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Labial alveolar bone thickness and its correlation with buccolingual maxillary incisors angulation: a CBCT based study

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Abstract. – OBJECTIVE: Understanding the labial alveolar bone thickness (ABT) and buccolingual teeth angulation may reduce the complication that might arise during or post-operative treatment. The operator could determine the precise method to ensure long-term treatment success. This study aimed to evaluate the ABT with buccolingual upper incisor teeth angulation based on the maxillary plane by using the cone-beam computed tomography (CBCT).

MATERIALS AND METHODS: A total of 371 CBCT radiographs were initially assessed and 100 CBCT radiographs were included. On the maxillary incisors, the labial alveolar bone thickness is evaluated at three points (Point A: Four mm below from CEJ, Point B: Midpoint from the labial alveolar-palatal alveolar crest plane and root apex. Point C: Root Apex of the tooth). The distance from these points to labial alveolar bone was measured for the ABT. Moreover, buccolingual angulation of the tooth was measured by the angle formed by the maxillary plane and the long axis of the tooth.

RESULTS: There is no significant difference observed between genders in the labial alveolar bone thickness. The labial alveolar bone thickness grew gradually from the cementoenamel junction (CEJ) level to the apical level. Moreover, there was a statistically significant positive correlation observed between labial alveolar bone thickness at the apical level (Point C) and angulation (p<0.05).

CONCLUSIONS: The labial bone thickness was less than 2 mm in the majority of cases at the three points among maxillary incisors. In addition, there is a correlation between buccolingual angulation of the maxillary incisors and labial alveolar bone thickness.

Key Words:

Labial bone thickness, Buccolingual angulation, Maxillary incisors teeth, Maxillary plane, Cone-beam computed tomography, Immediate implant placement.

Introduction

The lateral cephalometric radiograph is the standard method for determining incisor inclination. However, lateral cephalometric radiographs fabricate two-dimensional (2D) images which exhibit some extent of distortion. Therefore, three-dimensional (3D) images are more accurate to determine incisor inclination that is not influenced by the superposition of nearby structures or distortion[1]. Cone-beam computed tomography (CBCT) images provide a 3D evaluation of the quantity and quality of the bones without overlapping or distorting the anatomical landmarks[2].

The success rates of dental implants are high in terms of both mastication and cosmetic[3,4]. For the replacement of missing teeth, the dental implant becomes a very common treatment procedure; however, the placement of the implant in the esthetic area, particularly the anterior portion of the maxillary arch, is challenging for the dentists due to the expectation of the patients. In addition to the patients' expectations, there are more difficulties like compromised anatomy and risk factors including an improper selection of implant or the technique. Proper implant position is very important to achieve long-term success, especially for the anterior portion of the maxilla[1,5]. For determining the best treatment plan, the buccolingual teeth angulation along with the distance between cementoenamel junction (CEJ) and the alveolar crest should be taken into consideration.

Understanding the labial alveolar bone thickness (ABT) and buccolingual teeth angulation may reduce the complication that might arise

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during or postoperative treatment. The surgeon could determine the precise method to ensure long-term treatment results in both functional and esthetic patterns, particularly, during implant placement procedures within an esthetic region such as the maxillary incisors areas. Additionally, the results will expand the knowledge and information regarding the evaluation of maxillary labial ABT.

Horizontal and vertical bone loss after a tooth extraction is unavoidable[6-8]. The facial bone plates undergo more change than the palatal plates. The palatal and facial plates show more vertical bone loss. The resorption process of the facial bone plate is more in the anterior portion than the posterior area since the thinner walls of bones have more resorption rate. Anterior teeth and the premolars of the maxillary jaw have thinner facial plates than the posterior region. The thinnest facial cortical plate found in the maxillary incisors and canine[6,7,9,10]. After dental extraction, resorption of the bone is more severe for up to three months. However, less alveolar bone remodeling persists to occur up to one year, as a result of dimensional changes. Labial bone thickness and resorption of the bones are determined by the angle formed in the sagittal plane between the alveolar bone inclination and the long axis of the tooth. These factors must be considered before treatment planning and dental extraction. The use of bone regeneration techniques might be needed during or before placing the dental implant. For this purpose, CBCT is mandatory to be performed during or before implant placement to avoid compromising cosmetics in rehabilitation and choosing the proper approach[11]. Therefore, this study aimed to evaluate the ABT with buccolingual upper incisor teeth angulation based on the maxillary plane by using CBCT radiographs.

Materials and Methods

Ethical Guidelines and Inclusion Criteria

This study was approved by the Research Ethics Review Board of the Prince Sattam Bin Abdulaziz University, Alkharj, Saudi Arabia (Approval Number PSAU2021012). Written informed consent was obtained from all the participants who had their imaging records and were used in the current study. The following inclusion criteria were included in this study: healthy individuals without any oro-systemic disease; adult individuals aged 18 years or older; all four or at least 3 upper incisors present; all upper incisors free of caries and periodontal stable; CBCT-based dental records. The patients who did not meet the inclusion criteria were excluded from this study. During this study, all individuals were given the option of declining to participate without any penalty.

Study Design and Location

It was a cross-sectional study conducted at the Department of Oral and Maxillofacial Surgery, College of Dentistry, Prince Sattam Bin Abdulaziz University, Alkharj, Saudi Arabia. The study was conducted between June 2021 and February 2022.

Patient Screening

A total of 371 CBCT radiographs were initially assessed and, based on the inclusion criteria, 100 CBCT radiographs were selected for the current study.

Measurements of the CBCT

CBCT images were obtained using the Cone-Beam imaging technology (CareStream Dental Imaging Sciences International, Hatfield, PA, USA) by a calibrated and trained technician. The following criteria were followed for the CBCT images; Voxel size: 200 to 500 microns, Field of view: 8 cm × 8 cm to 6 cm × 13 cm, Tube voltage: 80 to 90 KVp, Current: 5 mA, exposure time: 40 seconds. Then, the images were converted to the CBCT-based Digital Imaging and Communications in Medicine (DICOM) format. All the CBCT images were evaluated *via* a software program (i-CAT FLX V-Series, Hatfield, PA, USA). For evaluating the labial ABT, all maxillary incisors were divided into three points. Point A: Four mm below from CEJ, Point B: Midpoint from the labial alveolar-palatal alveolar crest plane and root apex. Point C: Root Apex of the tooth. The distance from these points to labial alveolar bone was measured for the ABT (Figure 1, 2). Moreover, buccolingual angulation of the tooth was measured by the angle formed by the maxillary plane and the long axis of the tooth. The maxillary plane connects the anterior nasal spine (ANS) and posterior nasal spine (PNS) in the maxilla (Figure 3, 4). For the reliability of the measurements, a total

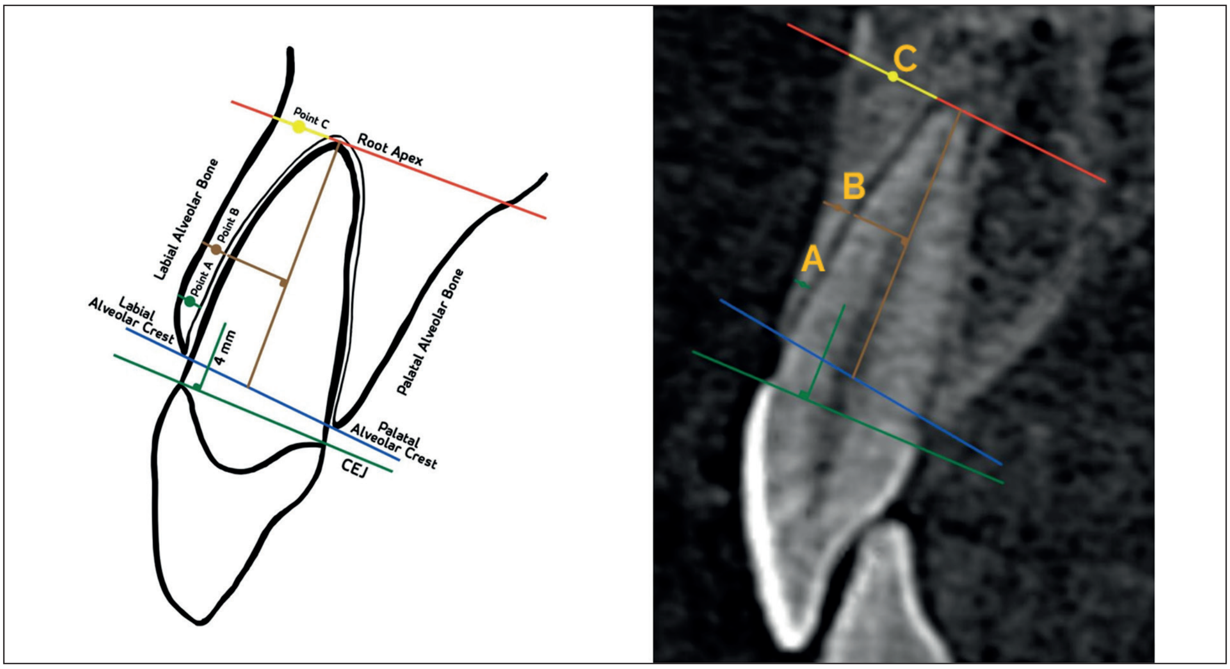

Figure 1. Diagram shows three points to measure the labial alveolar bone thickness.

of 20 CBCT radiographs were (20% of the total sample) assessed by two examiners; two times in two weeks intervals.

Statistical Analysis

All statistical analyses were performed using the SPSS version 20 software (Chicago, IL, USA). Intra-examiner and inter-examiner reliability were assessed using the Intra-class correlation (ICC) statistics. Shapiro-Wilk test was performed to check the distribution of the data. An independent *t*-test was performed to compare the mean of ABT and buccolingual maxillary incisors angulation between males and females. Pearson correlation was used to assess the linear relation between ABT and buccolingual maxillary incisors angulation.

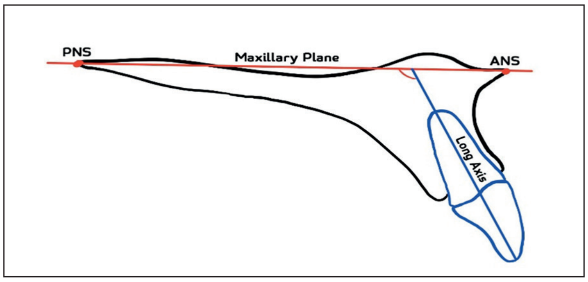

Figure 2. CBCT shows three points to measure the labial alveolar bone thickness

Results

ICC showed an excellent correlation between the intra-examiner and inter-examiner reliability for the measurement of ABT and buccolingual maxillary incisors angulation. Shapiro-Wilk test showed the normal distribution of the data; therefore, parametric tests were applied for the data analysis.

CBCT radiographs from 100 patients (male=57 and female=43) with a mean age of 30.51±8.51 years were included in this study (Table I). For all the investigated teeth, the labial ABT increased progressively from the CEJ towards the apical area.

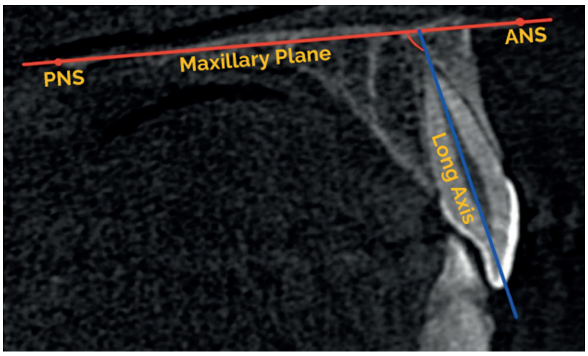

Figure 3. Diagram shows the buccolingual tooth angulation and CBCT.

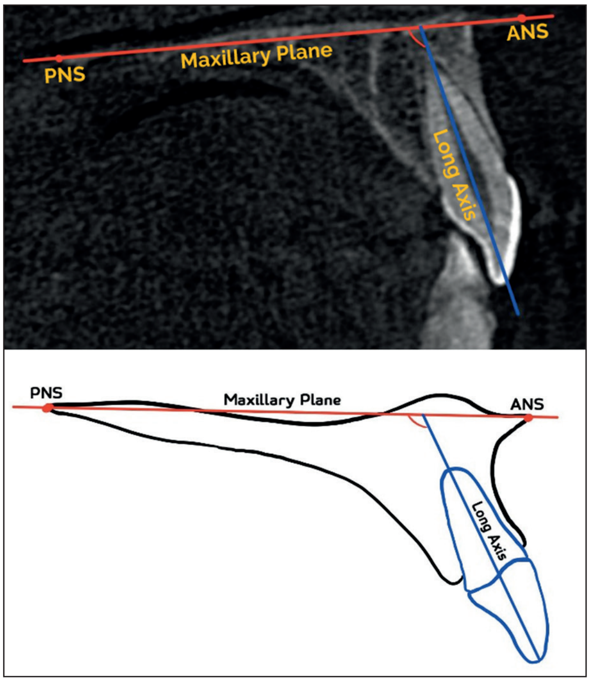

Figure 4. CBCT shows the buccolingual tooth angulation and CBCT.

The labial alveolar bone was the thinnest in males at the point A of the maxillary incisors; however, the thinnest labial alveolar bone was observed at point B for the females (Table II).

The mean labial alveolar bone thickness and mean angulation of teeth 11, 12, 21, and 22 did not differ significantly between genders. However, the mean thickness was slightly larger in males than in females at most of the inspected levels (Table III).

There was a statistically significant positive correlation between labial alveolar bone thickness at Point C and angulation among all four incisors ($p<0.05$), and a statistically significant negative correlation between buccolingual angulation with labial alveolar bone thickness at point B among the left and right lateral incisors (12 and 22) and at Point A among left central incisor (21) ($p<0.05$), (Table IV; Figure 5).

Table I. Distribution of mean age among males and females.

Gender	N	Mean age	SD
Male	57	30.68	9.39
Female	43	30.28	7.28
Total	100	30.51	8.51

N, Number of samples; SD, Standard deviation.

Discussion

CBCT is widely used for the treatment of implant procedures due to the low doses of radiation and precision which have been supported by many previous studies[1,12-14]. For achieving a perfect 3D view of the dental implant, the implant requires to insert in a similar direction as the extracted tooth, due to the growing interest in the restoration-driven concept. However, Lau et al[15] discovered that this principle could only be followed in 9.5% of their cases without jeopardizing the final treatment outcome.

The current study showed that at point A, the mean labial ABT of central incisors were 0.67 mm and 0.68 mm on the left and right, respectively, whereas 0.65 mm on both sides in lateral incisors. At point B, the mean labial ABT was 0.68 mm in central incisors on both sides and 0.62 mm and 0.64 mm in lateral incisors for the left and right side of the maxilla, respectively. Similarly, the mean labial ABT at Point C was 1.23 mm on both central incisors and 1.24 mm and 1.28 mm for the left and right lateral incisors, respectively. These measurements are close to those reported in previous studies[1,15]. However, a study with the Han Chinese population[16] showed that the mean labial ABT was 0.95 mm and 0.76 mm for central incisors and lateral incisors respectively, at the apical level which is a little bit decreased compared with the current study. The reason for the differences might be due to the measurements procedure as this study used the central slice of the alveolar bone and Zhang et al[16] measured the central slice of the tooth. The other minor discrepancies in measurement can be ascribed to the race and ethnicity of the population as well as differences in instrumentation standardization.

The current study did not observe any significant differences in the labial ABT of the maxillary incisors between the genders in all three points. Though there are no significant differences, the mean labial ABT is greater in males than the females. These findings are consistent with prior reports[17]. According to some studies[1,18,19], males had a statistically significant higher palatal bone width than females, and the difference between genders could be explained by the differences in bone remodeling phenomena between males and females. The success rate of the implant relies on the stability of the implants which is determined by the mechanical interaction between the cortical bone and the surface of the implant[18,19]. The implant should place

Table II. Mean distribution of Alveolar bone thickness and buccolingual maxillary incisors angulation between males and females.

Tooth#	Measurement	Male			Female			Total		
		N	Mean	SD	N	Mean	SD	N	Mean	SD
12	Point A (mm)	57	0.64	0.13	43	0.67	0.14	100	0.65	0.13
	Point B (mm)	57	0.66	0.19	43	0.62	0.16	100	0.64	0.18
	Point C (mm)	57	1.31	0.52	43	1.23	0.44	100	1.28	0.49
	Angulation	57	111.43	6.24	43	112.51	6.23	100	111.90	6.23
11	Point A (mm)	57	0.69	0.12	43	0.67	0.14	100	0.68	0.13
	Point B (mm)	57	0.70	0.15	43	0.65	0.17	100	0.68	0.16
	Point C (mm)	57	1.28	0.36	43	1.17	0.40	100	1.23	0.38
	Angulation	57	111.96	6.21	43	112.63	7.56	100	112.25	6.80
21	Point A (mm)	57	0.66	0.10	43	0.69	0.12	100	0.67	0.11
	Point B (mm)	57	0.71	0.14	43	0.66	0.15	100	0.68	0.14
	Point C (mm)	57	1.29	0.39	43	1.15	0.39	100	1.23	0.40
	Angulation	57	112.30	5.90	43	112.93	7.73	100	112.58	6.73
22	Point A (mm)	57	0.64	0.12	43	0.65	0.14	100	0.65	0.13
	Point B (mm)	57	0.63	0.18	43	0.60	0.14	100	0.62	0.16
	Point C (mm)	57	1.28	0.51	43	1.20	0.44	100	1.24	0.48
	Angulation	57	111.34	5.93	43	113.40	6.78	100	112.22	6.36

#, FDI notation; N, Number of samples; SD, Standard deviation; mm, millimeter.

Table III. Comparison of Alveolar bone thickness and buccolingual maxillary incisors angulation between males and females.

Tooth#	Measurement	Gender	N	Mean	SD	*p*
12	Point A (mm)	Male	57	0.64	0.13	0.397
		Female	43	0.67	0.14	
	Point B (mm)	Male	57	0.66	0.19	0.37
		Female	43	0.62	0.16	
	Point C (mm)	Male	57	1.31	0.52	0.411
		Female	43	1.23	0.44	
	Angulation	Male	57	111.43	6.24	0.394
		Female	43	112.51	6.23	
11	Point A (mm)	Male	57	0.69	0.12	0.419
		Female	43	0.67	0.14	
	Point B (mm)	Male	57	0.70	0.15	0.176
		Female	43	0.65	0.17	
	Point C (mm)	Male	57	1.28	0.36	0.177
		Female	43	1.17	0.40	
	Angulation	Male	57	111.96	6.21	0.633
		Female	43	112.63	7.56	
21	Point A (mm)	Male	57	0.66	0.10	0.23
		Female	43	0.69	0.12	
	Point B (mm)	Male	57	0.71	0.14	0.107
		Female	43	0.66	0.15	
	Point C (mm)	Male	57	1.29	0.39	0.097
		Female	43	1.15	0.39	
	Angulation	Male	57	112.30	5.90	0.648
		Female	43	112.93	7.73	
22	Point A (mm)	Male	57	0.64	0.12	0.909
		Female	43	0.65	0.14	
	Point B (mm)	Male	57	0.63	0.18	0.493
		Female	43	0.60	0.14	
	Point C (mm)	Male	57	1.28	0.51	0.38
		Female	43	1.20	0.44	
	Angulation	Male	57	111.34	5.93	0.112
		Female	43	113.40	6.78	

#, FDI notation; N, Number of samples; SD, Standard deviation; *p*, *p*-value; mm, millimeter.

Table IV. Correlation of Alveolar bone thickness with buccolingual maxillary incisors angulation.

Tooth#	Alveolar bone thickness with buccolingual maxillary incisors angulation	N	R	P
12	Point A (mm)	100	-0.142	0.160
	Point B (mm)	100	-0.396	0.001*
	Point C (mm)	100	0.288	0.004*
11	Point A (mm)	100	-0.185	0.067
	Point B (mm)	100	-0.113	0.264
	Point C (mm)	100	0.275	0.006*
21	Point A (mm)	100	-0.238	0.017*
	Point B (mm)	100	-0.189	0.061
	Point C (mm)	100	0.314	0.002*
22	Point A (mm)	100	0	0.999
	Point B (mm)	100	-0.252	0.012*
	Point C (mm)	100	0.324	0.001*

*Statistical significance (<0.05); R, Pearson Correlation coefficient; N, Number of samples; *p*, *p* value; #, FDI notation; mm, millimeter.

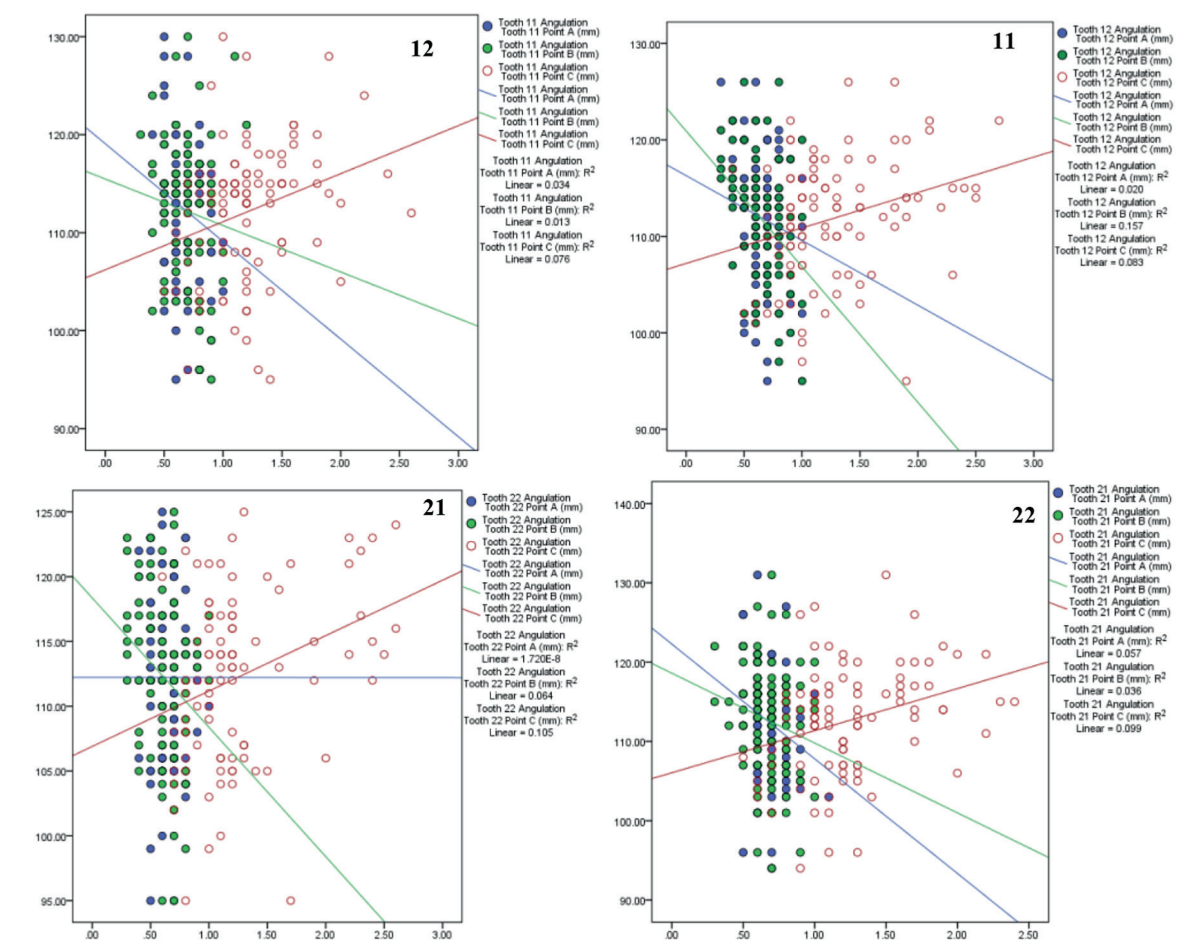

Figure 5. Correlation of Alveolar bone thickness with buccolingual maxillary incisors angulation.

with the maximum bone-to-implant contact at the beginning to confirm the preliminary stability[20]. According to the findings of this study, the thick alveolar bone was observed beyond the middle of the tooth socket; therefore, the initial drill should be positioned beyond the mid-point. This finding supports the previous studies[15,21]. The stability of the implant is also dependent on the angulation of the implant placement. Clinicians should, however, verify that the apex of the implant should not excessively incline towards the palatal surface. Otherwise, the implant would result in an unsatisfactory outcome due to the buccal tilt caused by the pressure of the buccal bone plate which ultimately initiates the marginal gingival recession[22].

The current study measured the angle produced by the maxillary plane and the long axis of the maxillary incisor which play an important role in selecting the implant's size and inclination. In order to achieve the best 3D position of the implant along with the effective rehabilitation, the inclination of the tooth and the angle of the implant should coordinate[11,23].

The labial alveolar bone thickness at the apical level had a moderate positive linear connection with the inclination of the maxillary incisors in this study (point C). This indicates that the buccolingual angulation and labial ABT at the apical area of all four incisors in the maxilla grow in the same direction. This result supports a previous study[24] where a positive correlation has been identified between the ABT and the degree of inclination. These findings imply that in protrusive maxillary incisors, which is prevalent in Asians, doctors should be aware that the labial alveolar bone may be thick, or the palatal bone plate may be thin[25]. This could pose a risk in both surgical and prosthetic procedures involving immediate implant placement. In the present study, the alveolar bone thickness at point A of the left central incisor and point B of lateral incisors had a statistically significant negative connection with buccolingual angulation of teeth. The findings of the current study are consistent with a previous study[26] that found that tooth angulation is negatively correlated with the alveolar bone thickness.

Furthermore, the buccolingual angulation or inclination of the teeth is influenced by genetic and environmental factors. In people with normal occlusion, one previous study[27] showed that the bone width in the apex of upper incisors on the palatal aspect is greater than the labial one. However, another study[28] stated that the inclination of central incisors of the upper jaw determined the alveolar bone thickness. It was shown a greater amount of bony wall at the root of normally inclined upper central incisors rather than lingually inclined[28]. Lee et al[17] reported that in a study done on Korean participants, the labial bone thickness was less than 2 mm at 3 mm and 5 mm below the CEJ at maxillary incisors. This is important to remember when having dental procedures, such as extraction of a tooth or immediate placement of a dental implant in upper anterior teeth.

The most common limitation of conducting the measurements *via* CBCT radiograph is a larger field of view with reduced resolution. However, the resolution of the CBCT may allow for a better evaluation while still exposing the patient to a minimal radiation dose. In addition, the smaller sample size is another limitation of this study. Therefore, further studies with a larger sample size should be recommended.

Conclusions

The present study, which was conducted on maxillary incisors, showed that majority of the teeth had less than 2 mm labial alveolar bone thickness when measured at three points – four mm below from CEJ (point A), midpoint from the labial alveolar-palatal alveolar crest plane and root apex (point B), and root apex of the tooth (point C). Furthermore, it was also concluded that the labial alveolar bone thickness and buccolingual angulation of the maxillary incisors are correlated. These findings are necessary during the treatment planning such as immediate implantation and tooth extraction.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Data Availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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