Correlation analysis of periodontal tissue dimensions in esthetic zone using a non-invasive digital method

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Abstract

Background. Recently, direct intraoral scanning and superimposing methods have been applied to measure the dimensions of periodontal tissues. The aim of this study was to analyze various correlations between labial gingival thickness and underlying alveolar bone thickness as well as clinical parameters among the three tooth types (central incisors, lateral incisors, and canines) using the digital method.

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. Gingival thickness at the alveolar crest level was positively correlated with the thickness of the alveolar bone plate ($p<0.05$). 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. The correlation analyses revealed no significant correlation between the clinical parameters and the hard and soft tissue thicknesses.

Conclusions. The gingival thickness at the alveolar crest level revealed a positive correlation with labial alveolar bone thickness, although this correlation at identical depth levels was not significant. 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.

1. Background

The variation in clinical appearance of periodontal tissues has been termed as the gingival biotype (1) and it was postulated that the gingival anatomy reflects the underlying bone architecture (2). In 1977, Weisgold introduced the terms “thick-flat” and “thin-scalloped” gingival biotype (1). The “thick-flat” biotype is described as a prognostic factor of esthetical implant outcomes (3), and the thickness of gingiva has been reported to influence the result of root coverage surgery (4). The so-called “thin-scalloped” gingiva is associated with a higher risk of gingival recession after immediate implant placement (5), and poorer healing of soft tissue after crown lengthening surgery (6). 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 (7, 8). However, there have been relatively few studies on this field due to the lack of standardized techniques for measuring hard and soft tissue thickness.

Calipers (9) and cone-beam computed tomography (CB-CT) (10, 11) are common tools to measure the thickness of alveolar bone. The simplest method to assess soft tissue thickness in clinical area is based on the visibility of the periodontal probe outline through the soft tissue while probing the buccal gingival sulcus (12–14). Another invasive probing method utilizing endodontic needles has been suggested (15–17), alternatively, the non-invasive ultrasonic devices have also been used (18). However, their ability to accurately determine the thickness of a specific site is limited, the results have been controversial and the delineation between thick and thin biotypes remains imprecise.

Recently, digital scanning and assessment methods have been applied to measure the dimensions 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 (19). Although the studies have demonstrated the precision and reliability of this non-invasive method (20), the possibility of errors in the impression-model fabrication procedure is a fundamental limitation. There are several reports measuring soft tissue dimensions as well as hard tissue thicknesses using CB-CT images (7, 21); however, more accurate outlines could be detected through digital scanning files with substantially higher resolutions.

In order to overcome the limitations of aforementioned methods such as invasiveness or inaccuracy, this study was designed to actively use the direct intraoral scanning and superimposing method for analysis of soft and hard tissue thicknesses. Studies have also shown an association of clinical parameters, such as tooth crown shape and the height of the gingival scallop, with gingival thickness.(8, 22, 23) However, these results were not consistent and the relationships should be verified. Hence, the objective of this study is to analyze various correlations between labial gingival thickness and underlying alveolar bone thickness as well as clinical parameters among the three tooth types (central incisors, lateral incisors, and canines) as a follow-up to the previous study(24)

2. Methods

2.1. Patient selection

This study was performed at the Department of Periodontology, Seoul National University Gwanak Dental Hospital between October 2015 and June 2016. Twenty-one patients(20–65 years old) who visited hospital for annual dental examination with intact maxillary anterior teeth (#13, 12, 11, 21, 22, 23), without signs of marginal or periapical bone loss, were included in this study. The following exclusion criteria were used: Pregnant female volunteers; Patients with fixed partial dentures or orthodontic appliances; 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; Patients showing signs of either periodontal disease as defined by a periodontal probing depth >3 mm or gingival recession; and Patients who refuse to fill out the consent form.

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. Ethical approval was obtained 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, Registered 18 September 2015)

2.2. Image acquisition and analysis

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 the CB-CT (CS9300; Carestream, NewYork, US) taking, maxillary arch was directly scanned with an intraoral scanner (Trios; 3Shape, Copenhagen, Denmark). The three cylindrical markers were used as a reference to match the scanned STL (stereolithography) files with the CB-CT images precisely. Image reconstruction and superimposition were performed by Platon software (Ezplant, Seoul, Korea) using a series of mathematical algorithms (Figure 1-B).

Measurements were taken in the same way as in the previous study (24). One of the two corresponding teeth in the first and second quadrants was randomly selected. A longitudinal slice dividing the crown mesio-distally into two equal parts was then captured. A line coinciding with the axis of the tooth was subsequently drawn in the sections.

The measurements of the labial alveolar bone width and the thickness of gingiva 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.

2.3. 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)(8). 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)(25). 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.

2.4. Statistical analysis

Data were analyzed using the SPSS statistical software package (Version 19.0; SPSS Inc., Chicago, IL, USA). 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. For the-post hoc test, statistical significance was defined as a P-value less than 0.017 according to the Bonferroni's correction.

3. Results

3.1. Mean values of clinical measurements

Table 1 shows the descriptive data of the clinical 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.

3.2. Relationship between labial bone and gingival thicknesses

The results of the Spearman's correlation tests are shown in Table 2. 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.

3.3. 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 4).

3.4. 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

Maxillary anterior regions were frequently investigated areas when discussing the aesthetic guidelines for the critical cases with thin gingival and/or alveolar bone thicknesses (7, 17, 21, 26). Unlike manual assessment with limited accuracy using calipers(27), endodontic depth markers(17),or ultrasonic instrument(18), this study used 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. Compared with recent studies(7, 18, 19), this new approach reduces the potential for error during the impression procedures and relatively low resolution of CB-CT taking, and enables the measurement of specific levels that would not be possible with bulky ultrasound instruments.

For the successful outcomes of the periodontal treatments, it could be important to analyze the correlation between soft and hard tissue thicknesses. In many studies describing a positive correlation between labial bone and gingival thickness (8), the gingival thickness was evaluated at the supracrestal level, while bone thickness was measured under the alveolar crest. In an in vivo study of 90 maxillary teeth in 15 patients, La Rocca et al. (2012) (17) observed no significant correlation between CB-CT scan results and gingival probing results. Their study did not perform the comparison at identical levels either. Therefore, the correlation between the thickness of the gingiva and the thickness of the labial alveolar bone at each depth levels 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(21). The lack of accuracy in measuring gingival thickness under the mucogingival junction due to mobility of the gingiva may also lead to this result.

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(14). 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(7, 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(14, 27), specifically 2-mm apical from the free gingival margin(13) 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 (17, 22, 23). However, only partial data for the correlation between labial gingival thickness and the width of keratinized tissue were reported(14, 22). Cook et al (2011) showed no relationship between biotype and tooth height-to-width ratio (22). 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 inadequate for the evaluation of gingival thickness in this study. 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. Conclusion

Gingival thickness at the alveolar crest level revealed a positive correlation with underlying alveolar bone thickness, although this correlation at the same depth level was not significant. However, measurements of gingival thickness at or below alveolar crest levels did not correlate with clinical parameters of the gingiva, such as crown morphology and gingival scallops, or keratinized gingival width.

Therefore, the classification of periodontal biotype on the basis of measurements such as crown form and gingival scallop should be made with caution. Digital 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, reliable measurement methods for supracrestal gingival areas should be developed, and it is necessary to reconsider the predictability of clinical parameters for soft tissue thickness.

6. Abbreviations

CB-CT: cone-beam computed tomography

3D: Three dimensional, STL: stereolithography

GW: The width of the keratinized gingiva

TRAN: The transparency of the periodontal probe outline through the gingival sulcus

SC: height of gingival scallop

CW/CL: The crown width/crown length ratio

7. Declarations

Ethics approval and consent to participate

Informed consent to participate in the study was obtained from all participants. This study has been performed in accordance with the declaration of

Helsinki and was approved by the Ethics Committee of Seoul National University under the reference number: EC/ S-D20150029

Consent for publication

Written consent was obtained for the publication of all materials.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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No funding was obtained for this study.

Authors' contributions

YJK has made a substantial contribution to the conceptualization and execution of this study. JP has contributed to the acquisition of digital data. The statistical analysis of the data was performed by HC. YJK was a major contributor in writing the manuscript and YK revised and edited the manuscript. All authors read and approve the manuscript.

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The authors reported no conflicts of interest related to this study.

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Tables

Due to technical limitations, please see the supplementary files to access the tables.

Figures

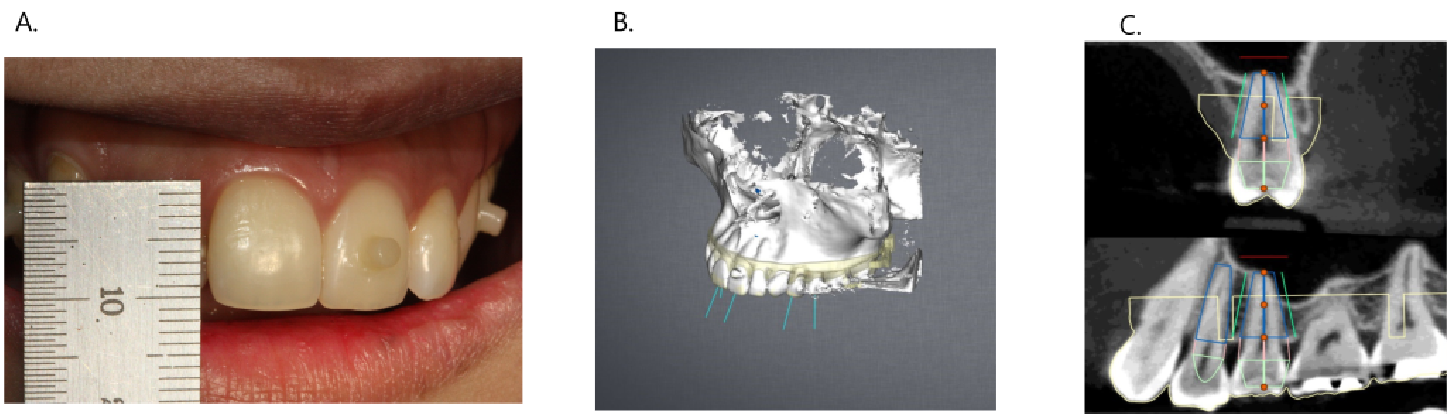

Figure 1

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,C).

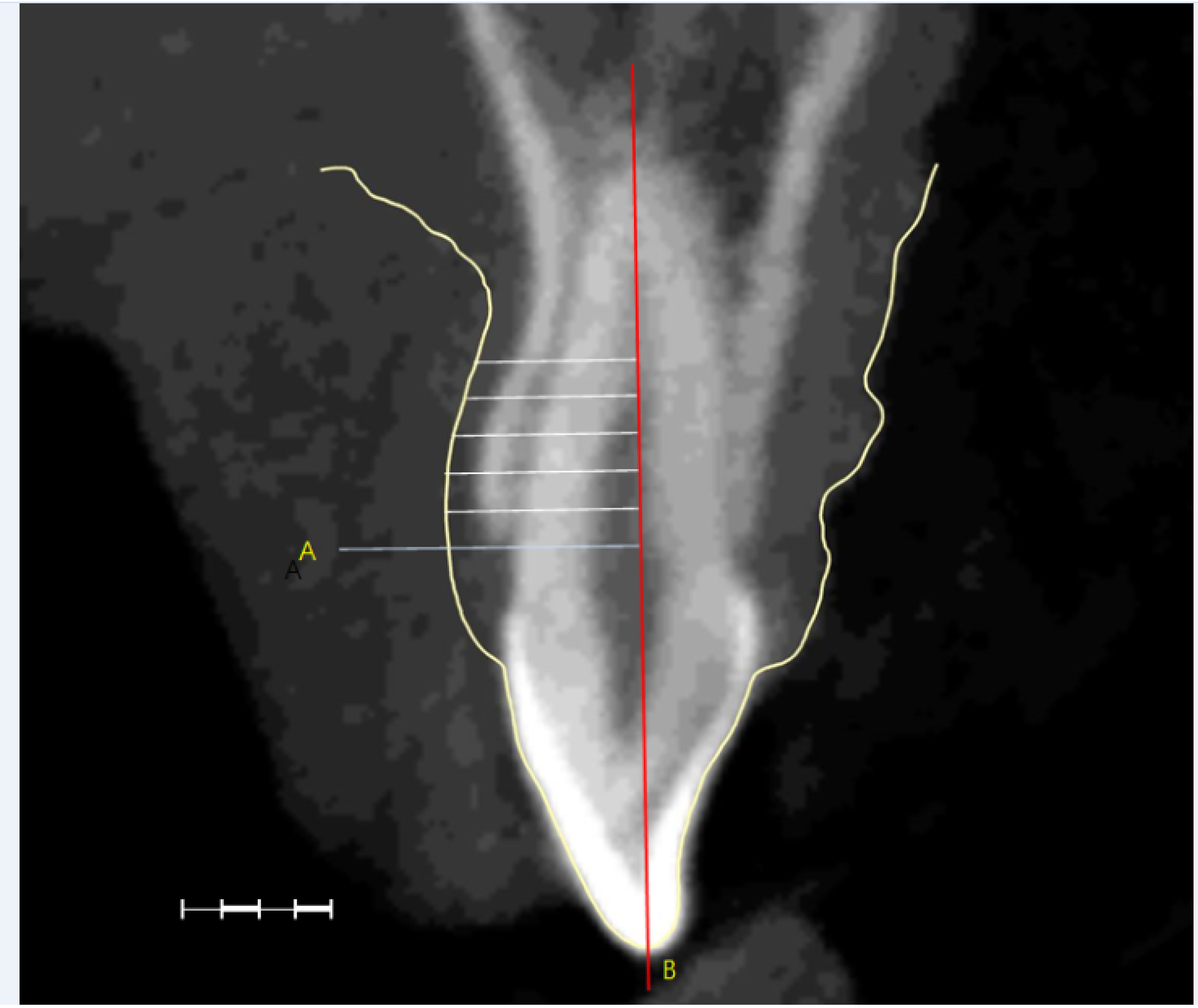

Figure 2

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).

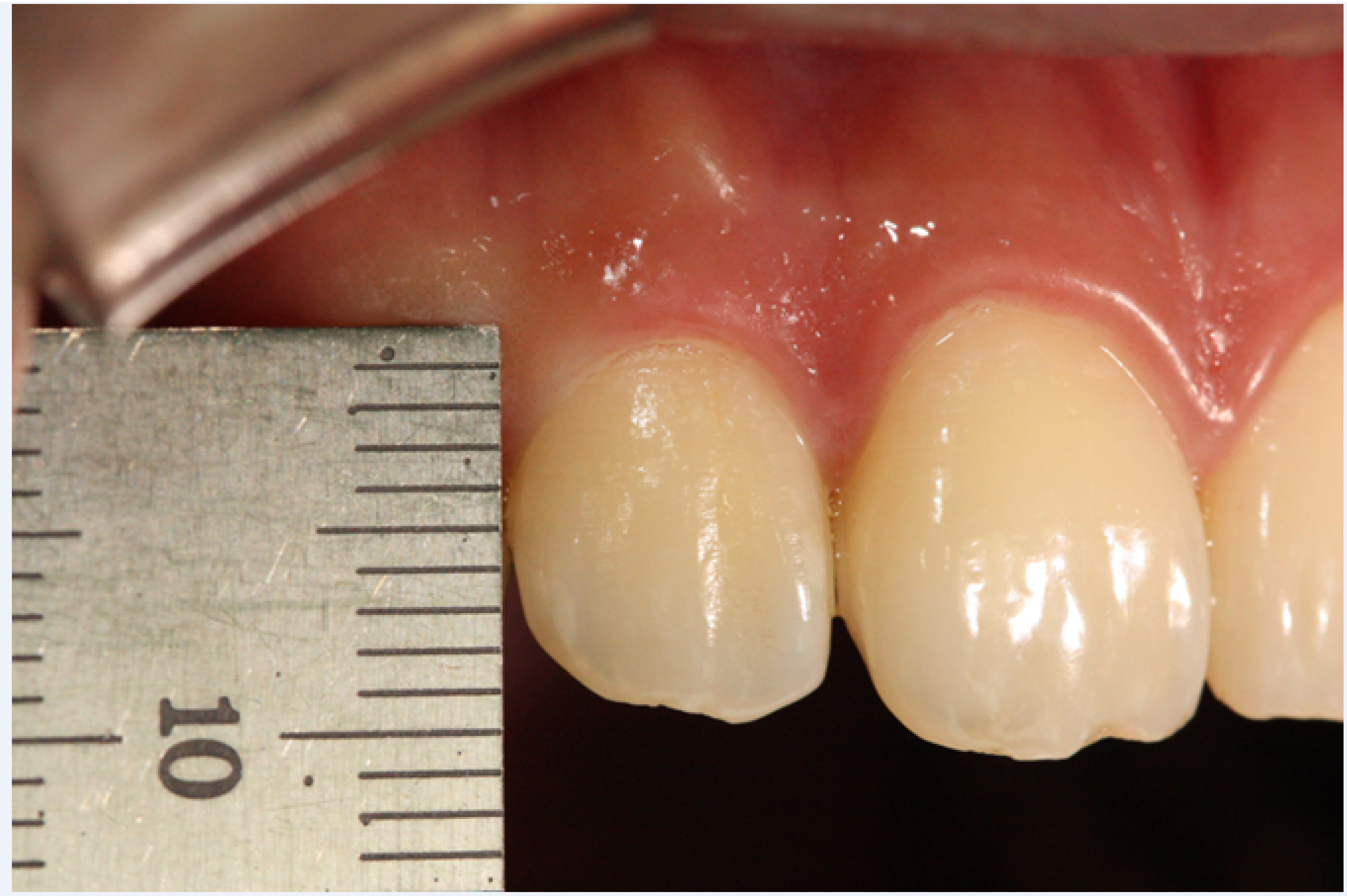

Figure 3

Clinical photograph of the index tooth

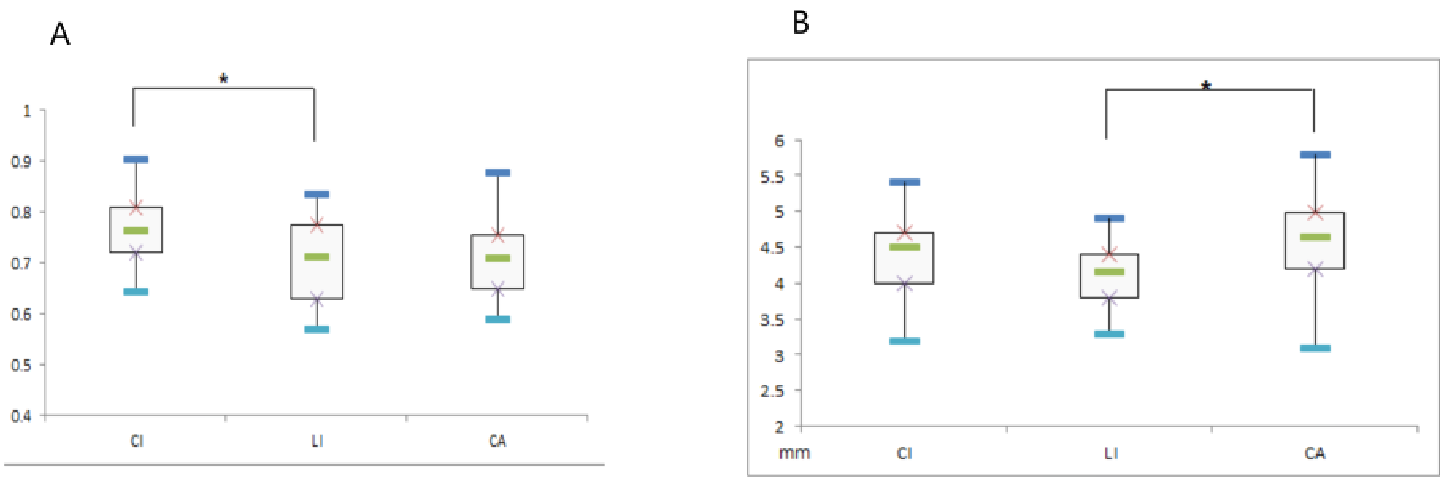

Figure 4

Comparison of 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) CW/CL (crown width/crown length ratio), and (B) SC (height of gingival scallop). *Statistically significant differences between groups, P<0.017

Supplementary Files

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