Insisiva Dental Journal: Majalah Kedokteran Gigi Insisiva
Website: http://journal.umy.ac.id/index.php/di/index

Literature Review

Alveolar Bone Thickness around Anterior Teeth in Different Classifications of Malocclusion: A Systematic Review

Nur Masita Silviana*
Department of Orthodontics, Faculty of Dentistry, Universitas Brawijaya, Jl. Veteran, Malang, 65145, Indonesia

Received date: October 7th, 2021; revised date: January 31st, 2022; accepted: March 28th, 2022
DOI: 10.18196/di.v10i1.12884

Abstract

Considering the alveolar bone thickness (ABT) in orthodontic treatment needs special attention. The movement of teeth depends on the mechanism of bone remodeling and tissue response to orthodontic forces to evaluate ABT of the maxillary and mandibular anterior teeth in various types of malocclusion. Methods: Only prospective original articles reporting ABT in subjects who have not undergone orthodontic treatment were selected. A total of 10 studies met the eligible criteria. Most all studies measured the thickness using CBCT. ABT on the labial side of the lower anterior teeth in the class I malocclusion group was thicker than in class II. The lingual side of the apical region of the mandibular incisors was lower in the class III group than in class I or II. ABT of the maxillary teeth on the labial surface showed no significant difference among the groups, whereas the palatal side of normal occlusion had a wider bone thickness. The inclination of the upper and lower anterior teeth was influenced by differences in the skeletal malocclusion pattern, which affected the thickness of the bone. Fenestration was more common in class II malocclusion. The results showed that ABT around anterior teeth varied according to the different classifications of malocclusion. The inclination of the upper and lower anterior teeth seemed to be influenced by the sagittal discrepancies. The pattern of facial growth also affected the thickness of the bone. Accurate evaluation is very important to prevent iatrogenic risks during orthodontic treatment.

Keywords: alveolar bone thickness; anterior teeth; incisors; classification of the malocclusion

INTRODUCTION

After orthodontic treatment, the balance and stability of the teeth' position concerning the alveolar bone and periodontal tissue are expected. It will minimize or even eliminate the occlusion and temporomandibular joint instability, prevent tooth relapse and maintain a good aesthetic result. After orthodontic treatment, the lower incisor's final position, which is right in the middle of the alveolar bone, is a factor that can maintain the stability of the tooth position. The risk of the tooth root and alveolar bone damage can also be minimized.[1]

One of the theories in orthodontic treatment presented by Coskun et al. stated that the ratio between orthodontic tooth movement to bone repair is ideally 1:1. Appropriate treatment planning is needed to determine the adaptations that may be made to the alveolar bone. How much correction is needed in the case of crowding teeth, for example, depends on the tooth's position in the alveolar bone. It is also noted that the thickness and height of the facial and lingual cortical bone layers can change depending on tooth alignment, root inclination, and occlusal forces.[2] Furthermore, Horner et al. found that the vertical growth pattern has been shown to affect the thickness of the alveolar bone. Individuals with hypodivergent mandibular angles have thicker alveolar bone morphology than

* Corresponding author, e-mail: nurmasita.fk@ub.ac.id

individuals with hyperdivergent angles.[3] Several other reports have suggested a direct relationship between the patient's facial type and the nature of the alveolar bone in anterior teeth, the morphology of the alveolar bone, and the amount of bone mineralization. Patients with dolicofacial growth exhibit a thin and elongated mandibular process that may affect the alveolar response to orthodontic tooth movement. It was also stated that around the mandibular incisors, there were more mineralized bones in-branch facial patients than in dolicofacial patients.[4,5]

In orthodontic management, the magnitude of tooth movement in the buccal or lingual direction of the teeth in patients with different skeletal types needs to be a concern. The movement of the anterior teeth in cases with severe skeletal discrepancies and indicated for orthognathic surgery is influenced by ABT and the surrounding periodontal tissue support. Considering the thickness of the alveolar bone around the incisor teeth deserves special attention. The movement of teeth through bone in orthodontic treatment depends on the mechanism of bone remodeling and the response of tissues to orthodontic forces. This literature study aims to provide an overview of the thickness of the alveolar bone surrounding the anterior teeth. It, therefore, can be considered in determining the therapeutic limits of tooth movement and during orthodontic treatment to maintain the integrity of the alveolar bone as much as possible.

MATERIALS AND METHODS

Search Strategy

The electronic search was conducted in PubMed and Medline from January 2011 to January 2022. The search strategy command consisted of the following terms: teeth, tooth, alveolar, bone, thickness/width, maxilla, mandible, anterior, incisor, classification, malocclusion, skeletal pattern, orthodontic, and treatment. All articles were filtered by title and abstract. The data obtained were filtered and assessed for further review.

Selection Process

Potential articles were checked with full text for eligibility. The inclusion criteria were: Scientific journals in the form of original articles using Indonesian or English; The publication years range from 2011 to 2022; Malocclusion patients who have not undergone orthodontic treatment; Studies measure alveolar bone thickness (ABT), anterior teeth, maxilla, and mandible; Studies reporting skeletal pattern/ classifications of malocclusion.

The exclusion criteria were: Case reports, study literature, systematic reviews, textbooks, editorials, doctoral theses, animal studies, and human cadaver studies; Subjects who are currently or have received orthodontic treatment; The teeth to be measured are canine or posterior; Languages other than Indonesian and English.

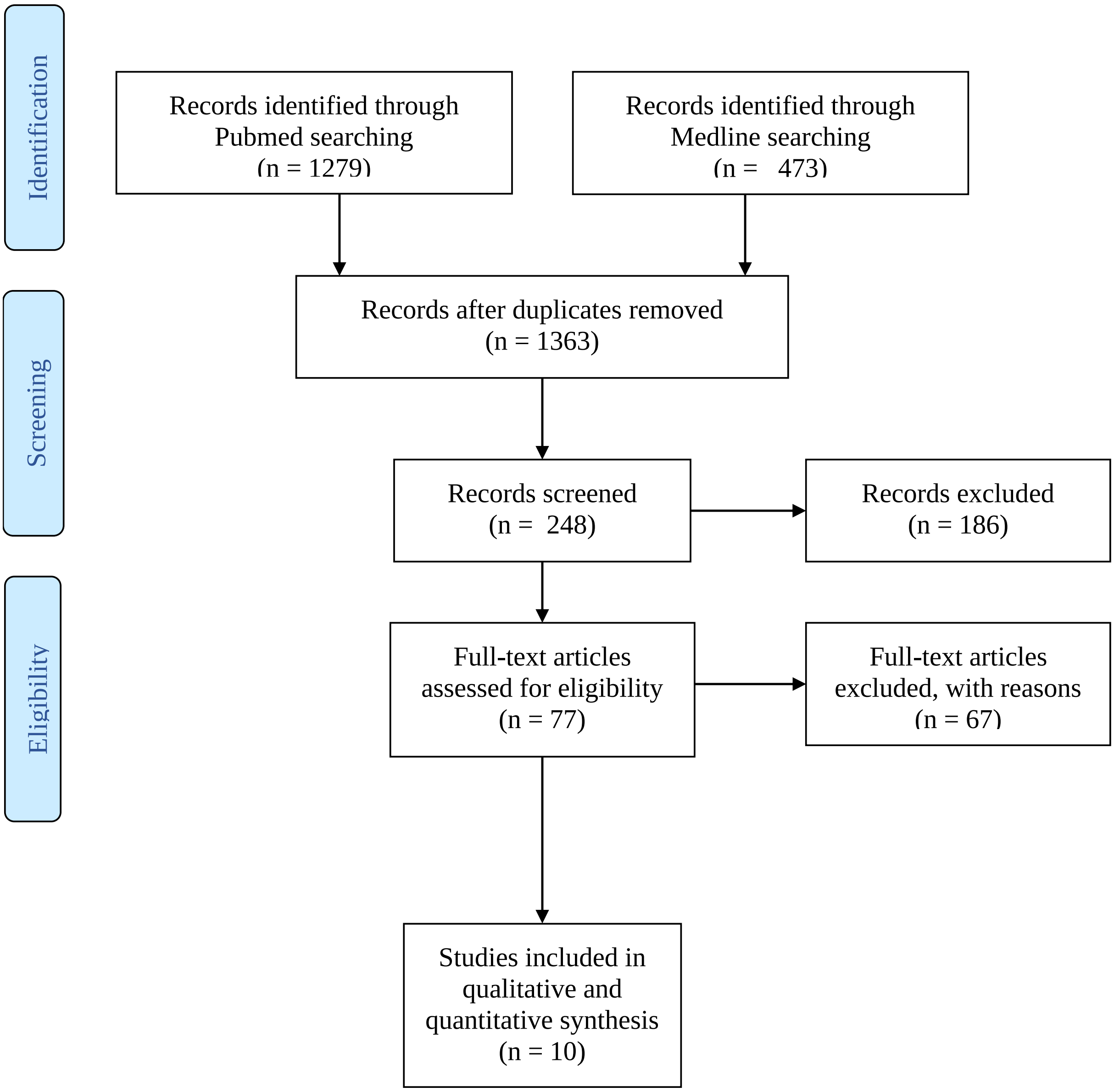

Figure 1. Prisma flow diagram

Data Items

The following information was taken from the included article: author (year), nationality, a method to assess the bone thickness, skeletal pattern (sample size), tooth type, reference points and results.

RESULT

The search and filter process are shown in figure 1 through the Prisma flow diagram. An electronic search found a total of 1279 articles after removing duplicates. The full-text assessment was continued on 248 articles through titles and abstracts that matched the inclusion criteria. A total of 67 of them were later issued for various reasons. Finally, 10 articles were eligible for selection in this systematic review (figure 1).

Almost all studies measured alveolar bone thickness using cone-beam computed tomography (CBCT). There was only one study that measured bone thickness using lateral cephalometric radiographs. Three articles assessed the thickness of bone around the incisors in adults who were not orthodontically treated with three groups of malocclusions, namely class I, class II, and Class III malocclusions.[6–8] Two articles compared alveolar bone thickness in subject with class I and class II malocclusions,[9,10] one article compared class I and class III,[11] one article compared class II and class III malocclusions,[12] one article evaluated alveolar bone thickness in skeletal class I dentoalveolar protrusive,[13] one article was with Angle Class I and mild to moderate crowding,[5] and one article was with skeletal class III malocclusion.[14] (Table 1)

Table 1. Summary articles

Author (year)	Nationality	Method to assess the bone thickness	Skeletal Pattern/ Sample Size	Tooth type	Reference Points	Results
Kook YA et al. (2012) [11]	Korea	CBCT	- Normal Occlusion /20 - Skeletal Class III malocclusion/20	U1, L1	Apex -UA, LA: Upper/ lower anterior ABT: 2 to 9 (perpendicular to line 7). -UP, LP: Upper/ lower posterior ABT: 2 to 10 (perpendicular to line 7)	Normal occlusion (mm): UA: 2-3 / UP: 6-7 / LA: 3-4 / LP: 2-3 Skeletal class III malocclusion (mm): UA: ±2 / UP: ±5 / LA: 1-2/ LP: 2-3 ABT was significantly thinner in class III malocclusion, except UA. UP, LP > UA, LA
Nahm KY et al. (2012) [13]	Korea	CBCT	Skeletal class I bidentoalveolar protrusive /24	U1, U2, L1, L2	1–10 mm below the crest. ABT at every 1/10 of root length on the facial and lingual side (level 0, CEJ; level 10, root apex region).	ABT of incisors in various root levels, increases in direction from CEJ to root apex. Posterior ABT > Anterior ABT All incisors < 1mm of ABT on the facial aspects up to root level 8 position, especially L1
Baysal A et al. (2013) [9]	Turkey	CBCT	-Class I malocclusions/41 (average-angle: 25; high-ngle:16) -Class II malocclusion/38 (average-angle: 19; high-angle:19) (mild to moderate crowding)	L1	Apex point A: the most anterior-superior point of mandibular alveolar bone; B: the most posterior-superior point of mandibular alveolar bone; C: the most anterior point of mandibular alveolar bone; F: the most posterior point of mandibular alveolar bone; D: the inner contour of the anterior cortical plate; E: the inner contour of the posterior cortical plate	Class I Average-angle (mm) D-C: 1.41±0.45 / E-F: 1.96 ± 0.56 / E−D: 4.51 ± 1.28 / F−C: 7.89 ± 1.47 High-angle (mm) D−C: 1.39 ± 0.51 / E−F: 1.86 ± 0.53 / E−D: 3.78 ± 1.19 / F−C: 7.04 ± 1.48 Class II Average-angle (mm) D−C: 1.10 ± 0.31 / E−F: 2.17 ± 0.44 / E−D: 5.41 ± 1.72 / F−C: 8.69 ± 1.82 High-angle (mm) D-C: 1.09 ± 0.46 / E−F: 1.79 ± 0.45 / E−D: 4.25 ± 1.23 / F−C: 7.14 ± 1.53 Buccal ABT Class II < Class I

Author (year)	Nationality	Method to assess the bone thickness	Skeletal Pattern/ Sample Size	Tooth type	Reference Points	Results
						L1 Class II average-angle > protrusive and proclined in the subgroup than others.
Al-Masri MM et al. (2015) [6]	Syrian Arab Republic	CBCT	-Class 1 malocclusion/16 -Class II malocclusion/16 - Class III malocclusion/16	L1, L2	Cervical, middle and apical levels of the root ABT on facial and lingual surfaces of mandible incisors	Class I Cervical thickness (mm) Buccal: 0.17 / Lingual: 0.05 Middle thickness (mm) Buccal: 0.64 / Lingual: 1.31 Apical thickness (mm) Buccal: 3.64 / Lingual: 3.28 Class II Cervical thickness (mm) Buccal: 0.06 / Lingual: 0.03 Middle thickness (mm) Buccal: 0.61 / Lingual: 1.09 Apical thickness (mm) Buccal: 3.70 / Lingual: 3.05 Class III Cervical thickness (mm) Buccal: 0.079 / Lingual: 0.07 Middle thickness (mm) Buccal: 0.48 / Lingual: 1.06 Apical thickness (mm) Buccal: 2.37 / Lingual: 2.96
Raber A et al. (2019) [7]	United Arab Emirates	CBCT	-Class 1 malocclusion/27 -Class II malocclusion/9 - Class III malocclusion/18	U1, U2, L1, L2	Mid-root, apex ABT -jaw (Md: mandible; Mx: maxilla), -incisor position (Cen: central; Lat: lateral), -side (L: left; R: right)	Class (means and standard errors) (mm) I: 0.75 (0.04) II: 0.64 (0.08) III: 0.88 (0.05) Jaw Md: 0.63 (0.05) Mx: 0.89 (0.05) Incisor Cen: 0.88 (0.04) Lat: 0.64 (0.04) Side L: 0.76 (0.04) R: 0.76 (0.04)
Ma J et al. (2019) [12]	China	CBCT	-High-angle Class II /31 - High-angle Class III /31	U1, U2, L1, L2	2, 4, 6 mm below CEJ, apical	Class II Maloclusion U1-Labial (mm) 2: 0.36 ± 0.45 / 4: 1.65 ± 0.86 / 6: 1.91 ± 0.78 / Apical: 5.65 ± 3.30 U2-Labial (mm) 2: 0.32 ± 0.62 / 4: 1.37 ± 0.94 / 6: 1.46 ± 0.73 / Apical: 2.78 ± 2.59 U1-Palatal (mm) 2: 0.66 ± 0.58 / 4: 2.69 ± 0.98 / 6: 4.31 ± 1.37 / Apical: 29.74 ± 13.82 U2-Palata (mm)l 2: 0.31 ± 0.39 / 4 : 1.70 ± 0.98 / 6: 3.06 ± 1.40 / Apical: 22.64 ± 10.83 Class III Maloclusion

Author (year)	Nationality	Method to assess the bone thickness	Skeletal Pattern/ Sample Size	Tooth type	Reference Points	Results
						U1-Labial (mm) 2: 0.36 ± 0.45 / 4: 2.00 ± 0.90 / 6: 2.24 ± 0.72 / Apical: : 5.57 ± 2.85 U2-Labia (mm)l 2: 0.40 ± 0.75 / 4: 1.68 ± 0.88 / 6: 1.70 ± 1.17 / Apical: 4.16 ± 3.19 U1-Palatal (mm) Maxillary central incisors 2: 0.61 ± 0.50 / 4: 2.55 ± 0.81 / 6: 4.10 ± 1.36 / Apical: 24.06 ± 8.86 U2-Palatal (mm) 2: 0.30 ± 0.20 / 4: 1.92 ± 0.70 / 6: 2.88 ± 1.09 / Apical: 20.88 ± 9.43 Class II Maloclusion L1-Labial (mm) 2: 0.36 ± 0.68 / 4: 1.13 ± 0.62 / 6: 1.05 ± 0.68 / Apical: 4.83 ± 2.65 L2-Labia (mm)l 2: 0.28 ± 0.47 / 4: 1.15 ± 0.77 / 6: 0.91 ± 0.65 / Apical: 4.86 ± 3.45 L1-Lingual (mm) 2: 0.04 ± 0.11 / 4: 0.94 ± 0.61 / 6: 2.05 ± 0.86 / Apical: 10.89 ± 3.77 L2-Lingual 2: 0.06 ± 0.15 / 4: 1.02 ± 0.72 / 6: 2.17 ± 0.88 / Apical: 14.75 ± 5.73 Class III Maloclusion L1-Labial (mm) 2: 0.24 ± 0.33 / 4: 1.01 ± 0.76 / 6: 0.94 ± 0.67 / Apical: 3.11 ± 2.20 L2-Labial (mm) 2: 0.23 ± 0.29 / 4: 1.15 ± 0.82 / 6: 0.84 ± 0.71 / Apical: 3.42 ± 2.69 L1-Lingual (mm) 2: 0.04 ± 0.07 / 4: 0.60 ± 0.186 / 6: 0.89 ± 0.00 / Apical: 5.43 ± 0.028 L2-Lingual (mm) 2: 0.06 ± 0.13 / 4: 0.87 ± 0.66 / 6: 1.33 ± 0.97 / Apical: 9.81 ± 6.14
Wang Z et al. (2020) [8]	China	CBCT	-Class 1 malocclusion/30 -Class II malocclusion/33 - Class III malocclusion/28	L1, L2	Cervical, middle and apical levels of the root ACHBT, PCHBT: horizontal bone thickness at the	Lower middle incisors Class I (±SD) (mm) ACHBT: 0.46 ± 0.69 / PCHBT: 0.41 ± 0.64 / AMHBT: 0.53 ± 0.35 / PMHBT: 1.42 ± 1.22 / AAHBT: 1.77 ± 0.57 / PAHBT: 2.06 ± 0.83 /

Author (year)	Nationality	Method to assess the bone thickness	Skeletal Pattern/ Sample Size	Tooth type	Reference Points	Results
					middle level of the coronal third of the buccal and lingual side, respectively. AMHBT, PMHBT: horizontal bone thickness at the middle level of the middle third of the labial and lingual side, respectively. AAHBT, PAHBT: horizontal bone thickness at the middle level of the apical third of the labial and lingual side, respectively. AVBL& PVBL: vertical alveolar bone level at the labial and lingual side, respectively.	AVBL:32.65 ± 2.16 / PVBL:1.94 ± 2.08 Class II (±SD) (mm) ACHBT: 0.17 ± 0.40 / PCHBT: 0.27 ± 0.41 / AMHBT: 0.35 ± 0.46 / PMHBT: 0.76 ± 0.78 / AAHBT: 1.56 ± 0.90 / PAHBT: 1.78 ± 1.01 / AVBL: 5.05 ± 3.14 / PVBL: 3.81 ± 2.84 Class III (±SD) (mm) ACHBT: 0.24 ± 0.14 / PCHBT: 0.31 ± 0.5 / AMHBT: 0.23 ± 0.15 / PMHBT:0.96 ± 0.99 / AAHBT: 1.30 ± 0.64 / PAHBT: 1.82 ± 0.85 / AVBL: 4.06 ± 2.81 / PVBL: 2.00 ± 1.40 Lower lateral incisors Class I (±SD) (mm) ACHBT: 0.61 ± 0.64 / PCHBT: 0.73 ± 0.66 / AMHBT: 0.29 ± 0.46 / PMHBT: 1.56 ± 1.05 / AAHBT: 2.05 ± 0.99 / PAHBT: 2.48 ± 1.56 / AVBL: 2.93 ± 2.16 / PVBL:1 62 ± 1.88 Class II (±SD) (mm) ACHBT: 0.26 ± 0.45 / PCHBT: 0.38 ± 0.39 / AMHBT: 0.27 ± 0.45 / PMHBT: 0.98 ± 0.80 / AAHBT: 1.54 ± 0.74 / PAHBT: 1.94 ± 1.59 / AVBL: 4.89 ± 3.14 / PVBL: 3.60 ± 3.00 Class III (±SD) (mm) ACHBT: 0.31 ± 0.46 / PCHBT: 0.65 ± 0.5 / AMHBT: 0.34 ± 0.56 / PMHBT: 1.16 ± 0.94 / AAHBT: 1.50 ± 0.31 / PAHBT: 2.07 ± 1.31 / AVBL: 4.64 ± 3.11 / PVBL: 2.07 ± 2.15
Oh SH et al. (2020) [14]	Korea	CBCT	Skeletal Class III malocclusion /24	U1, U2, L1, L2	1–10 mm below the crest anterior region. ABA: Alveolar BoneArea ABL: Alveolar Bone Loss	-ABA < 1.0 mm from the labial side to root level 7 (70% of the root length). - The lingual ABA L2 > L1 - Maxillary labial ABL: 21.8% - Mandibular labial ABL: 34.4% - Mandibular lingual ABL: 27.6% - Maxillary lingual ABL:18.3% Fenestrations > at root level 6.

Author (year)	Nationality	Method to assess the bone thickness	Skeletal Pattern/ Sample Size	Tooth type	Reference Points	Results
Gaffuri F et al. (2021) [5]	Italy	CBCT	-Angle Class I: mild to moderate crowding/ 30: hypodivergent (<39_), normodivergent (41 ± 2_), hyperdivergent (>43_).	U1, U2, L1, L2	Mid-root, apex BHv: Buccal bone height BHp: Palatal bone height aBTv: Apical buccal bone thickness aBTp: Apical palatal bone thickness mBTv: Mid-root buccal bone thickness mBTp: Mid-root palatal bone thickness	Hyperdivergent (mm) BHv: 0.31 ± 0.46 / BHp: 0.65 ± 0.5 / aBTv: 0.34 ± 0.56 / aBTp: 1.16 ± 0.94 / mBTv: 1.50 ± 0.31 / mBTp: 2.07 Hypodivergen (mm) BHv: 0.31 ± 0.46 / BHp: 0.65 ± 0.5 / aBTv: 0.34 ± 0.56 / aBTp: 1.16 ± 0.94 / mBTv: 1.50 ± 0.31 / mBTp: 2.07 Normodivergent (mm) BHv: 0.31 ± 0.46 / BHp: 0.65 ± 0.5 / aBTv: 0.34 ± 0.56 / aBTp: 1.16 ± 0.94 / mBTv: 1.50 ± 0.31 / mBTp: 2.07
Andrews WA et al. (2022) [10]	USA	Lateral Cephalograms	-Optimal occlusions (NOO)/ 115 -Class II malocclusions/57	U1, L1	The maxillary root midpoint: Mx-Alv: U1-lab+ U1-pal. The mandibular root midpoint: Md-Alv: L1-lab+L1-ling.	NOO (mm) U1-pal: 6.49 ± 1.09 U1-lab: 3.84 ± 0.50 L1-ling: 5.32 ± 1.41 L1-lab: 5.08 ± 1.44 Class II (mm) U1-pal: 6.24 ± 1.26 U1-lab: 3.58 ± 0.51 L1-ling: 5.02 ± 1.60 L1-lab: 6.18 ± 1.79

Seven studies evaluated the middle and lateral incisors. Five studies evaluated the maxillary and mandibular incisors [5,7,12–14,] and two evaluated the mandibular incisors.[6,8] Two studies evaluated the maxillary and mandibular middle incisors[10,11,] and one study evaluated the mandibular middle incisors, respectively.[9] Among these, two studies evaluated the labial and lingual sides,[5,10] and only one article evaluated the labial side.[7] Two studies reported alveolar thickness per 1/10 of root length on the facial and lingual side (level 0, cementoenamel junction (CEJ) region; level 10, root apex region).[13,14] Two studies evaluated bone thickness at different distances from the CEJ and apex [9,11,] and one study evaluated at 2, 4 and 6 mm from CEJ.[12]

This study indicated that ABT on the labial surface of the maxillary incisors in each patient varied and was influenced by differences in skeletal patterns. Different skeletal patterns determined the inclination of the maxillary and mandibular anterior teeth.[7,10,13] On the lingual side, especially on the mandibular incisors, the decrease in bone thickness was more pronounced.[10,14] The hyperdivergent facial pattern group had the facial apical bone thickness and lingual/palatal middle root level significantly thinner than the hypodivergent facial pattern.[5,9,12] The incidence of fenestrations was higher in the mandibular anterior teeth than maxillary in different skeletal patterns. A greater prevalence of dehiscence was shown in class II and III malocclusion groups than in the class I.[13,14]

DISCUSSION

Several methods have measured bone thickness. Examination using CBCT allows getting a better quality of the alveolar bone morphology results to minimize distortion or superimposition. 3D CBCT provides visualization of bone anatomy due to the inherent accuracy of CBCT, which can visualize the thin alveolar bone in the center of complex overlapping craniofacial structures. It was possible to use a lateral cephalogram to measure the width of the labiolingual bone, but all the structures overlapped, so the measurement was inaccurate.[6,10,11] It is still possible to check using cephalogram radiographs such as the results of Andrews et al. Examination using cephalometric radiographs is still possible to assess root assessment positions limited to one landmark for each incisor: root apex midpoint of maxillary and mandibular. Assessing the thickness of the alveolar bone in several or different landmarks along the long axis of the root may have provided additional insight.[10] Cephalometric radiographs are also required when determining the sagittal and vertical relationships of the skeletal pattern.

In this literature review, although the ten selected studies were very heterogeneous, the three types of malocclusion had something in common: the ABT was wider in the lingual region of the mandible compared to the labial region. ABT is also larger in the upper incisors than the lower incisors.[13] In individuals who did not receive orthodontic treatment, the maxillary central incisors tend to be in the anterior third of the maxilla alveolar process. In individuals with optimal occlusion who did not receive orthodontic treatment, the root apex of the mandibular central incisor tended to be centered in the mandibular alveolar process. Meanwhile, in individuals who did not receive orthodontic treatment with class II malocclusion, the position of the mandible was relatively retrognathic, the mandibular middle incisors tended to be more proclined, and the root apex was more posterior compared to individuals with optimal occlusion who did not receive orthodontic treatment.

The results of the ABT study around the mandibular anterior teeth showed that in the skeletal class I group, the alveolar bone on the facial side of the mandibular anterior teeth was thicker than in the class II group. When bone thickness was evaluated by comparing the three malocclusion patterns, the bone thickness on the lingual side at the apical region of the mandibular incisors teeth was lower in class III than in class I or class II group.[9] ABT increased from the cervical region to the apical.[6] Al-Masri et al. analyzed that the inclination of the mandibular incisors possibly influenced this condition. In individuals with a skeletal class III, the lower incisors tended to retroclinate compared to individuals with a class I occlusion relationship and a class II skeletal relationship that tended to proclinate. Kook et al. also reported similar results, namely, in class I subjects, the apical thickness of the labial surface of the incisors was wider than in subjects with skeletal class III.[11]

In the evaluation of maxillary teeth comparing the three malocclusion groups, the value of alveolar bone thickness showed no significant difference between groups, whereas, on the palatal side, the group with normal occlusion had wider bone thickness.[11] However, the study results by Raber et al. found it in class III skeletal pattern with very large maxillary proclination. ABT in the apical region showed a significantly greater amount when compared with the subject in skeletal class I and II. It was stated that this inclination was a compensatory proclination of the upper anterior teeth, which were located further back in a Class III skeletal pattern.[7] Another study reported that the labial surface ABT was less inclined than the teeth in normal occlusion in the maxillary incisors with a palatal inclination. A review of these studies showed that the ABT on the labial surface of the anterior teeth varied based on the bone differences in each individual. The inclination of the upper and lower anterior teeth was influenced by differences in the skeletal malocclusion pattern, which affected the thickness of the bone.[7,15]

Besides being influenced by the inclination of the teeth, this study found a statistically significant relationship between ABT and facial growth patterns. Research conducted by Baysal et al. found that in the class II subgroup with a high-angle mandibular growth, the size of the spongy bone was thinner, and the position of the apex was closer to the cortex when compared to the same subgroup with the average angle. Likewise, ABT on the labial and lingual sides in the class III subgroup was very thin in high-angle subjects. When comparing the classification of class II malocclusion and class III malocclusion, it appeared that in subjects with class III malocclusion with high angle, the mandibular bone morphology was thinner than in subjects with class II malocclusion with high angle. It is believed that it may occur during the vertical growth of the face, which is partly due to the divergence of the mandible. ABT on the facial and lingual surfaces is reduced when the incisors erupt to reach an overbite.[5,9,12]

The thickness of the bone around the anterior teeth is also associated with fenestration and dehiscence. Fenestration is a condition of loss of bone covering the tooth's root surface. The root surface is covered only by the periosteum and gingiva. In such a lesion, the marginal bone is intact. When this bone defect progresses toward the marginal bone, the condition is called dehiscence.[16] The study reported by Enhos et al., and associated with the growth pattern, showed that subjects with high angles and average angles had more frequent dehiscence events than subjects with low angles. Fenestration and dehiscence were found more on the facial side of all vertical growth patterns. Fenestrations are often found in the maxillary alveolar area, whereas dehiscence is more often found in the mandibular.[17]

On the sagittal relation type, Yagci et al. found that fenestration was more common in Class II malocclusions than in Class I or III malocclusions. It is most likely related to the majority of research results which stated that class II malocclusion was dominated by the presence of protrusive maxillary incisor images. In addition, the inclination of the mandibular incisors is also mostly buccal so that the surrounding alveolar bone becomes thinner.[18] Fenestration and dehiscence are more commonly found on the facial (labial/buccal) surface than the lingual surface of the root and are more common in anterior teeth than posterior teeth. It was further explained that the anterior teeth most prone to dehiscence were the lower central incisors. It occurs because there is a match between the anatomical characteristics and its location in the mandibular symphysis with the thin surrounding cortical bone.[14,19] Evangelista et al. also reported a similar finding showing that dehiscence frequency was higher in the lower central incisors.[16]

Malocclusion accompanied by crowding and misaligned teeth can also be a risk factor for bone fenestration and dehiscence. Inadequate bone support during orthodontic movements can damage the teeth and their periodontium. Movement in the buccal-lingual direction poses a greater risk of the presence of surrounding alveolar bone so that it can cause resorption. This bone defect is more commonly found on the buccal surface than lingual. It is associated with thinner bone on the buccal surface, where the amount of bone marrow is less dense than in the lingual area.[18,20] On the palatal surface, higher bone remodeling is believed to result from tooth retraction movements that are often performed in orthodontic treatment. Although the loss of alveolar bone on the palatal side does not affect the esthetics, it can cause loss of periodontal tissue support. [21,22]

Before starting orthodontic treatment, it is necessary to thoroughly evaluate the periodontal tissues, especially in cases with dentoalveolar protrusions. This study can be a reference as data for clinicians about the characteristics of ABT in various patterns of skeletal malocclusion. It is expected that evaluating alveolar bone thickness around anterior teeth can provide useful information for dentists to prevent iatrogenic risk, the occurrence of fenestration and dehiscence and describe the therapeutic limits of anterior tooth movement before orthodontic treatment begins.

CONCLUSION

Based on the result of this study, it can be concluded that there were variations in ABT due to differences in bone in each subject to the different classifications of malocclusion. The inclination of the upper and lower incisors seemed to be influenced by the sagittal discrepancies. The pattern of facial growth also affected the thickness of the ABT. Thus, accurate evaluation is highly important to prevent iatrogenic risks during orthodontic treatment.

REFERENCES

1. Steiner GG, Pearson JK, Ainamo J, Miller S, Maria S. Changes of the Marginal Periodontium as a Result of Labial Tooth Movement in Monkeys. *J Periodontol*, 1981;52:314-320. https://doi.org/10.1902/jop.1981.52.6.314
2. Coşkun İ, Kaya B. Relationship between alveolar bone thickness, tooth root morphology, and sagittal skeletal pattern: A cone-beam computed tomography study. *Journal of Orofacial Orthopedics*. 2019;80(3):144-158. https://doi.org/10.1007/s00056-019-00175-9
3. Horner KA, Behrents RG, Kim KB, Buschang PH. Cortical bone and ridge thickness of hyperdivergent and hypodivergent adults. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2012;142(2): 170-178. https://doi.org/10.1016/j.ajodo.2012.03.021
4. Srebrzyńska-Witek A, Koszowski R, Różyło-Kalinowska I. Relationship between anterior mandibular bone thickness and the angulation of incisors and canines—a CBCT study. *Clinical Oral Investigations*.2018;22(3):1567-1578. https://doi.org/10.1007/s00784-017-2255-3
5. Gaffuri F, Cossellu G, Maspero C, et al. Correlation between facial growth patterns and cortical bone thickness assessed with cone-beam computed tomography in young adult untreated patients. *Saudi Dental Journal*. 2021;33(3):161-167. https://doi.org/10.1016/j.sdentj.2020.01.009
6. Al-Masri MM, Ajaj MA, Hajeer MY, Al-Eed MS. Evaluation of Bone Thickness and Density in the Lower Incisors' region in Adults with Different Types of Skeletal Malocclusion using Cone-beam Computed Tomography. *Journal of Contemporary Dental Practice*. 2015; 16(8):630-637. https://doi.org/10.5005/jp-journals-10024-1733
7. Raber A, Kula K, Ghoneima A. Three-dimensional evaluation of labial alveolar bone overlying the maxillary and mandibular incisors in different skeletal classifications of malocclusion. *International Orthodontics*. 2019; 17(2):287-295. https://doi.org/10.1016/j.ortho.2019.03.011
8. Wang Z, Ma Z, Yang C. Alveolar bone loss around mandibular anterior teeth in Class I, II, and III malocclusions: a CBCT evaluation study. Published online 2020. https://doi.org/10.21203/rs.3.rs-34913/v1
9. Baysal A, Ucar FI, Buyuk SK, Ozer T, Uysal T. Alveolar bone thickness and lower incisor position in skeletal class I and class II malocclusions assessed with cone-beam computed tomography. *Korean Journal of Orthodontics*. 2013;43(3):134-140. https://doi.org/10.4041/kjod.2013.43.3.134
10. Andrews WA, Abdulrazzaq WS, Hunt JE, Mendes LM, Hallman LA. Incisor

position and alveolar bone thickness. *The Angle Orthodontist*.2022;92(1):3-10. https://doi.org/10.2319/022320-122.1
11. Kook YA, Kim G, Kim Y. Comparison of alveolar bone loss around incisors in normal occlusion samples and surgical skeletal Class III patients. *Angle Orthodontist*. 2012;82(4):645-652. https://doi.org/10.2319/070111-424.1
12. Ma J, Huang J, Jiang J hui. Morphological analysis of the alveolar bone of the anterior teeth in severe high-angle skeletal Class II and Class III malocclusions assessed with cone-beam computed tomography. *PLoS ONE*.2019;14(3). https://doi.org/10.1371/journal.pone.0210461
13. Nahm KY, Kang JH, Moon SC, et al. Alveolar bone loss around incisors in Class I bidentoalveolar protrusion patients: A retrospective three-dimensional cone-beam CT study. *Dentomaxillofacial Radiology*. 2012; 41(6):481-488. https://doi.org/10.1259/dmfr/30845402
14. Oh SH, Nahm KY, Kim SH, Nelson G. Alveolar bone thickness and fenestration of incisors in untreated Korean patients with skeletal class III malocclusion: A retrospective 3-dimensional cone-beam computed tomography study. *Imaging Science in Dentistry*.2020;50(1):9-14. https://doi.org/10.5624/isd.2020.50.1.9
15. Tian Y Lou, Liu F, Sun HJ, et al. Alveolar bone thickness around maxillary central incisors of different inclination assessed with cone-beam computed tomography. *Korean Journal of Orthodontics*. 2015;45(5):245-252. https://doi.org/10.4041/kjod.2015.45.5.245
16. Evangelista K, Vasconcelos KDF, Bumann A, Hirsch E, Nitka M, Silva MAG. Dehiscence and fenestration in patients with class I and class II division 1 malocclusion assessed with cone-beam computed tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2010;138(2): 133.e1-133.e7. https://doi.org/10.1016/j.ajodo.2010.02.021
17. Enhos S, Uysal T, Yagci A, Velid I, Ucare FI, Ozerf T. Dehiscence and fenestration in patients with different vertical growth patterns assessed with cone-beam computed tomography. *Angle Orthodontist*. 2012;82(5):868-874. https://doi.org/10.2319/111211-702.1
18. Yagci A, Veli I, Uysal T, Ucar FI, Ozer T, Enhos S. Dehiscence and fenestration in skeletal Class I, II, and III malocclusions assessed with cone-beam computed tomography. *Angle Orthodontist*. 2012;82(1):67-74. https://doi.org/10.2319/040811-250.1
19. Kajan ZD, Monir SES, Khosravifard N, Jahri D. Fenestration and Dehiscence in the Alveolar Bone of Anterior Maxillary and Mandibular Teeth in Cone-Beam Computed Tomography of an Iranian Population. Dental Research Journal. 2020;17(5):380-387.
20. Klinge A, Becktor K, Lindh C, Becktor JP. Craniofacial height in relation to cross-sectional maxillary and mandibular morphology. Progress in Orthodontics. 2017;18(1): 32. https://doi.org/10.1186/s40510-017-0187-8
21. Sadek MM, Sabet NE, Hassan IT. Alveolar bone mapping in subjects with different vertical facial dimensions. Eur J Orthod. 2014;37(2):194–201. https://doi.org/10.1093/ejo/cju034
22. Fiorellini JP, Kim DM, Uzel NG. Anatomy of the periodontium. In: Newman MG, Takei H, Klokkevold PR, editors. Carranza's Clinical Periodontology. 11th ed. St. Louis,

MO: Saunders Elsevier. 2015; pp.11,31-7.