the lower jaw. In contrast to the findings of the current study, Al-Masri et.al (Al-Masri et al.,

2015) reported a significantly thinner cervical buccal bone thickness in the mandibular arch for Class II patients compared to Class I subjects (0.60±0.20 mm versus 0.17±0.29 mm).

The findings of this study align with those reported by Lee et al. (Lee et al., 2019), indicating that the alveolar bone thickness at the buccal areas of upper incisors is generally 1 mm or less, while bone thickness is greater in the palatal areas. Similarly, other studies have revealed thinner alveolar bone in the crest area of lower incisors among patients with various malocclusions. Renaud et al. (Renaud, 2021) demonstrated that the mean bone thickness in the crest, middle, and apex areas of the lower jaw did not significantly differ between class I and class II subjects. A retrospective study by Zhnag et al. (Zhang et al., 2023) investigated and compared alveolar bone dimensions in patients with different jaw relationships. Their findings indicated that that crestal buccal bone thicknesses in the anterior mandible did not significantly differ between Class I and Class II groups.

In contrast, the results of the current study contradict those of Al-Masri et al. (Al-Masri et al., 2015), who observed that alveolar bone thickness at the middle area of lower anterior teeth on the buccal side was smaller in class II subjects compared to class I subjects. Baysal et al. (Baysal et al., 2013) also found that the alveolar bone at the labial side of lower anterior teeth was smaller in class II subjects than in class I subjects. Furthermore, Evangelista et al. (K. Evangelista et al., 2010) reported that dehiscence was significantly greater in class I patients than in class II patients, leading them to conclude that defects in alveolar bone before orthodontic treatment are more prevalent in class I malocclusion patients.

The present study did not evaluate vertical growth pattern of the subjects and this should be considered as the limitation of the study. A previous study by Baysal et.al (Baysal et al., 2013) studies demonstrated that bone thickness is influenced by both sagittal and vertical growth patterns. Another limitation of the present study was the relatively small sample size, particularly in the lower jaw. Therefore, future investigations should aim to increase the sample size to obtain more conclusive outcomes bout alveolar bone thickness in different malocclusions.

5. Conclusion:

Under the conditions used in this study:

1- Some differences were found in alveolar bone thickness between class I and class II patients in the upper jaw. Maxillary bone thickness was significantly greater in class II than in class I patients in the palatal crest and buccal apex areas. At the palatal side of the apex, the mean bone thickness was significantly lower in class II than in class I subjects. These differences should be considered in orthodontic diagnosis and treatment planning to prevent iatrogenic damage.

2- The anterior alveolar crest of the mandible was found to be thin (< 1 mm) in both class I and class II patients, emphasizing the need for precise monitoring during orthodontic treatment to prevent bone fenestration at this area.

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Table 1. Comparison of age and gender distribution between class I and class II patients evaluated in upper and lower jaw analyses

		Upper jaw			Lower jaw		
		Class I	Class II	Significance	Class I	Class II	P-value*
Age, mean ± SD		23.2 ± 6.28	22.8 ± 5.08	P = 0.825	21.8 ± 4.49	22 ± 3.23	0.603
Gender, Number (%)	Female Male	14 (56) 11 (44)	12 (48) 13 (52)	P = 0.571	6 (60) 4 (40)	4 (40) 6 (60)	P = 0.371

*Statistically significant differences were noted at P<0.05; SD: Standard deviation

Table 2. Comparison of alveolar bone thickness at different areas of the root on the buccal and palatal sides of the upper central incisor between class I and class II patients

Area	Side	Class I	Class II	P-value*
		Mean ± SD	Mean ± SD	
Crest	Buccal	1.04 ± 0.55	1.16 ± 0.52	0.435
	Palatal	1.21 ± 0.41	1.42 ± 0.32	0.049
Middle	Buccal	1.49 ± 0.85	1.19 ± 0.36	0.115
	Palatal	3.17 ± 1.09	2.67 ± 0.82	0.076
Apex	Buccal	2.09 ± 0.67	3.30 ± 0.68	<0.001
	Palatal	5.53 ± 1.77	4.22 ± 0.74	0.001

*Statistically significant differences were noted at P<0.05; SD: Standard deviation

Table 3. Comparison of alveolar bone thickness at different areas of the root on the buccal and lingual sides of the lower central incisor between class I and class II patients

Area	Side	Class I	Class II	P-value*
		Mean ± SD	Mean ± SD	
Crest	Buccal	0.6±0.29	0.71±0.39	0.475
	Lingual	0.70±0.36	0.79±0.32	0.581
Middle	Buccal	1.20±0.69	1.22±0.33	0.920
	Lingual	1.73±0.98	1.49±0.49	0.499
Apex	Buccal	1.71±0.71	1.91±0.62	0.517
	Lingual	3.61±1.09	2.98±1.25	0.245

*Statistically significant differences were noted at $P<0.05$; SD: Standard deviation

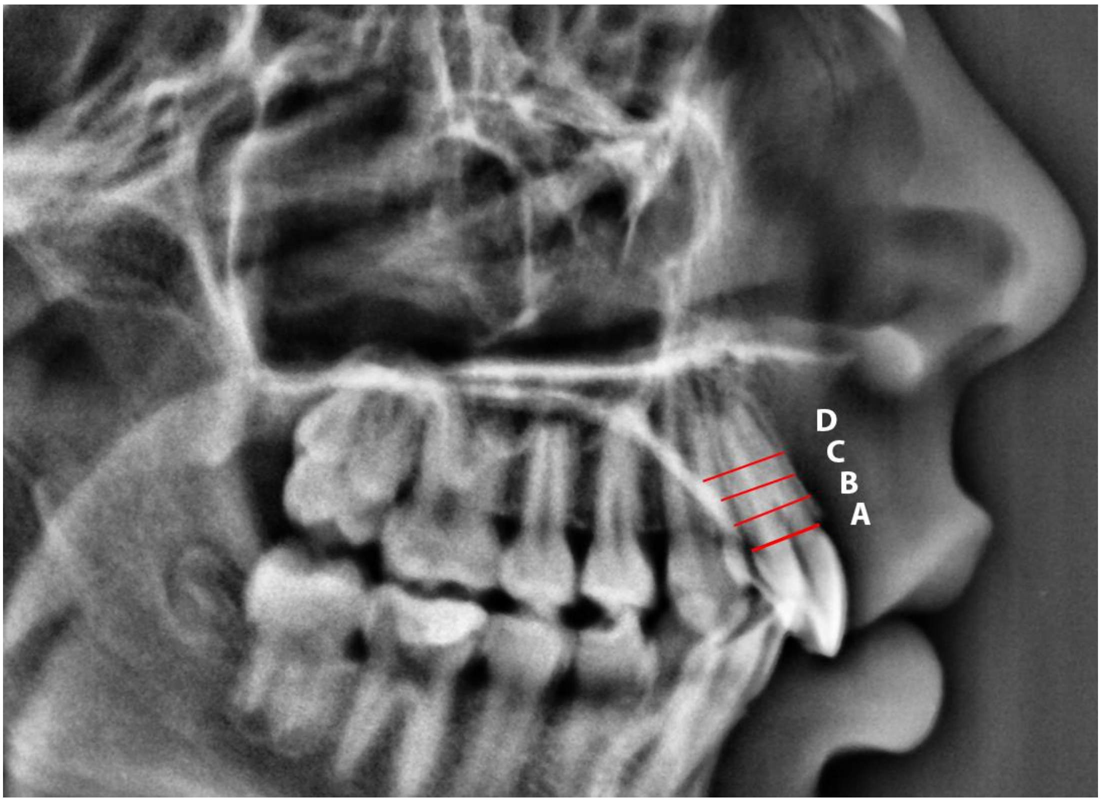

Figure 1. Drawing of reference lines perpendicular to the long axis of the central incisor

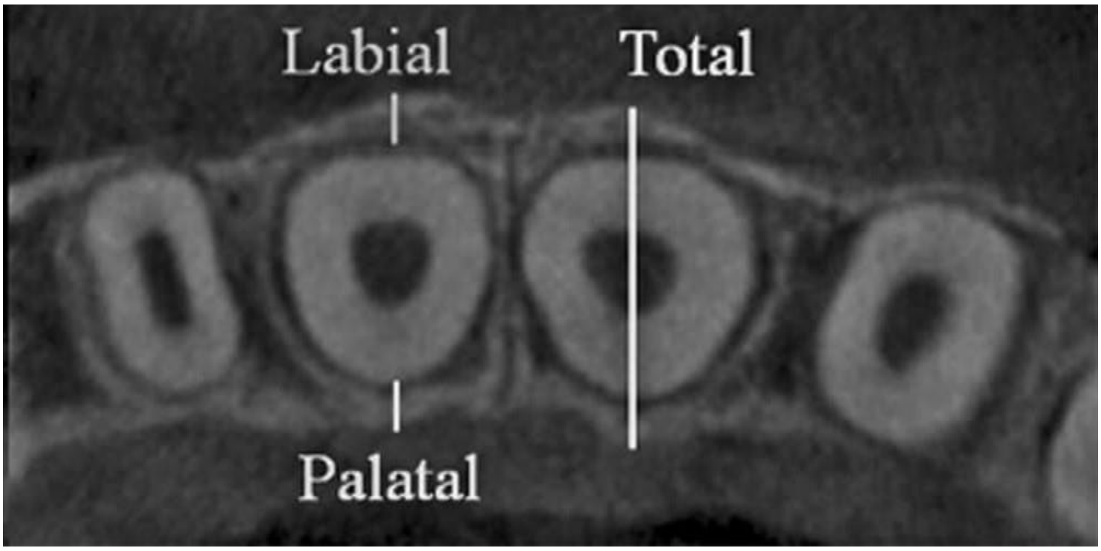

Figure 2. Measurement of alveolar bone thickness in the axial view