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The gingival biotype: measurement of periodontal tissue dimensions in esthetic zone using a non-invasive digital method

비침습적 디지털 방식을 이용한 건강한 치주조직의 계측 및 평가

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김 윤 정

Abstract

The gingival biotype: measurement of periodontal tissue dimensions in esthetic zone using a non-invasive digital method

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Objectives. The aim of this study was to measure and determine the relationship between labial alveolar bone and gingival thicknesses using a non-invasive and relatively accurate digital registration method**.** In addition, the correlation of different morphometric parameters with the thickness of the labial gingiva and alveolar bone at different apico-coronal levels was evaluated.

Methods. In 20 periodontally healthy subjects, cone-beam computed tomography (CB-CT) images and intraoral scanned files were obtained. Measurements of labial alveolar bone and gingival thickness at the central incisors, lateral incisors, and canines were performed at 0–5 mm points from the alveolar crest on the superimposed images. Clinical parameters including the crown width/crown length ratio (CW/CL), gingival width (GW), gingival scallop (SC), and transparency of the periodontal probe through the gingival sulcus (TRAN) were examined.

Results. The mean labial alveolar bone thicknesses at the central incisors, lateral incisors, and canines were 0.86, 0.83, and 0.9 mm, respectively. Likewise, the mean gingival thicknesses at the central incisors, lateral incisors, and canines were 0.92, 0.83, and 0.81 mm, respectively. Significant differences in gingival thickness were observed at the alveolar crest level (G0) between the central incisors and the canines ($p=0.001$), and between the central incisors and the lateral incisors ($p=0.001$). At the G1 level (gingival thickness at 1 mm inferior to the alveolar crest), there was also a difference between the central incisors and the canines ($p=0.002$), and between the central incisors and the lateral incisors ($p=0.004$). Gingival thickness at the alveolar crest level was positively correlated with the thickness of the alveolar bone plate ($p<0.05$). The correlation analyses revealed no significant correlation between the clinical parameters and the hard and soft tissue thicknesses.

Conclusions. Despite the morphologic variations of the periodontium, the gingival and labial alveolar bone thicknesses of the anterior maxillary teeth were found to be relatively thin (<1 mm) overall. An analysis of the mean thickness at each level showed that gingival thickness tended to increase and that alveolar bone thickness tended to decrease toward the root apex. With respect to the tooth types, a significant difference in gingival thickness at the alveolar crest level was observed. The gingival thickness at the alveolar crest level also revealed a positive correlation with labial alveolar bone thickness, although this correlation at identical depth levels was not significant. However, the measurement of gingival thickness at, or under the alveolar crest level, was not associated with the clinical parameters of the gingival features, such as the crown form and the gingival scallop, or the keratinized gingival width. Therefore, it is recommended that, in future studies, accurate measuring methods of the supracrestal gingival area should be developed, and the predictive potential of clinical parameters on tissue thickness should be verified.

Keywords: Cone-Beam Computed Tomography; Gingiva; Maxilla; Computer-assisted radiographic image interpretation

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Contents

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1. Introduction

The clinical appearance of periodontal tissues differs between individuals [1]. This variation in morphology has been termed as the gingival biotype [2] and it was postulated that the gingival anatomy reflects the underlying bone architecture [3]. In 1977, Weisgold introduced the terms “thick-flat” and “thin-scalloped” gingival biotype [2]. The “thick-flat” biotype is described as a prognostic factor of esthetical implant outcomes [4], and the thickness of gingiva has been reported to influence the result of root coverage surgery [5]. The so-called “thin-scalloped” gingiva is associated with a higher risk of gingival recession after immediate implant placement [6], and poorer healing of soft tissue after crown lengthening surgery [7]. These results may be explained by a few studies that reported a weak to moderate correlation between the thickness of the underlying bone and the thickness of gingiva that covers it [8, 9]. However, owing to the lack of standardized techniques for measuring hard and soft tissue thickness at identical positions, there have been relatively few studies in this area. The commonly used tools to measure the thickness of alveolar bone are calipers [10] and cone-beam computed tomography (CB-CT) [11, 12]. In studies using CB-CT scans, quantified variations have been reported between the patients and the tooth types.

With respect to soft tissue thickness assessment, several methods have been proposed. The simplest method in clinical area is based on the visibility of the periodontal probe outline through the soft tissue while probing the buccal gingival sulcus [13-15]. If the outline of the probe can be detected visually, the thickness is classified as a thin biotype; if not, it would be classified as a thick biotype. Another transgingival probing method utilizes endodontic needles and has been suggested as a method for measuring soft tissue thickness [16-18].

However, this method is invasive and requires the rounding of obtained values. Alternatively, the use of ultrasonic devices have been proposed to measure gingival thickness [19]. Although such ultrasonic methods are non-invasive and quite reliable, their ability to accurately determine the thickness of a specific site is limited. The reconstructed images of CB-CT scans, which have been widely used as a detecting method for hard tissue dimensions, provided relatively low resolution for measuring soft tissue dimensions. Recently, digital scanning and assessment methods have been applied to measure the volume of periodontal tissues. This approach has been successfully used in clinical studies to assess volumetric changes, in conjunction with linear measurements of soft and hard tissues [20]. Although studies have demonstrated the precision and reliability of this non-invasive method [21], the possibility of introducing errors with the impression-model fabrication procedure has also been described. There have been several reports measuring soft tissue dimensions as well as hard tissue thicknesses using CB-CT images[8, 22]; however, more accurate outlines could be obtained through digital scanning files with substantially higher resolutions.

The limitations associated with the aforementioned methods for studying the relationship between soft and hard tissue thickness, such as their invasive nature and limited accuracy, warrant further studies in this area, in addition to the development of superior methodologies. Based on the direct intraoral scanning and superimposing method, we can limit the incidence of errors that occurs during the impression procedure.

Studies have also shown an association of clinical parameters, such as tooth crown shape and the height of the gingival scallop, with gingival thickness.[9, 23, 24] However, these results were not consistent and the relationships should be verified. Hence, the objectives of this study were as follows:

- To measure the labial alveolar bone and gingival thicknesses using a non-invasive digital registration method.
- To compare the labial alveolar bone and gingival thicknesses at each identical depth as well as clinical parameters among the three tooth types (central incisors, lateral incisors, and canines).
- To assess the relationship between labial gingival thickness and underlying alveolar bone thickness.
- To evaluate the correlations among the crown form, width of the keratinized gingiva, height of the gingival scallop, and the visibility of the periodontal probe outline through the sulcus with the gingival thickness and the labial alveolar bone thickness at different apico-coronal levels.

2. Materials and Methods

2.1. Patient selection

Twenty-one patients (20-65 years old) with intact maxillary anterior teeth (#13, 12, 11, 21, 22, 23), who did not show signs of marginal or periapical bone loss, were included in this study. They had visited the Department of Periodontology, Seoul National University, Gwanak Dental Hospital, for annual scaling, between October 2015 and June 2016. The following exclusion criteria were applied.

1) Pregnant female volunteers.

2) Patients with fixed partial dentures or orthodontic appliances.

3) Patients with systemic disease or those who were taking medication that may have affected the thickness of the soft tissue, such as calcium channel blockers or immunosuppressive drugs.

4) Patients showing signs of either periodontal disease as defined by a periodontal probing depth >3 mm or gingival recession.

Following the exclusion of one patient due to the poor quality of the radiographic images, 20 participants (10 male patients and 10 female patients) were included in this study. Each participant provided signed informed consent after being presented with a thorough explanation of the nature, risks, and benefits of our clinical investigation. The study protocol was approved by the Ethics Committee of Seoul National University, and the investigation was carried out in the Department of Periodontology, Seoul National University Gwanak Dental Hospital (EC/ S-D20150029).

2.2. Stereolithography image acquisition and data matching

Patients underwent scaling, followed by attachment of three radiopaque, cylindrical fiducial markers, measuring 2 mm in diameter by 2mm in height, to both maxillary second premolars and one incisor (Figure 1-A). Following a CB-CT (CS9300; Carestream, NewYork, US) scan of the maxilla, the maxillary arch of each participant was optically scanned with a 3D scanner (Trios; 3Shape, Copenhagen, Denmark). The three fiducial markers were used as a reference to match the scanned STL (stereolithography) files with the CB-CT images. Image reconstruction for visual analysis was performed using Platon software (Ezplant, Seoul, Korea) to automatically superimpose the images using a series of mathematical algorithms (Figure 1-B).

2.3. Image analysis and measurements

First, one of the two corresponding teeth in the first and second quadrants was randomly selected from the superimposed images. A longitudinal slice that divided the crown mesio-distally into two equal parts was then selected. A line coinciding with the axis of the tooth was subsequently drawn in the transversal images of the sections.

The measurements of the labial alveolar bone and the thickness of gingiva that covers it were performed to the nearest 0.01 mm, 1–5 mm from the alveolar crest (A) at the mid-buccal aspect of each tooth and perpendicular to the axis of the tooth (B). The gingival thickness in the alveolar crest line (G0) was also determined (Figure 2). All of the values were measured by the same clinician. Duplicate registration was performed for intra-examiner reliability.

2.4. Clinical examination and photographic analysis

Intraoral examinations were performed on the randomly selected index tooth (central incisor, lateral incisor, and the canine), in addition to the direct measurement and analysis of the clinical photograph of the region of the index tooth. The measuring was carried out according to the method of Stein (2013)[9]. All measurements were performed by one clinician. The following assessments were made directly on the patients using a periodontal probe (CPU 15 UNC; Hu-Friedy, Chicago, IL, USA):

• The width of the keratinized gingiva (GW) was measured from the mid-buccal point of the marginal gingiva to the mucogingival junction, to the nearest 0.5 mm.

• The transparency of the periodontal probe outline through the gingival sulcus (TRAN) was also determined after the insertion of the probe into the sulcus on the mid-buccal position. The visibility of the periodontal probe outline was recorded as a categorical variable (0 = probe visible; 1 = probe not visible).

On the clinical photograph (Figure 3), the following parameters were recorded using image processing software (Image J 1.51f; Microsoft Java, USA):

• The crown width/crown length ratio (CW/CL) was measured according to the method of Olsson & Lindhe (1991)[1]. The crown length was measured from the incisal edge to the margin of the labial gingiva. For the assessment of the width, the crown length was divided into three equal portions. The distance between the approximal crown surfaces at the border between the middle and the cervical portion was recorded.

• The height of the gingival scallop (SC) was detected as the widest distance between the line connecting the peaks of the two adjacent inter-dental papillae and the most apical point of the buccal marginal gingiva.

2.5. Statistical analysis

Data were analyzed using the SPSS statistical software package (Version 19.0; SPSS Inc., Chicago, IL, USA). The Friedman test was used to compare the thicknesses of labial alveolar bone and gingiva at each depth between the three tooth types (central incisors, lateral incisors, and the canines). Statistical significance was defined as a P-value less than 0.05. If a significant difference was observed, the tooth types were compared in a two-by-two manner using post-hoc Wilcoxon matched-pairs signed rank tests. For the-post hoc test, statistical significance was defined as a P-value less than 0.017 according to the Bonferroni's correction. The Spearman's correlation coefficient was calculated to assess the correlation between the labial alveolar bone thickness and the gingival thickness according to the tooth type. With the corresponding 95% confidence interval, the correlativity of the following parameters were calculated: CW/CL, SC and GW with the thickness of the gingiva at different apico-coronal levels (G0–G5), as well as the thickness of the labial alveolar bone plate at different apico-coronal levels (A1-A5). The relationship between the TRAN and the thickness measurements was evaluated with the point-biserial correlation coefficient. The comparisons of clinical parameters among the tooth types were observed using the Friedman test and the post-hoc Wilcoxon signed rank test.

3. Results

3.1. Mean thickness of hard and soft tissues at each level

The labial alveolar bone and gingival thickness were measured at 1–5 mm from the alveolar bone crest at the mid-buccal aspect of each tooth, perpendicular to the tooth axis (Figure 2). The mean value at each level showed a tendency for the gingival thickness to increase and for the bone thickness to decrease toward the root apex (Figure 4). The mean labial bone thicknesses at the central incisors, lateral incisors, and canines were 0.86, 0.83, and 0.9 mm, respectively. Likewise, the mean gingival thicknesses at the central incisors, lateral incisors, and canines were 0.92, 0.83, and 0.81 mm, respectively.

3.2. Mean values of clinical measurements

Table 1 shows the descriptive data of the clinical and radiographic measurements. The specimens were described on the basis of their crown forms, which ranged from a tapered long form with a very low CW/CL to a squared short shape with a maximum CW/CL. The average CW/CL values were 0.76, 0.71, and 0.71 at the central incisors, lateral incisors, and canines, respectively. The mean SC values for the central incisors, lateral incisors, and the canines were 4.37, 4.05, and 4.62 mm, respectively, whereas the mean values for GW were 5.15, 4.95, and 4.90 mm, respectively. The insertion of the periodontal probe at the mid-buccal aspect of the sulcus was visible in 40% of subjects at the central incisors, 70% at the lateral incisors, and 75% at the canines.

3.3 Comparison of labial alveolar bone and gingival thickness with respect to tooth type

Based on the results of the Friedman test, there was a significant difference among the tooth types for G0 (p=0.004), G1 (gingival thickness at 1 mm inferior to the alveolar crest) (p=0.025), and A5 (labial bone thickness at 5 mm inferior to the alveolar crest) (p=0.025). The post-hoc Wilcoxon signed-rank tests indicated a significant difference in gingival thickness at the G0 between the central incisors and the canines (p=0.001), and between the central incisors and the lateral incisors (p=0.001). At the G1 level, there was also a difference between the central incisors and the canines (p=0.002), and between the central incisors and the lateral incisors (p=0.004). At the A5 level, there were no significant differences in two-by-two comparisons (p>0.017). (Figure 5)

3.4. Relationship between labial bone and gingival thicknesses

The results of the Spearman's correlation tests are shown in Table 2. At each identical level, no correlation was evident between the labial bone thickness and the gingival thickness according to the tooth type. However, gingival thickness at the G0 was positively correlated with the thickness of the labial alveolar bone plate. The central incisors revealed a strong correlation between A1 and A2 (labial alveolar bone thickness at 1 and 2 mm, respectively, inferior to the alveolar crest) with the thickness of the gingiva at the G0, whereas G0 and labial bone thickness at every level were positively correlated at the lateral incisors and canines.

3.5. Comparison of clinical parameters with respect to tooth type

There was a significant difference among the tooth types for CW/CL (p=0.022), SC (p=0.004), and TRAN (p=0.020) according to the results of

Friedman test. The post-hoc Wilcoxon tests indicated a significant difference for CW/CL between the central incisors and lateral incisors (p=0.015). The SC values revealed significant differences between the lateral incisors and canines (p=0.000). Lastly, there was a difference between the central incisors and lateral incisors for TRAN (p=0.014) (Table 1, Figure 5).

3.6. Correlation between clinical and radiographic measurements

The correlation analyses revealed no significant correlation between the clinical parameters and the hard and soft tissue thicknesses (Table 3). Additionally, TRAN was positively correlated with G0 at the central incisors and with A1 at the lateral incisors. Furthermore, GW and G0 were most correlated at the canines. For SC, a weak correlation with G1 was detected at the lateral incisors. A weak correlation was also detected for CW/CL with G5 at the canines. The correlations between the remaining parameters were not statistically significant ($p>0.05$).

4. Discussion

The accurate knowledge about the dimensions of soft and hard tissue is important because of the influence on the outcome of periodontal and restorative treatments, particularly in esthetically critical areas. Therefore, maxillary anterior regions were commonly analyzed to present reliable guidelines for the identification of critical cases with thin gingival and/or alveolar bone thicknesses, which might be associated with compromised treatment outcomes [8, 18, 22, 25]. Until now, various parameters have been used to express the gingival thickness. However, the results have been controversial and the delineation between thick and thin biotypes remains imprecise. One such reason accounting for this lack of definition may be attributable to the tendency of clinicians to assess gingival thickness at different vertical levels. The gingival thicknesses measured at different apico-coronal levels (G0–G5) showed different results in this study. Therefore, the results of the previous studies were hardly comparable. Another reason may be attributable to the method of measuring the soft tissue thickness. Manual assessment using calipers[26], endodontic depth markers[18], or ultrasonic instruments [19] have limited accuracy. In contrast, this study describes the novel technique of utilizing superimposed images of CB-CT and optically scanned files, which consistently produced images that allowed for the measurement of the soft and hard tissue dimensions at identical levels. We used the radiopaque marker attachment technique to improve the accuracy of image matching. With this simple and non-invasive technique, it was possible to reconstruct the precise para-axial images of the teeth, including those of the labial alveolar bone and the gingival contour. Compared with recent studies[8, 19, 20], this method reduced the incidence of errors often associated with impression procedures or the relatively low resolution of CB-CT images and with the use of bulky ultrasonic instruments. In addition, the method described in this study was also able to measure the bone and gingival thicknesses at identical levels and at various depths.

Our measurements for labial alveolar bone thickness at the central incisors, lateral incisors, and canines were 0.86, 0.83, and 0.9 mm, respectively. Overall, the percentage of sites with a thin labial wall (<1 mm) was significantly high: 77% at the central incisors, 71% at the lateral incisors, and 63% at the canines. Several studies have measured bone thickness using CB-CT. For example, Younes et al. (2016) reported the mean values of bone thickness of 1.07, 1.16, and 0.98 mm at the central incisors, lateral incisors and the canines, respectively[19]. In other studies, the corresponding labial bone thickness of the maxillary frontal teeth was relatively thin[12]. One possible explanation accounting for the relatively thin bone width evident in our study was the race-specific factors of bony architecture[19]. Consistent with this possibility, a previous study conducted in Korea reported that the labial bone was extremely thin in this population[11]. The observed discrepancy could also be the result of a difference in CB-CT settings or due to the occurrence of software inaccuracies during the measurement of bone thickness. In the present study, a thick labial bone wall (≥2 mm) was not identified, which was consistent with the findings of Younes et al. (2016) and Nowzari et al. (2012) [19, 27]. As most tooth sites in the anterior maxilla have a thin facial bone wall, the incidence of marked dimensional diminution may be noted following tooth extraction.

In addition to labial alveolar bone thickness, the mean values for gingival thickness at the central incisors, lateral incisors, and canines were measured at 0.92, 0.83, and 0.81 mm, respectively. The results revealed thicknesses that were thinner [18] or similar [22, 25] to the values reported in the literature. Interestingly, the mean thickness at each depth level exhibited similar trends at the central incisors, lateral incisors, and canines. Toward the root apex, the mean value of gingival thickness increased, while that of bone thickness decreased.

We also examined the relationship between labial alveolar bone and soft tissue thicknesses. To predict the outcomes of the periodontal treatments for detecting only the gingival thicknesses, it could be important to investigate the correlation between soft and hard tissue thicknesses. A perfect match between the hard and soft tissue registration areas is necessary for performing such an analysis; this was facilitated in this study using a digital superimposition method. However, this approach did not reveal a significant correlation between hard and soft tissue thicknesses at any identical depth level, which contrasted with previous findings. For instance, Stein et al. (2013) performed a comparative study of 60 individuals and described a positive correlation between labial bone and gingival thickness[9]. However, in their comparison, the depth level was not standardized at an identical line. Instead, the gingival thickness was evaluated at the supracrestal level, while bone thickness was measured under the alveolar crest. Conversely, in an in vivo study of 90 maxillary teeth in 15 patients, La Rocca et al. (2012) [18]observed no significant correlation between the results of the CB-CT scans and those that were acquired with transgingival probing. In addition, their study did not perform the comparison at identical levels. Therefore, the correlation between the gingival thicknesses at all levels and the thickness of the labial alveolar bone was calculated to compare and contrast with previous studies. Remarkably, a significant relationship was evident between the gingival thickness at the alveolar crest level (G0) and the bone thicknesses at all levels, particularly at the lateral incisors and the canines. This observation expands upon the results of previous studies, which recognized that a moderate correlation between the supracrestal gingival thickness and the alveolar bone thickness was evident. Nikiforidou et al. (2016) also reported a strong positive correlation between gingival thicknesses at the level of the CEJ with labial bone thicknesses[22]. The lack of accuracy in measuring gingival thickness under the mucogingival junction due to mobility of the gingiva may also lead to this result.

The comparison of labial alveolar bone thicknesses among the tooth types in the maxillary anterior region has been performed in a few studies[12, 19]. This comparison was conducted because of the differences in both tooth angulation and the convexity of root shapes between central incisors, lateral incisors, and canines. However, the results were not revealed in detail until now. In several studies, labial gingival thicknesses showed a decreasing tendency from central incisor to lateral incisor and canine as well as the results of this study [19, 25]. We observed a significant difference in the thickness at G0, G1, and A5. Specifically, the proximity to the alveolar crest level (G0 and G1) was associated with a significant difference in gingival thickness between the central incisors and the lateral incisors, as well as canines, in this study. According to the clinical parameters, CW/CL, SC, and TRAN appeared to have a significant difference among tooth types. Differences in clinical parameters between tooth types may be influenced by differences in gingival thickness near the alveolar crest.

However, the present investigation found no significant correlation between clinical parameters and thickness. De Rouck et al. (2009) observed that the gingival biotypes were not necessarily associated with the height of scallop[15]. Therefore, the gingival scallop cannot be an indicator of gingival biotype. The visibility of the periodontal probe outline has not always correlated with gingival thickness measurements[8, 28]. Studies that do show evidence of this correlation indicate that the visibility of the probe was related to the thickness of the gingiva at the supracrestal level[15, 26], specifically 2-mm apical from the free gingival margin[14] or 1-mm coronal to the gingival pocket within free and keratinized gingiva[29]. In this study, only the gingival thickness at the crestal level (G0) and TRAN (transparency of the periodontal probe) were statistically correlated at the central incisors. In a comparison between the central and lateral incisors, we also observed significant differences in TRAN according to the differences in labial gingival thicknesses. These results partially support the usefulness of TRAN as a predictor of labial gingival thickness limited to the supracrestal level. For G0, the correlation was also strong with gingival width (GW) at the canines. Several previous studies found positive associations between labial bone thickness and keratinized tissue [18, 23, 24]. However, only partial data for the correlation between labial gingival thickness and the width of keratinized tissue were reported[15, 23]. Cook et al (2011) showed no relationship between biotype and tooth height-to-width ratio [23]. This study observed differences in crown width/crown length ratio (CW/CL) between central and lateral incisors, but no significant correlations between crown shape and gingival thickness were found.

Overall, clinical parameters were inappropriate for the evaluation of gingival thickness in this study. Therefore, the classification of periodontal biotype on the basis of measurements such as crown form and gingival scallop should be made with caution. The potential limitations of this study include a small sample size and lack of measurements at the gingival margin level. Measurements of gingival thickness below the alveolar crest level could not be correlated with the clinical parameters of CW/CL, height of gingival scallop (SC), and TRAN, which were acquired from gingival features around the gingival margin above the alveolar crest level. In addition, the buccolingual tooth position and the axis of anterior teeth could influence labial gingival features, despite the exclusion of subjects with gross misalignment of dentition.

5. Conclusions

Despite morphologic variation in the periodontium, the gingival and labial alveolar bone thickness of the anterior maxillary teeth was found to be relatively thin (<1 mm) overall. An analysis at each level showed that mean gingival thickness tended to increase and that bone thickness tended to decrease toward the root apex. With respect to tooth types, a significant difference in gingival thickness at the alveolar crest level was observed. Gingival thickness at the alveolar crest level also revealed a positive correlation with labial alveolar bone thickness, although this correlation at identical depth levels was not significant. However, the measurement of gingival thickness at or below the alveolar crest level was not correlated with the clinical parameters of gingival features, such as the crown form and gingival scallop, or the keratinized gingival width.

Therefore, gingival biotype identification by assessment of clinical features is not sufficiently reliable and objective. Accurate measurement of labial gingival thickness can be a superior indicator for evaluation of gingival biotype, which determines the outcome of periodontal treatment. In future studies, accurate measurement methods should be developed for the supracrestal gingival area, and the predictive value of clinical parameters for tissue thickness should be verified.

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Table and Figures

Table 1. Clinical and radiographic measurements

	Central incisor	Lateral incisor	Canine
Crown width/crown length ratio (CW/CL)	0.76±0.07	0.71±0.08	0.71±0.08
Height of gingival scallop (SC) (mm)	4.37±0.55	4.05±0.46	4.62±0.65
Gingival width (GW) (mm)	5.15±0.90	4.95±0.79	4.90±0.90
Transparency of the periodontal probe (TRAN)	40%	70%	75%
Gingival thickness (mm)			
G0	1.58±0.32	1.30±0.24	1.32±0.26
G1	0.76±0.16	0.61±0.19	0.64±0.15
G2	0.72 ±0.12	0.63±0.19	0.69±0.27
G3	0.75 ±0.16	0.70±0.21	0.68±0.20
G4	0.81±0.21	0.80±0.27	0.73±0.24
G5	0.91±0.26	0.94±0.29	0.84±0.22
Alveolar bone plate thickness (mm)			
A1	0.89 ±0.19	0.90±0.21	0.93±0.24
A2	0.93 ±0.20	0.96±0.31	0.98±0.28
A3	0.89 ±0.19	0.87±0.33	0.94±0.28
A4	0.83±0.18	0.77±0.33	0.87±0.26
A5	0.78±0.18	0.66±0.31	0.81±0.25

Mean±SD or number(%)

G0, gingival thickness at the alveolar crest line; G1-5, gingival thickness at 1-5mm inferior to the alveolar crest; A1-5, alveolar bone thickness at 1-5mm inferior to the alveolar crest.

*Statistically significant differences between groups, P<0.017

Table 2. Spearman's correlation between labial bone and soft tissue thickness

(A) Central incisor

		G0	G1	G2	G3	G4	G5
A1	Correlation coefficients	.467*	.033	.163	.308	.174	-.069
	P-value	.038	.890	.491	.186	.462	.773
A2		.514*	.104	.166	.241	.091	-.142
		.020	.664	.483	.305	.704	.549
A3		.391	.038	.132	.215	.112	-.088
		.088	.875	.580	.363	.639	.713
A4		.403	.098	.168	.206	.124	-.037
		.078	.682	.479	.383	.603	.876
A5		.273	.064	.149	.280	.280	.063
		.245	.787	.532	.231	.233	.793

(B) Lateral incisor

		G0	G1	G2	G3	G4	G5
A1	Correlation coefficients	.597*	.022	-.155	-.213	.078	.096
	P-value	.005	.927	.514	.366	.744	.687
A2		.534*	-.043	-.266	-.310	-.031	-.083
		.015	.856	.257	.184	.896	.727
A3		.508*	.099	-.120	-.162	.006	-.168
		.022	.677	.614	.494	.980	.479
A4		.483*	.096	-.131	-.231	-.119	-.308
		.031	.687	.582	.327	.617	.187
A5		.528*	.332	.110	-.022	-.006	-.224
		.017	.153	.643	.927	.980	.341

(C) Canine

		G0	G1	G2	G3	G4	G5
A1	Correlation coefficients	.658*	-.089	-.198	-.068	.141	-.147
	P-value	.002	.710	.402	.777	.552	.536
A2		.581*	.000	-.115	-.090	.094	-.155
		.007	.999	.628	.707	.694	.513
A3		.540*	.031	-.141	-.141	.061	-.189
		.014	.898	.552	.553	.797	.425
A4		.526*	.079	-.100	-.104	.077	-.183
		.017	.742	.676	.661	.747	.440
A5		.514*	.154	-.050	-.047	.123	-.160
		.021	.517	.835	.845	.606	.500

G0, gingival thickness at the alveolar crest line; G1-5, gingival thickness at 1-5mm inferior to the alveolar crest; A1-5, alveolar bone thickness at 1-5mm inferior to the alveolar crest.

*Statistically significant (P<0.05)

Table 3. Spearman's correlation between CW/CL, gingival scallop, width of keratinized gingiva and probe transparency with gingival and alveolar bone thicknesses

(A) Central incisor

		GO	G1	A1	G2	A2	G3	A3	G4	A4	G5	A5
CWCL	Correlation coefficients	-.078	-.349	.191	-.263	.069	-.169	.097	-.037	.032	-.165	.010
	P-value	.745	.132	.419	.262	.772	.476	.683	.876	.892	.487	.966
SC		-.019	.156	.141	.186	.158	.389	.140	.296	.125	.176	.310
		.936	.511	.552	.433	.506	.090	.556	.206	.598	.458	.184
GW		.081	.167	-.189	.221	-.044	-.203	.046	-.316	.089	-.309	.042
		.735	.482	.424	.350	.853	.391	.846	.175	.708	.185	.862
TRAN		.505*	.319	.142	.266	.230	-.106	.133	-.284	.186	-.195	-.027
		.023	.171	.551	.257	.328	.655	.577	.225	.432	.410	.911

(B) Lateral incisor

		GO	G1	A1	G2	A2	G3	A3	G4	A4	G5	A5
CWCL	Correlation coefficients	.029	.068	.226	.184	.170	.083	.211	.105	.245	.022	.145
	P-value	.902	.774	.338	.438	.474	.728	.371	.658	.297	.927	.541
SC		.229	.473*	-.031	.397	-.114	.338	-.025	.157	.150	.085	.316
		.332	.035	.895	.083	.632	.145	.915	.508	.527	.721	.175
GW		.399	.199	.051	.126	.015	.058	.061	-.043	.021	-.007	.043
		.081	.399	.831	.597	.949	.808	.798	.857	.930	.976	.858
TRAN		.341	.057	.455*	.047	.303	.028	.284	.237	.114	.350	.133
		.141	.812	.044	.843	.194	.905	.225	.315	.633	.130	.577

(C) Canine

		GO	G1	A1	G2	A2	G3	A3	G4	A4	G5	A5
CWCL	Correlation coefficients	-.023	-.239	.069	-.062	.046	-.243	.054	-.225	.027	-.456*	-.084
	P-value	.925	.309	.772	.796	.847	.303	.823	.340	.910	.043	.724
SC		-.128	-.116	.210	.032	.070	.325	.092	.385	.044	.420	.051
		.589	.627	.374	.894	.769	.163	.699	.093	.854	.066	.832
GW		.563*	.392	.212	-.101	.249	-.247	.292	-.270	.309	-.418	.332
		.010	.088	.369	.672	.289	.294	.212	.250	.185	.067	.153
TRAN		.251	.422	.000	-.010	.100	-.060	.090	-.200	.090	-.010	.080
		.286	.064	1.000	.967	.674	.801	.705	.397	.705	.967	.737

*Statistically significant (P<0.05)

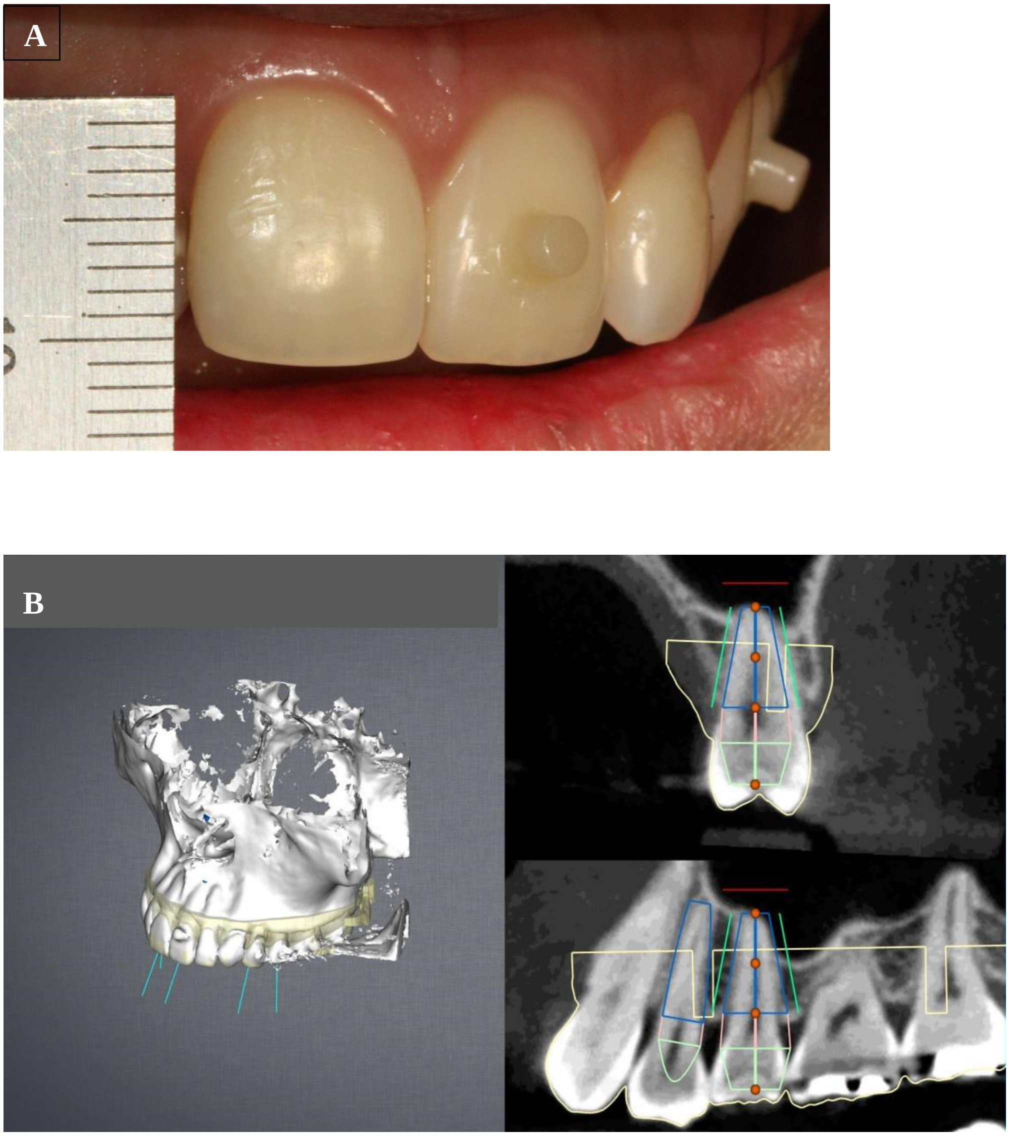


Figure 1. Three radiopaque, cylindrical fiducial markers, measuring 2 mm in diameter by 2 mm in height, were attached to both maxillary premolars and one incisor (A). Image reconstruction for visual analysis was performed using Platon software (Ezplant, Seoul, Korea) to automatically superimpose the images (B).

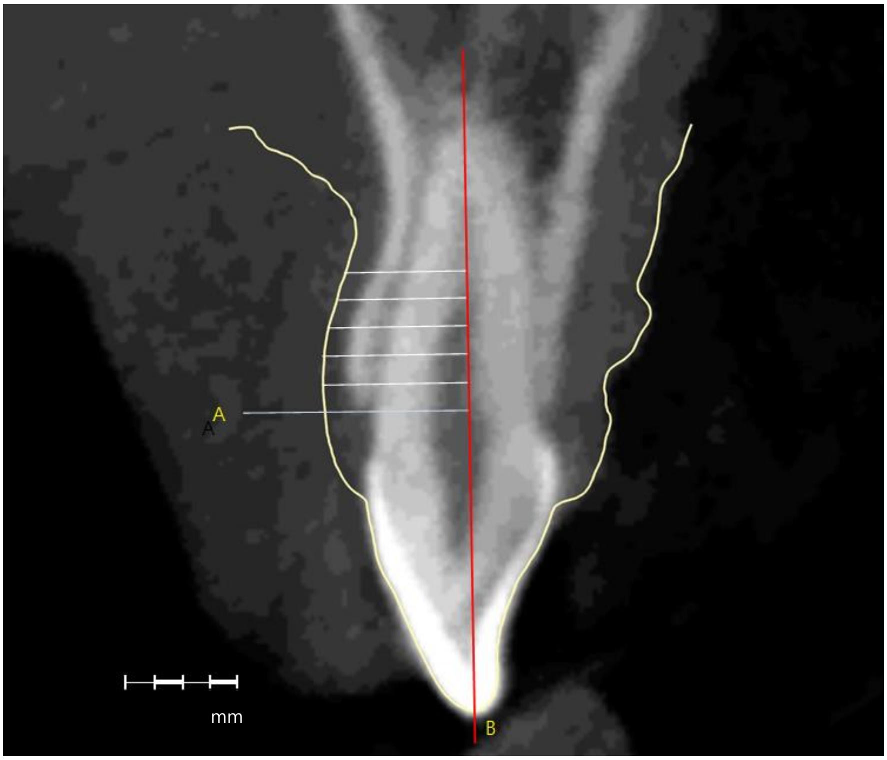


Figure 2. Para-axial slice at the mid-buccal aspect of the lateral incisor. Gingival outline obtained from a scanned file is marked as a yellow line. Thickness measurements at 1-5 mm from the alveolar crest (A), and perpendicular to the root axis (B).

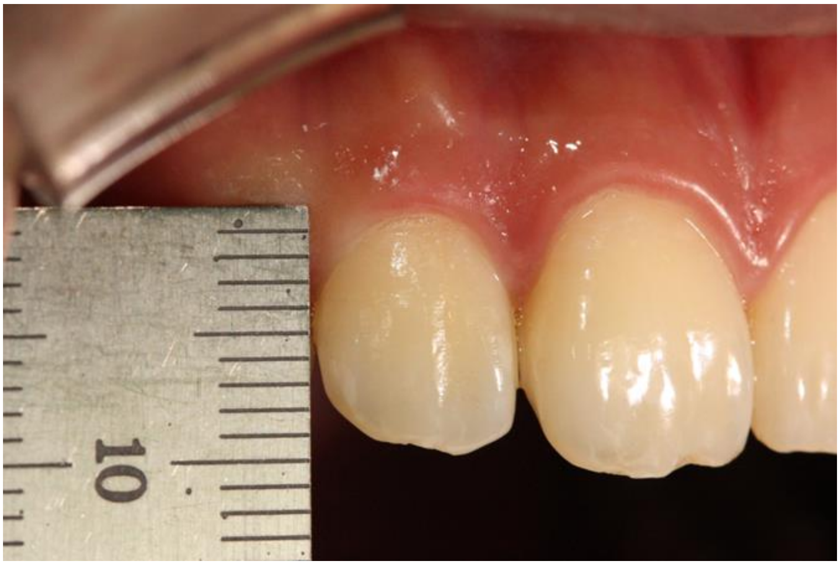


Figure 3. Clinical photograph of the index tooth

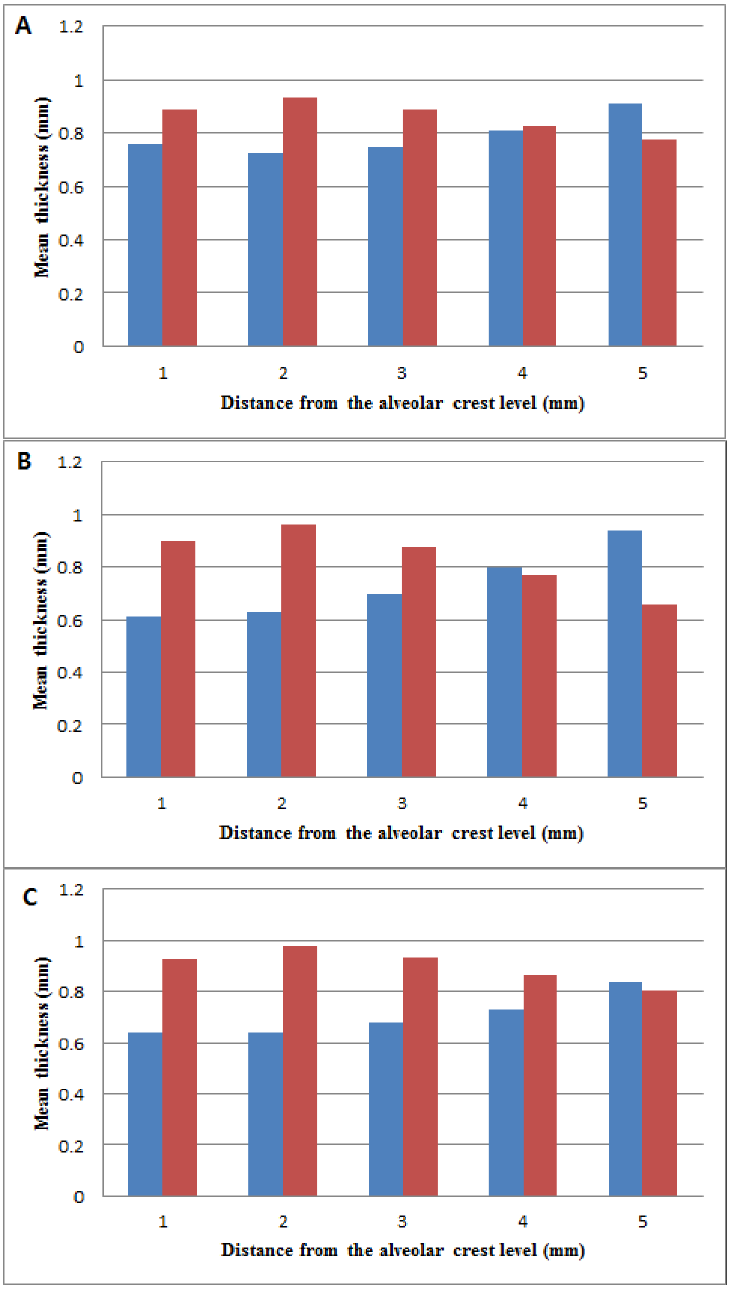
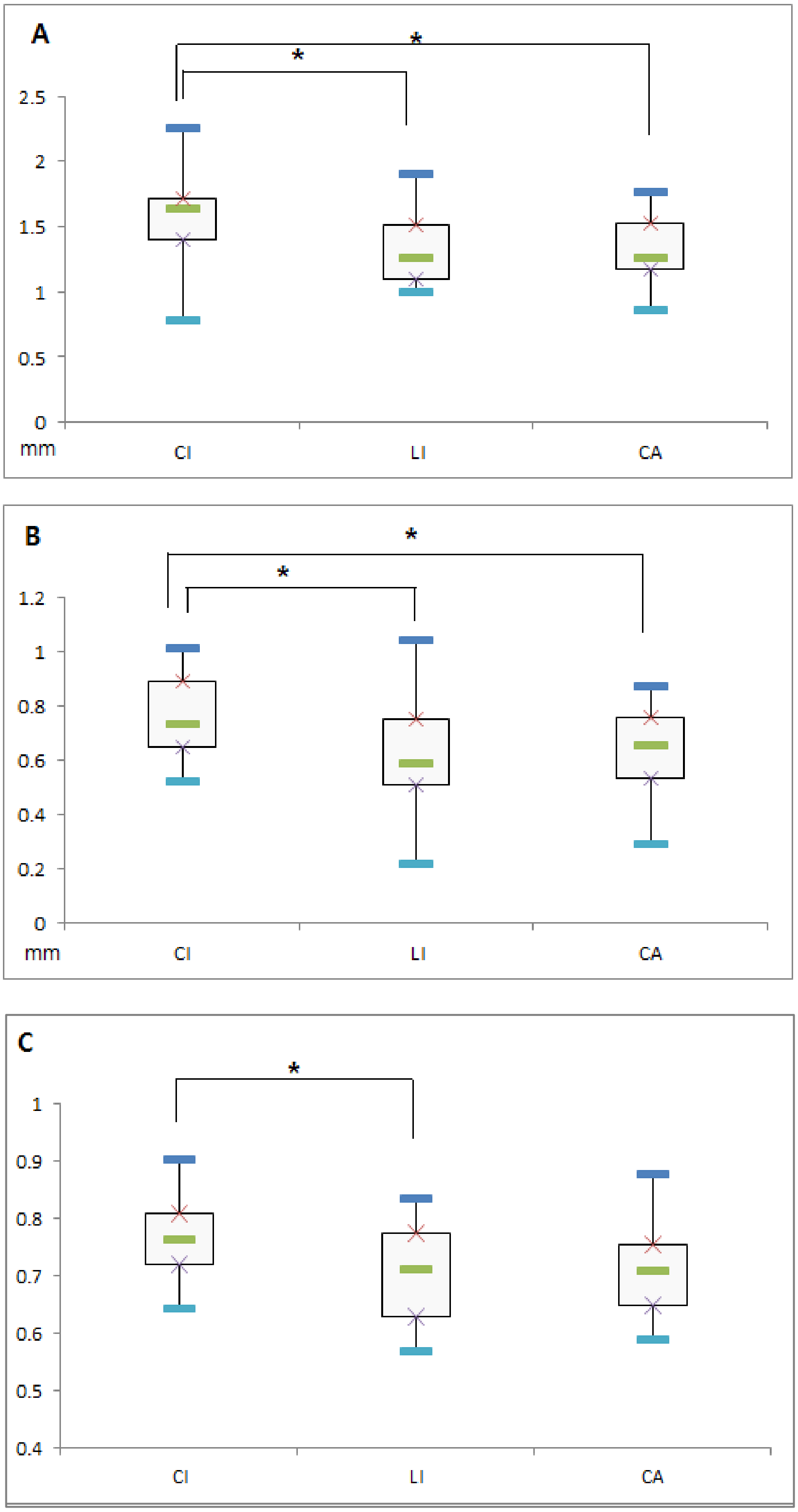


Figure 4. Mean thicknesses of hard and soft tissues at each level (1-5 mm below the alveolar crest level). Blue and red bars indicate gingival and labial bone thickness, respectively. (A) Central incisors, (B) Lateral incisors, (C) Canines.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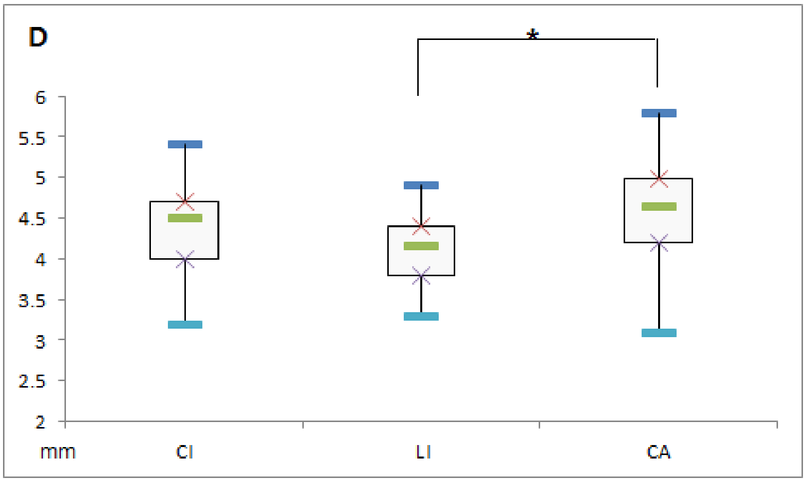

Figure 5. Comparison of gingival thickness and clinical parameters with respect to tooth type. CI, central incisor; LI, lateral incisor; CA, canine. There was a significant difference between tooth types for (A) G0 (gingival thickness at alveolar crest line), (B) G1 (gingival thickness at 1 mm inferior to the alveolar crest), (C) CW/CL (crown width/crown length ratio), and (D) SC (height of gingival scallop).

*Statistically significant differences between groups, $P<0.017$

국문초록

비침습적 디지털 방식을 이용한 건강한 치주조직의 계측 및 평가

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1. 연구목적

이 연구의 목적은 구강 내 3차원 디지털 인상과 컴퓨터 단층촬영을 통한 영상중첩을 이용하여 비침습적으로 건강한 상악 전치부 치주조직의 폭경을 계측하고, 연조직과 경조직 간의 상관관계와 치아별 차이를 분석하는 것이다. 또한 치은 및 순측 치조골 두께와 치관형태, 치은 외형, 치주탐침자의 비침정도와 같은 임상적 측정치와의 관계를 알아보고자 하는 것이다.

2. 연구방법

치주과에 정기검진을 위해 내원한 환자 중 상악중절치, 측절치, 견치가 각각 1개 이상 존재하며 해당치아가 치주질환에 이환되지 않은 자 20명(20-65세)을 대상으로 임상사진 촬영 및 구강 스캐너를 이용한 3차원 영상 획득 그리고 컴퓨터 단층촬영을 시행하였다. 상악중절치, 상악측절치, 상악견치 치아 중심부위에서 단층촬영 영상과 구강 내 스캔 영상을 중첩시켜 종단면 상의 순측골 두께 와 순측 치은 두께를 측정하였다. 치관의 폭경/길이 비율, 각화치은의 폭, 치은연의 외형, 치주탐침자의 비침 정도를 임상사진 분석 및 직접 계측을 통해 획득하였다.

3. 연구결과

대상자의 상악 전치부 순측 치은 두께 및 순측 골 두께는 대체로 1mm 이하로 얇게 나타났으며, 치조골정에서 치근단 측으로 향할수록 순측 치은 두께는 증가하고, 치조골 두께는 감소하는 경향을 보였다. 치조골정 높이에서의 순측 치은두께는 다양한 높이에서의 치조골 두께와 상당 부분 통계학적으로 유의미한 상관관계를 보였으며 ($p<0.05$), 치아 간의 차이도 뚜렷하게 나타났다 ($p<0.017$). 치조골정 높이에서의 순측 치은두께의 경우 상악중절치와 측절치 ($p=0.001$), 중절치와 견치($p=0.001$)간의 유의미한 차이가 있음이 드러났으며, 치조골정에서 1mm 하방의 순측치은두께 또한 중절치

와 견치(p=0.002), 중절치와 측절치(p=0.004)간의 차이가 나타났다. 치은 외형과 관련한 임상 측정치를 분석한 결과 치주탐침자의 비침 정도와 각화치은의 폭이 일부 치조골정에서의 치은 두께와 연관이 있었으나, 대체로 순측 치은두께와의 명확한 상관관계는 찾을 수 없었다.

4. 결 론

비침습적 디지털 구강내 인상을 이용한 상악전치부의 치주조직 계측 결과, 치조골정에서의 순측 치은두께와 하방 치조골 두께가 뚜렷한 상관관계를 보였으며, 치조골정에 가까울수록 치아 간의 순측 치은 두께 간 차이도 유의미하게 나타났다. 치관 및 치은변연 형태와 관련한 임상 측정치는 순측 치은 및 치조골 두께와 일관된 연관관계를 보이지 않았다. 향후 연구를 통해 치조골정 상방의 치은 두께를 정확하게 계측하고, 다양한 임상 계측치와의 연관성을 규명할 수 있도록 다양한 방법의 개발이 필요할 것이다.

주요어: 컴퓨터단층촬영, 치은, 상악골, 디지털 영상 중첩

학 번: 2011-30650