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Research Article

Maxillary bone characteristics between thick and thin gingival biotypes with dentoalveolar protrusion

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ABSTRACT

Objective: To compare gingival thickness and five alveolar bone characteristics on the labial and palatal sides between thick and thin gingival biotypes in maxillary anterior teeth with dentoalveolar protrusion.
Methods: The prospective study included 40 healthy patients with 240 anterior teeth (33 men and seven women) with skeletal Class I malocclusion and dentoalveolar protrusion. The mean age was 20.5 ± 2.2 years. The thick (n = 108) and thin (n = 132) gingival biotypes were assessed by probe transparency. The gingival thicknesses and five alveolar bone parameters from cone beam computed tomography were measured. The differences between the thick and thin gingival biotype parameters were statistically analyzed.
Results: Gingival thickness and palatal bone gradually increased toward the apical area, whereas the labial bone thickness was almost even. The thick gingival biotype showed thicker gingiva and alveolar bone than in the thin gingival biotype. The thick gingival biotype showed a shorter distance from the alveolar crest to the cementoenamel junction and less palatal cortical bone height than the thin gingival biotype. Cancellous bone was detected only on the palatal side, which started 4 mm (in thick) and 8 mm (in thin) apical to the crestal bone level toward the root apex. In addition, the thick gingival biotype showed significantly greater palatal cancellous bone than the thin gingival biotype ($P < 0.01$).
Conclusion: Patients with anterior dentoalveolar protrusion presented with either thick or thin gingival biotypes. The thick gingival biotype showed more favorable alveolar bone characteristics than the thin gingival biotype as far as orthodontic treatment is concerned.

1. Introduction

Patients frequently seek orthodontic care for protruded upper anterior teeth [1]. For many patients, the maxillary anterior region is their greatest esthetic concern [2]. Therefore, the position and appearance of the maxillary anterior teeth both during smiling and at rest is esthetically important during orthodontic treatment planning [3]. Many patients with maxillary dentoalveolar protrusion present with thin layers of alveolar bone [4]. This condition may be the cause of alveolar bone compromise and gingival recession when unfavorable orthodontic forces are applied [5]. When protruded teeth are retracted bodily, the amount of palatal cancellous bone is important because it allows the root to move favorably so that treatment may be accomplished successfully [6]. However, if anterior tooth movement is not undertaken carefully, uncontrolled tipping may occur [7], allowing the root to tip forward and contact the labial bone, resulting in apical root resorption [8].

A routine clinical examination may not be enough to predict the periodontal changes that will accompany anterior maxillary tooth retraction. Assessment of the patient's gingival biotype is a simple tool to help predict changes that may occur and therefore affect the overall treatment outcome [9]. Gingival biotypes are classified by the gingival thickness into two main types: thick and thin gingival biotypes [10]. It has been previously shown that a patient's gingival biotype can be used to help predict final esthetic results [11]. The difference between gingival biotypes was demonstrated to be associated with different responses of the periodontal

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tissues, which are composed of gingiva and bone, to various oral conditions [12].

The thick gingival biotype is more resistant to recession even when the underlying bone undergoes resorption [13]. However, the thick gingiva may inhibit tooth movement because it is difficult to be remodeled, although no studies have elucidated the actual thickness that slows or prevents tooth movement. For patients with a thin gingival biotype, many studies emphasized the greater risk for gingival recession to occur [11,14,15].

Alveolar bone is composed of cortical and cancellous bone. The cortical bone may serve as a limitation to the envelope of tooth movement due to its high density and low rate of remodeling [16]. Attempting to move teeth into thick cortical bone may cause a delay in tooth movement [17], whereas, moving teeth into the thin cortical bone could increase risk for root resorption [18], or increased bone loss [19]. Cancellous bone serves as a reservoir for the progenitor cells that promote bone remodeling and also provides an area that is favorable for tooth and root movement [16].

There is no previous study that assessed the amount of cortical and cancellous bone present in subjects with different gingival biotypes, especially in those patients presenting with dentoalveolar protrusion. Therefore, this study compared the characteristics of alveolar bone in patients with maxillary dentoalveolar protrusion between those presenting with thick and thin gingival biotypes using cone beam computed tomography (CBCT).

2. Materials and methods

2.1. Patient selection

The study protocol was approved by the Institutional Review Board for human patients (protocol EC6103-10-P-HR) of the Faculty of Dentistry, Prince of Songkla University, and conducted in accordance with the Declaration of Helsinki. Forty patients were recruited from June 2018 to October 2018 at the Faculty of Dentistry, Prince of Songkla University. The patients included 33 men and seven women with a mean age of 20.5 years (range 18–27). The inclusion criteria were as follows: 1) healthy adults aged 18 to 30 years; 2) no periodontal diseases; 3) no significant medical illness related to bone metabolism; 4) dentoalveolar protrusion (upper incisor [UI]- a Nasion (N) point to subspinale (A) point [NA] >8 mm); 5) skeletal Class I (A point, nasion, B point [ANB] = 1–4 degrees); and 6) normodivergent facial pattern (mandibular plane angle [MPA] = 23–35 degrees) [20]. The exclusion criteria were as follows: 1) pregnancy; 2) probing depth >4 mm; 3) history of orthodontic treatment; 4) previous surgery in the upper anterior region; 5) past or present use of drugs known to increase the risk for gingival overgrowth (phenytoin, nifedipine, cyclosporine, amlodipine); and 6) gingival enlargement.

2.2. Probe visibility assessment

Once each participant was informed of the study objectives and relevant information, written consent was obtained, and the clinical data were gathered. The probe transparency method [21] was used to categorize participants into two gingival biotype groups. The thick biotype was defined as when the probe color could not be seen through the soft tissue, and the thin biotype was defined when the probe could be seen through the soft tissue.

2.3. CBCT

Before acquiring the CBCT images, a lip retractor and cotton roll were inserted to retract the tongue and lip. The difference in the density between air and soft tissue was used to determine the location of the extent of gingival tissue on the CBCT.

The maxillary anterior teeth were scanned using CBCT (80 kV, 5 mA, 9.2-second exposure time, 0.125-mm voxel resolution, 80 × 80-mm field of view; Veraviewepocs J Morita MPG, Fushimi-ku, Kyoto, Japan). CBCT data were reconstructed at 0.125-mm increments. The images were evaluated for gingival thickness and five alveolar bone parameters. The thickness and height measurements were in millimeters to the nearest two decimals by i-Dixel One Volume Viewer software (J Morita MPG; Fushimi-ku, Kyoto, Japan).

2.4. Gingival thickness measurements

Each CBCT image was oriented along the tooth long axis of the root and the sagittal plane running transversely through the midpoint of the tooth axis [22]. The vertical levels of the maxillary teeth were measured from the crestal bone level to 2 mm and 4 mm apical to the crestal bone level, as shown in Fig. 1. The gingival thickness was measured from the most outer surface of the gingiva to the cortical bone perpendicular to the tooth long axis on both the labial and palatal sides, as shown in Fig. 2.

2.5. Alveolar bone measurements

The measurements of five parameters included the alveolar bone thickness, cortical bone thickness, cancellous bone thickness, alveolar bone height, and cortical bone height in the same planes as the gingival thickness measurements, in 2-mm increments up to 10 mm, as shown in Fig. 2.

2.5.1. Alveolar bone thickness

Alveolar bone thickness was measured from the outermost surface of the alveolar bone to the innermost surface of the alveolar bone on both the labial and palatal sides, perpendicular to the tooth long axis.

2.5.2. Cortical bone thickness

Cortical bone thickness was measured from the outermost surface of the cortical bone to the innermost surface of the cortical bone on both the labial and palatal sides, perpendicular to the tooth long axis.

2.5.3. Cancellous bone thickness

Cancellous bone thickness was measured from the outermost surface of the lamina dura to the innermost surface of the cortical bone on both the labial and palatal sides, perpendicular to the tooth long axis.

2.5.4. Alveolar bone height

Alveolar bone height was the vertical distance parallel to the tooth axis from the cementoenamel junction (CEJ) to the alveolar bone crest.

2.5.5. Cortical bone height

Cortical bone height was the vertical distance of the cortical bone parallel to the tooth axis from the alveolar bone crest to the interface of the cortical bone and the cancellous bone.

2.6. Statistical analyses

The Shapiro-Wilk test showed that the variables were not normally distributed; therefore, the Mann-Whitney *U* test was used to assess the differences of gingival and bone variables between thick and thin gingival biotypes. All statistical analyses were performed using SPSS version 17 (SPSS, Chicago, IL). The level of significance of all tests was established at 0.05.

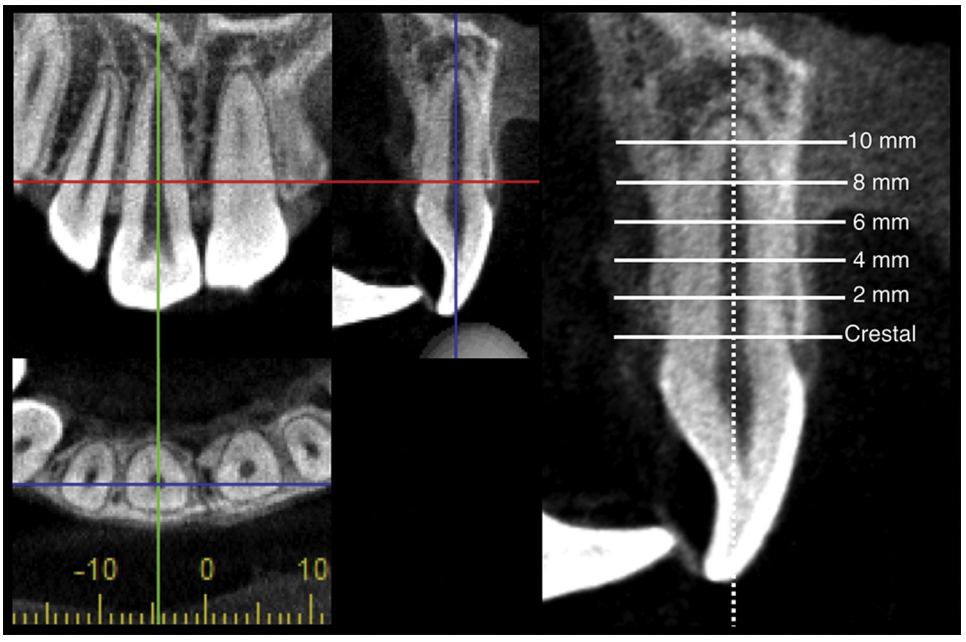

Fig. 1. Tooth orientation, vertical references. Each CBCT image shows the tooth long axis and the sagittal plane running transversely through the midpoint of the long axis. The vertical levels of maxillary teeth were measured from the crestal bone level to 2 mm, 4 mm, 6 mm, 8 mm, and 10 mm apical to the crestal bone level.

2.7. Sample analysis

The six maxillary anterior teeth were analyzed separately according to gingival biotype. The central incisors, lateral incisors, and canines on the right were compared with those on the left. Because there were no statistically significant differences between them, the measurements from both left and right were combined. A comparison of parameters according to tooth types was analyzed with the Kruskal-Wallis test. Because there were no statistically significant differences among the tooth types, all of the anterior teeth were combined into one group for each biotype. The sample sizes of the thick gingival biotype were 108 teeth, and 132 teeth were in the thin gingival biotype. Means and standard deviations of the gingival thickness, alveolar bone thickness, cortical bone thickness, cancellous bone thickness, alveolar bone height, and cortical bone height were calculated and compared between thick and thin gingival biotypes using the Mann-Whitney *U* test.

2.8. Sample size calculation

Before commencement of the study, a power analysis showed a sample size of 240 teeth was sufficient to detect a difference of 0.212 mm in alveolar bone thickness between thick and thin gingival biotypes and provide a power above 80% [23].

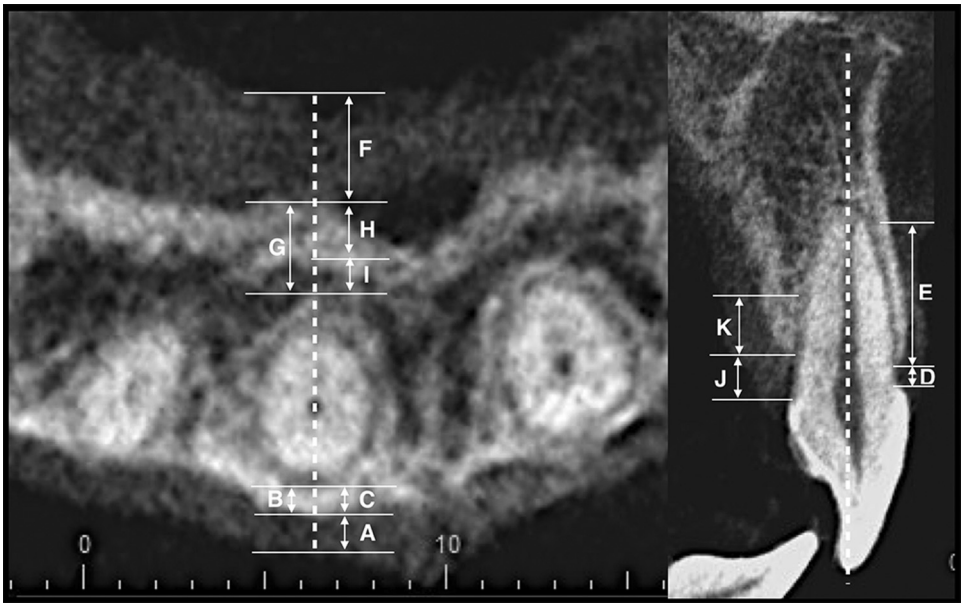

Fig. 2. CBCT measurements. CBCT parameters of (A) to (E) on labial aspect: (A) labial gingival thickness, (B) labial alveolar bone thickness, (C) labial cortical bone thickness, (D) labial alveolar bone height, (E) labial cortical bone height. CBCT parameters of (F) to (K) on palatal aspect: (F) palatal gingival thickness, (G) palatal alveolar bone thickness, (H) palatal cortical bone thickness, (I) palatal cancellous bone thickness, (J) palatal alveolar bone height, (K) palatal cortical bone height.

Table 1
Differences of tooth inclination (UIPP and UI-NA [angles]), and tooth position (UI-NA [distance]) between thick and thin gingival biotypes

	Thick	Thin	Differences (Δ)	Significant difference
UIPP (degree)	127.4 ± 3.1	128.8 ± 2.2	1.4	NS
UI-NA (degree)	31.3 ± 3.7	31.7 ± 3.9	0.4	NS
UI-NA (mm)	8.3 ± 1.0	8.8 ± 1.5	0.5	NS

NS, not significant; PP, palatal plane; UI, upper incisor; NA, Nasion to Point A line

2.9. Quality controls

All measurements were performed by one examiner blinded to the gingival biotypes of the subjects. To determine the intra-examiner measurement reliability of the method, 10 randomly selected samples were remeasured at least 2 weeks after the initial measurements by the same examiner. An independent *t*-test that compared the first and second sets of the measurements showed no significant differences between the two sets ($P < 0.05$) and the intraclass correlation coefficient of 0.81 indicated good reliability.

3. Results

3.1. Descriptive data assessment

Of the total of 240 anterior teeth, 108 teeth were of the thick gingival biotype (18 subjects) and 132 teeth were of the thin gingival biotype group (22 subjects). The initial cephalometric data of the subjects showed a skeletal Class I relationship (ANB = 2.51 ± 1.22 degrees) with normal vertical pattern (MPA = 28.14 ± 4.56 degrees). There were no significant differences in the upper incisor inclinations (i.e., UI to palatal plane [UIPP] angle and UI-NA angle) and upper incisor position (i.e., UI-NA distance) between the two gingival biotypes (Table 1).

3.2. Gingival thickness

The thickness of the labial and palatal gingiva gradually increased toward the apical area in both gingival biotypes (Table 2). The measurements were performed only on attached gingiva. On the labial side, the thicknesses were measured up to 4 mm, because, apical to the 4-mm level, there was alveolar mucosa. However, on the palatal side, the measurements were to the 10 mm level. On the labial side, the thick gingival biotype showed statistically significantly thicker gingiva than the thin gingival biotype ($P < 0.01$). The differences were between 0.23 and 0.33 mm. On the palatal side, the thick gingival biotype showed statistically significantly thicker gingiva at the crestal bone level ($P < 0.03$) and at 2 mm ($P = 0.01$). The differences were 0.48 and 0.52 mm, whereas the remaining levels showed no significant differences.

3.3. Alveolar bone thickness and height

The thicknesses of labial bone were almost equal in both gingival biotypes (Table 3). The thicknesses were 0.41 to 0.54 mm in the thick gingival biotype and 0.32 to 0.46 mm in the thin gingival biotype. The thicknesses of palatal bone gradually increased toward the apical area in both gingival biotypes. On the labial side, the thick gingival biotype showed statistically significantly thicker alveolar bone except at the 10-mm level. The differences were 0.09 to 0.13 mm. On the palatal side, the thick gingival biotype showed statistically significantly thicker alveolar bone than the thin gingival biotype. The differences were 0.75 to 1.74 mm. The distance from the alveolar crest to the CEJ in the thick gingival biotype was significantly less than the thin gingival biotype ($P < 0.01$) on both the labial and palatal sides.

3.4. Cortical bone thickness and height

The thicknesses of labial cortical bone were almost uniform along the tooth from the crestal to apical levels in both gingival biotypes, whereas the thicknesses of palatal bone gradually increased toward the apical area (Table 3). On the labial side, the thick gingival biotype showed significantly thicker cortical bone than the thin gingival biotype except at the 10-mm level. On the palatal side, the thick gingival biotype showed significantly thicker cortical bone than the thin gingival biotype. The differences were 0.29 to 0.82 mm. Although there were no differences in the labial cortical bone height between the two gingival biotypes, the palatal cortical bone height in the thick gingival biotype was found to be significantly more coronal than in the thin gingival biotype ($P < 0.01$).

3.5. Cancellous bone thickness

No cancellous bone was detected in the labial bone at the levels measured in either gingival biotype (Table 3). In the palatal side, there was cancellous bone from 4 mm apical to the crestal bone level toward the root apex in the thick gingival biotype, whereas cancellous bone was observed from 8 mm apical to the crestal bone level in the thin gingival biotype. The amount of palatal cancellous bone in the thick gingival biotype was significantly greater than in the thin gingival biotype at all measured levels ($P < 0.01$).

4. Discussion

Protruded maxillary anterior teeth usually present with thin surrounding alveolar bone that is vulnerable to damage when excessive force is applied [24]. Recognition of a patient's gingival biotype is important, because tooth movement toward the gingiva can lead to gingival recession, especially in the thin gingival biotype [25]. This study was conducted to determine the thicknesses of the maxillary gingiva and alveolar bone in bimaxillary dentoalveolar protrusion. The probe transparency method was selected as the method to identify the gingival biotypes because the method is accurate and reliable for gingival biotype discrimination and simple to apply clinically [26].

Gingival thickness in the thick gingival biotype was significantly thicker than those in the thin gingival biotype. This was consistent with the results of the previous studies [11,27] in which facial gingival dimension in maxillary anterior teeth region was investigated. Even though a significant difference was observed in the current study, the differences were between 0.23 and 0.33 mm, which may be too little to have clinical significance. The thicknesses gradually increased apically from 0.72 to 1.24 mm and from 0.45 to 1.01 mm in the thick and thin gingival biotypes, respectively. Most studies did not report gingival thicknesses on the palatal areas because it is considered irrelevant [28]. Also, on the palatal side, the differences were also small (0.30–0.52 mm), which implied questionable clinical significance.

The labial alveolar bone in the thick gingival biotype was significantly thicker statistically than in the thin biotype, which was similar to a study by Cook et al. [29]; however, the measured thickness in the current study was less. This was most likely because the current study was conducted in protruded teeth and increased inclination may be associated with a reduction in labial alveolar bone as found by Nahm et al. [4]. Furthermore, the difference was small (0.08–0.13 mm) and not likely to have clinical

Table 2
Comparisons of gingival thickness between thick and thin gingival biotypes

	Labial				Palatal			
	Thick	Thin	Δ	Significant difference	Thick	Thin	Δ	Significant difference
Maxillary teeth (n = 240)								
At crestal bone	0.72 ± 0.13	0.45 ± 0.11	0.27	<0.01	2.36 ± 0.26	1.87 ± 0.35	0.48	0.03
2 mm under crestal bone	0.94 ± 0.09	0.61 ± 0.11	0.33	<0.01	2.76 ± 0.21	2.24 ± 0.08	0.52	0.01
4 mm under crestal bone	1.24 ± 0.13	1.01 ± 0.08	0.23	0.01	2.90 ± 0.32	2.55 ± 0.26	0.35	NS
6 mm under crestal bone	–	–	–	–	3.12 ± 0.45	2.82 ± 0.31	0.30	NS
8 mm under crestal bone	–	–	–	–	3.46 ± 0.34	3.14 ± 0.31	0.32	NS
10 mm under crestal bone	–	–	–	–	3.66 ± 0.31	3.22 ± 0.31	0.44	NS

NS, not significant; –, unmeasured data.

significance. The alveolar bone thicknesses of 0.41 to 0.54 mm and 0.32 to 0.46 mm in the thick and thin gingival biotypes, respectively, were considered thin. Fuhrmann [19] found that this thin labial bone plate was an anatomic risk for bone dehiscence when uncontrolled sagittal or vertical movement was introduced.

The level of the labial alveolar bone (CEJ to alveolar crest) in the thick gingival biotype was closer to the CEJ than in the thin gingival biotype, which was in agreement with the findings of Cook et al. [29]. Thin gingival biotype with dentoalveolar protrusion presented more distance from the CEJ to alveolar crest than without dentoalveolar protrusion [25].

The palatal alveolar bone thickness in the thick gingival biotype was also significantly thicker than in the thin gingival biotype. No previous study reported a comparison of this area. The differences between the two gingival biotypes were between 0.75 and 1.74 mm, which could be clinically significant. Thicknesses of 1.12 to 4.28 mm in the thick gingival biotype would not be easily resorbed [13], whereas thicknesses of 0.37 to 0.48 mm in the thin gingival biotype at the crestal bone level and 2 mm apical to the crestal bone level may be of concern because they were quite thin with the risk of resorption if the roots are tipped with excessive force.

The height of the palatal alveolar bone (CEJ to alveolar crest) in the thick gingival biotype was closer to the CEJ than in the thin gingival biotype with a 1.06-mm mean difference. Compared with a normal alveolar bone height [30], this could be considered healthy for both groups.

Labial alveolar bone in both the thick and thin gingival biotypes was only cortical bone and no cancellous bone was present. When pure cortical bone is present on all alveolar plates, only an optimal application of force would be appropriate to create the desired frontal bone resorption.

The palatal alveolar bone in the thick gingival biotype had pure cortical bone from the crestal bone level to 2 mm apical to the crestal bone level, and cancellous bone that started at 4 mm apical to the crestal bone level with a total height of 3.82 mm. However, in the thin gingival biotype, the mean pure cortical bone height was 7.73 mm with cancellous bone that started at 8 mm apical to the crestal bone level. Assuming a root length of 10 mm, that would imply that the thick gingival biotype has a pure cortical bone height/root length ratio of 4/10, whereas the thin gingival biotype has a cortical bone/root length ratio of 8/10. This information may be useful to orthodontists when applying forces to retract anterior teeth. If excessive retraction force is unintentionally applied in the thin gingival biotype, bone loss can occur as high as 8 mm because there is no cancellous bone to allow undermining resorption. Root resorption is also a major concern in orthodontics, especially when the root moves against the cortical bone with excessive force [18]. The thicker cancellous bone is favored for greater root movement.

Table 3
Comparisons of alveolar bone parameters between thick and thin gingival biotypes

Maxillary teeth (n = 240)	Labial				Palatal			
	Thick	Thin	Δ	Significant difference	Thick	Thin	Δ	Significant difference
1. Alveolar bone thickness								
At crestal bone	0.41 ± 0.08	0.32 ± 0.03	0.09	0.02	1.12 ± 0.27	0.37 ± 0.10	0.75	<0.01
2 mm apical to crestal bone	0.43 ± 0.09	0.33 ± 0.03	0.10	0.03	1.30 ± 0.25	0.48 ± 0.13	0.82	<0.01
4 mm apical to crestal bone	0.45 ± 0.09	0.32 ± 0.05	0.13	0.05	2.08 ± 0.11	0.90 ± 0.16	1.18	<0.01
6 mm apical to crestal bone	0.48 ± 0.07	0.37 ± 0.06	0.11	0.04	2.45 ± 0.14	1.25 ± 0.21	1.20	<0.01
8 mm apical to crestal bone	0.51 ± 0.06	0.39 ± 0.07	0.12	<0.01	3.28 ± 0.25	2.06 ± 0.18	1.23	<0.01
10 mm apical to crestal bone	0.54 ± 0.05	0.46 ± 0.12	0.08	NS	4.28 ± 0.39	2.54 ± 0.35	1.74	<0.01
2. Alveolar bone height (CEJ to alveolar crest)	1.69 ± 0.26	3.02 ± 0.57	1.33	<0.01	1.11 ± 0.25	2.17 ± 0.31	1.06	<0.01
3. Cortical bone thickness								
At crestal bone	0.41 ± 0.08	0.32 ± 0.03	0.09	0.02	1.12 ± 0.27	0.37 ± 0.10	0.75	<0.01
2 mm apical to crestal bone	0.43 ± 0.09	0.33 ± 0.03	0.10	0.03	1.30 ± 0.25	0.48 ± 0.13	0.82	<0.01
4 mm apical to crestal bone	0.45 ± 0.09	0.32 ± 0.05	0.13	0.05	1.36 ± 0.10	0.90 ± 0.16	0.46	<0.01
6 mm apical to crestal bone	0.48 ± 0.07	0.37 ± 0.06	0.11	0.04	1.67 ± 0.20	1.25 ± 0.21	0.42	0.02
8 mm apical to crestal bone	0.51 ± 0.06	0.39 ± 0.07	0.12	<0.01	1.62 ± 0.17	1.32 ± 0.09	0.29	0.03
10 mm apical to crestal bone	0.54 ± 0.05	0.46 ± 0.12	0.08	NS	1.89 ± 0.36	1.26 ± 0.2	0.63	0.03
4. Cortical bone height	11.62 ± 1.37	10.39 ± 0.22	1.23	NS	3.82 ± 0.14	7.73 ± 0.16	3.91	<0.01
5. Cancellous bone thickness								
At crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS	0.00 ± 0.00	0.00 ± 0.00	0	NS
2 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS	0.00 ± 0.00	0.00 ± 0.00	0	NS
4 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS	0.72 ± 0.10	0.00 ± 0.00	0.72	<0.01
6 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS	0.79 ± 0.18	0.00 ± 0.00	0.79	<0.01
8 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS	1.67 ± 0.34	0.73 ± 0.16	0.94	<0.01
10 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS	2.39 ± 0.39	1.28 ± 0.21	1.11	<0.01

CEJ, cementoenamel junction; NS, not significant.

Therefore, patients with thick gingival biotypes are more likely to have thicker cancellous bone, thus providing more space to move the roots as far as 2.39 mm at 10 mm apical to the crestal bone level, whereas movement of only 1.28 mm would be possible in the thin gingival biotype.

5. Conclusions

- Both thick and thin gingival biotypes can be found in patients with anterior dentoalveolar protrusion.
- Patients with thick gingival biotype showed thicker alveolar, cortical, and cancellous bone than in the thin gingival biotype.
- Only cortical bone was found on the labial side in both gingival biotypes, whereas palatal cancellous bone was initially found apical to 4 mm in the thick gingival biotype and apical to 8 mm in the thin gingival biotype.
- A shorter distance from the CEJ to the alveolar crest and a shorter palatal cortical bone height was observed in the thick gingival biotype than in the thin gingival biotype.

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