CBCT Analysis Of Crestal Soft Tissue Thickness Before Implant Placement And Its Relationship With Cortical Bone Thickness

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Abstract

Background: The importance of crestal soft tissue thickness and its influence in peri-implant tissue health has been evaluated in few clinical studies. Cone beam computed tomography (CBCT) imaging offers a unique opportunity to investigate variations in crestal soft tissue thickness. The aim of this retrospective study was to evaluate the correlation between crestal soft tissue thickness and hard tissue measurements on CBCT images, and to compare crestal soft tissue thickness among different patient and edentulous site groups.

Methods: CBCT images of partially edentulous adult patients treated at ECU School of Dental Medicine were evaluated. 160 patients with 189 edentulous sites were included. Demographic data were collected from electronic health records. Cross-sectional CBCT images at the center of each edentulous site were used to measure soft tissue and hard tissue parameters. Linear mixed models were used to compare crestal soft tissue thickness and hard tissue measurements by gender, age groups, and edentulous sites. Pearson correlation was applied to evaluate the correlation between crestal soft tissue thickness and different hard tissue measurements. Association between crestal soft tissue thickness and independent variables (gender, age groups, edentulous sites) was evaluated using repeated measure logistic regression, while the crestal soft tissue thickness was dichotomized by a threshold of 2mm.

Results: Mean age of patients included was 60 (range 21 to 81 years). Female to male ratio was 0.96. Mean crestal soft tissue thickness of all patients was 2.09mm. Mean thickness of cortical bone at alveolar crest was 0.94mm. Thickness of buccal and lingual cortical plates 5mm apical to alveolar crest were 1.14mm and 1.56mm, respectively. Pearson's correlation showed moderate positive correlation among hard tissue measurements, but weak correlation between soft tissue thickness and hard tissue measurements. Anterior sites [OR=3.277 (1.238-8.671)] had higher odds of presenting with more than 2mm of soft tissue at the alveolar crest.

Conclusions: More than half of the patients had crestal soft tissues at edentulous sites thicker than 2mm. Thickness of crestal soft tissue was not significantly associated with hard tissue measurements. Edentulous anterior sites presented with thicker crestal soft tissue at alveolar crest as compared to posterior sites.

Background

The use of dental implants to support prostheses is a widely accepted treatment modality of high success and predictability. The importance of peri-implant bone stability for the success and longevity of treatment has always been emphasized.¹ Various factors, such as implant design and surface configuration,^{2,3} platform switching,⁴ implant insertion depth and abutment height,⁵ occlusal loading,⁶ and the amount of soft-tissue volume and keratinized tissue,⁷ have been reported to be crucial for predictable peri-implant crestal bone stability. Among them is initial crestal soft tissue thickness. In 1996, Berglundh and Lindhe first demonstrated in an animal study that a certain minimum thickness of peri-

implant mucosa was necessary to establish stable soft tissue attachment around dental implants.⁸ Recent clinical studies and systemic reviews have also shown that thick initial mucosa (>2mm) surrounding implants is associated with significantly less crestal bone change in the short term.^{9–12}

Crestal soft tissue can also be called “vertical soft tissue.” To date, most of the methods for measuring vertical soft tissue width have focused on direct physical measurement with surgical manipulation. Linkevicius et al. reported a clinical method used to measure crestal soft tissue thickness prior to dental implant placement.¹³ After the administration of local anesthesia, a full-thickness buccal flap was raised, and the thickness of the unseparated lingual flap was measured with a periodontal probe at the alveolar crest in the center of future implant placement. Jeong et al. described another method to measure soft tissue thickness where flapless implant placement was planned.¹⁴ They used a 3-mm soft tissue punch at the proposed implant site, removed the core soft tissue from over the crestal bone, then measured the crestal soft tissue thickness using a periodontal probe. However, both methods were invasive and were applied shortly prior to implant placement surgery. Thus, accurate measurement of crestal soft tissue thickness was unknown until the day of implant surgery.

The recent development of radiological imaging in the form of cone-beam computed tomography (CBCT) provides a non-invasive, precise demonstration of anatomical structures and has been proved extremely useful in dentistry due to its relatively low exposure dose and high resolution.^{15,16} CBCT has become increasingly utilized in presurgical evaluations of jawbone quality and quantity.¹⁷ Although CBCT was initially an exclusive tool for hard maxillofacial tissue imaging, it has been used to analyze soft tissue in facial area in the last decades. Studies have proved that CBCT can be a precise and noninvasive method for soft maxillofacial tissue imaging.^{18–21} Despite the vast scientific literature on the importance of crestal soft tissue thickness to peri-implant bone stability, no study was designed to investigate variations of crestal soft tissue thickness and its correlation to hard tissue measurements using non-invasive CBCT images.

Therefore, the objectives of this study were to use CBCT images to evaluate thickness of crestal soft tissue of edentulous sites ready for implant placement, to determine correlation between alveolar hard tissue measurements and crestal soft tissue thickness, and to compare crestal soft tissue thickness among different patient groups and different edentulous sites.

Methods

This retrospective study was approved by East Carolina University (ECU) institutional review board (UMCIRB 20-000945). Dental records of partially edentulous adult patients (≥ 18 years old) who were treated with single implant supported crowns at Comprehensive Care Clinic of ECU School of Dental Medicine from March 1, 2014 to March 31, 2020 and had at least one CBCT image taken prior to implant placement were reviewed. Inclusion criteria were: (1) generally healthy patients, no medical contraindication for implant surgery; (2) patient's single implant site was adjacent to two natural teeth or distal to one natural tooth if the implant site was the most distal site of the arch; (3) patient's CBCT image

showed measurable crestal soft tissue at the implant site. Patient's records were excluded if they did not meet the inclusion criteria and if they additionally (1) had soft tissue graft surgery at the implant site before taking CBCT; (2) had medical conditions or were taking medications that can affect bone or soft tissue wound healing, such as uncontrolled diabetes mellitus or osteoporosis, or using bisphosphonates. Patients who had socket preservation surgery or other bone grafting procedure before taking CBCT were included but no hard tissue related measurements were analyzed. The patient-related factors collected from patients' dental records were: (1) age; (2) gender; (3) ethnicity; (4) edentulous site planned for implant placement.

Cbct Imaging Acquisition And Measurement

Two types of CBCT units were used, Instrumentarium OP300 (KaVo Dental Excellence, Biberach, Germany) and Sirona Orthophos SL (Dentsply Sirona, Charlotte, NC, USA). The scans taken with Instrumentarium OP300 were acquired at 89.8 kV and 6 mA, 13 seconds, 0.3 mm³ voxel size, and signal grey scale was 16-bit. Field of view (FOV) of scans used in this study was 60 x 80 mm². The scans taken with Sirona Orthophos SL were acquired at 85 kV and 10 mA, 14 seconds, 0.2 mm³ voxel size, and signal grey scale was 16-bit. FOV of scans used in this study was 80 x 80 mm². All images were displayed on a MacBook Pro (15-inch, 2017) laptop computer (Apple, Cupertino, CA, USA) equipped with graphic card 2048 MB, 2560 x 1440 pixels.

Vertical cross-section views perpendicular to the alveolar ridge at the center of each edentulous site were reviewed and measured using Invivo 6™ Software (Anatomage, San Jose, CA, version 6.0.3). Measurements evaluated on CBCT images were as follows (Figure 1 Measurements evaluated on CBCT images): (1) thickness of crestal soft tissue at the alveolar crest; (2) thickness of cortical bone at the alveolar crest; (3) thickness of buccal and lingual cortical plates 5 mm apical to the alveolar crest; and (4) width of alveolar ridge (from buccal cortical plate to lingual cortical plate) 5 mm apical to the alveolar crest. Units were measured in millimeters.

One general dentist (X.C.) was trained and assessed CBCT scans from 10 randomly selected patients for calibration, measuring the factors listed above. The measurements were repeated one week later with the initial reading being blinded. To achieve a high consistency, the examiner repeated the measurements until a high degree of agreement between the readings of the same set is achieved. Further, two-way mixed model intraclass correlation co-efficient (ICC) test was performed to check intra-examiner reliabilities. ICCs ranged from 0.900 to 0.997, which were interpreted as highly calibrated.²²

Statistical analysis

All statistical analyses were performed using SPSS software, version 25 (Chicago, IL, USA) and SAS version 9.4 (SAS Institute Inc., Cary, NC). Descriptive statistics (frequencies, means, standard deviation and standard error) were conducted. Although the crestal soft tissue thickness and the hard tissue

measurements were slightly right skewed, our sample size was large enough for us to employ linear mixed models. Since some participants had multiple implants, linear mixed models were used to compare the crestal soft tissue thickness and the hard tissue measurements by gender, age groups, ethnic groups, and edentulous sites. Pearson correlation was applied to evaluate correlation between crestal soft tissue thickness and different hard tissue measurements while taking into account of repeated measures.²³ The association between crestal soft tissue thickness and the independent variables (gender, age groups, site groups) was evaluated using repeated measure logistic regression, while the crestal soft tissue thickness was dichotomized by a threshold of 2.0 mm. Odds ratios and 95% confidence intervals were estimated. Ethnicity was excluded from the logistic model due to its lack of variation. The statistical significance level was set to $p < 0.05$.

Results

A total of 160 patients (79 female and 81 male) with 189 edentulous sites were included, of which 121 sites had both soft tissue and hard tissue measurements from the CBCT scans. The mean age of the patients was 60 years (standard deviation 14.24, range 21 to 81 years). The majority of the patients (79.38%) were not Hispanic or Latino, seven patients were Hispanic or Latino, twenty-seven patients did not report their ethnicity. Ninety-one of the edentulous sites were maxillary posterior sites, sixty-seven sites were mandibular posterior sites, incisors and canines were 22 and 9, respectively (Table 1). Since a sizable proportion of the patients did not disclose ethnicity, comparison of crestal soft tissue thickness and hard tissue measurements among different ethnic groups, and association between ethnicity and clinical parameters were not analyzed.

Table 1
Characteristics of patients (n=160) and 189
edentulous sites

Variables	N (%)
Gender	
Female	79 (49.4%)
Male	81 (50.6%)
Age	59.5 (14.1)
Age Group	
18 – 40	16 (10.0%)
41 – 65	77 (48.1%)
>65	67 (41.9%)
Ethnic Group	
Not Hispanic or Latino	126 (78.7%)
Hispanic or Latino	7 (4.4%)
No Response	27 (16.9%)
Edentulous Site Group	
Incisors	22 (11.6%)
Canines	9 (4.8%)
Maxillary Posterior Sites	91 (48.2%)
Mandibular Posterior Sites	67 (35.4%)

The estimated mean crestal soft tissue thickness of all patients was 2.09 mm, standard error (SE) was 0.056 mm. The mean thickness of cortical bone at the alveolar crest was 0.94 mm (SE = 0.046). Thickness of buccal and lingual cortical plates 5 mm apical to the alveolar crest were 1.14 mm (SE = 0.065) and 1.56 mm (SE = 0.07) respectively. Mean width of alveolar ridge (from buccal cortical plate to lingual cortical plate) 5 mm apical to the alveolar crest was 9.20 mm (SE = 0.248). Pearson's correlation showed moderate positive correlation among hard tissue measurements, but weak correlation between crestal soft tissue thickness and hard tissue measurements. Thickness of buccal cortical plate 5 mm apical to the alveolar crest was positively correlated with thickness of cortical bone at the alveolar crest, thickness of lingual cortical plate 5 mm apical to the alveolar crest, and width of alveolar ridge 5 mm apical to the alveolar crest. Thickness of lingual cortical plate 5 mm apical to the alveolar crest was positively correlated with width of alveolar ridge 5 mm apical to the alveolar crest (Table 2).

Table 2

Pearson's correlation between vertical soft tissue thickness and different hard tissues measurements

	Thickness of soft tissue at the alveolar crest	Thickness of cortical bone at the alveolar crest	Thickness of buccal cortical plate 5 mm apical to the alveolar crest	Thickness of lingual cortical plate 5 mm apical to the alveolar crest	Width of alveolar ridge 5 mm apical to the alveolar crest
Thickness of soft tissue at the alveolar crest	1				
Thickness of cortical bone at the alveolar crest	0.04	1			
Thickness of buccal cortical plate 5 mm apical to the alveolar crest	-0.07	0.40*	1		
Thickness of lingual cortical plate 5 mm apical to the alveolar crest	-0.17	0.12	0.56*	1	
Width of alveolar ridge 5 mm apical to the alveolar crest	-0.00	-0.11	0.48*	0.43*	1
*Correlation is significant at the 0.01 level (2-tailed)					

Linear mixed models revealed the crestal soft tissue thickness, thickness of buccal cortical plate, lingual cortical plate and the width of alveolar ridge were significantly different among edentulous site groups ($p < 0.01$). Mandibular posterior sites had significantly more thickness of buccal cortical plate (mean=1.58, SE=0.082, $p < 0.001$), thickness of lingual plate (mean=2.20, SE=0.076, $p < 0.001$), and width of alveolar ridge (mean=10.31, SE=0.316, $p < 0.001$) than maxillary posterior sites and anterior sites (incisors and canines). However, the crestal soft tissue thickness of anterior sites (mean=2.51, SE=0.129, $p < 0.01$) was significantly more than that of maxillary posterior sites (mean=2.03, SE=0.077) and mandibular posterior sites (mean=1.98, SE=0.088). The result also showed the male patients had significant more width of alveolar ridge (mean=9.71, SE=0.335, $p < 0.05$) than female patients (mean=8.63, SE=0.355). The crestal soft tissue thickness and hard tissue measurements among different age groups did not show statistical significance (Table 3).

Table 3
Estimated means and SEs of crestal soft tissue thickness and hard tissue thickness

Demographics	Group	Thickness of crestal soft tissue at the alveolar crest	Thickness of cortical bone at the alveolar crest	Thickness of buccal cortical plate 5 mm apical to the alveolar crest	Thickness of lingual cortical plate 5 mm apical to the alveolar crest	Width of alveolar ridge 5 mm apical to the alveolar crest
All		2.09 (0.056)	0.94 (0.046)	1.14 (0.065)	1.56 (0.07)	9.20 (0.248)
Gender	Female	2.02 (0.081)	0.88 (0.069)	1.02 (0.092)	1.46 (0.101)	8.63 (0.355)*
	Male	2.17 (0.079)	0.99 (0.062)	1.25 (0.087)	1.65 (0.095)	9.71 (0.335)*
Age Group	18-40	2.15 (0.18)	1.06 (0.165)	1.38 (0.222)	1.43 (0.246)	9.10 (0.862)
	41-65	2.06 (0.082)	0.93 (0.067)	1.07 (0.094)	1.62 (0.103)	9.13 (0.365)
	>65	2.12 (0.087)	0.92 (0.071)	1.17 (0.097)	1.53 (0.106)	9.30 (0.376)
Edentulous Site Group	Mandibular posterior sites	1.98 (0.088)**	0.99 (0.073)	1.58 (0.082)***	2.20 (0.076)***	10.31 (0.316)***
	Maxillary posterior sites	2.03 (0.077)**	0.86 (0.066)	0.81 (0.077)***	1.15 (0.071)***	8.83 (0.295)***
	Anterior sites	2.51 (0.129)**	1.09 (0.143)	0.92 (0.153)***	0.95 (0.144)***	6.68 (0.576)***
*: p < 0.05; **: p < 0.01; ***: p < 0.001						

Abbreviation: SE, standard error

The repeated measure logistic regression model testing the association between thin or thick crestal soft tissue thickness (2.0 mm as the threshold) and the independent variables (gender, age groups, edentulous site groups) showed anterior sites [OR=3.277 (1.238-8.671)] had higher odds of presenting with ≥ 2.0 mm thickness of soft tissue at the alveolar crest compared to mandibular posterior sites (Table 4).

Table 4 Association between crestal soft tissue thickness and gender, age, and edentulous sites using logistic regression

	Crestal Soft Tissue Thickness		Crude Odds Ratio	
	N (%)			
	< 2.0 mm	≥ 2.0 mm	Odds Ratio (CI 95%)	<i>p</i> -value
Gender				0.999
Male	49 (50.0)	49 (50.0)	Ref	
Female	45 (49.5)	46 (50.6)	1.000 (0.535-1.872)	
Age Group				0.582
18-40	10 (52.6)	9 (47.4)	Ref	
41-65	46 (52.3)	42 (47.7)	1.253 (0.406-3.866)	0.693
>65	38 (46.3)	44 (53.7)	1.655 (0.525-5.221)	0.388
Edentulous Site Group				0.055
Mandibular Posteriors	40 (59.7)	27 (40.3)	Ref	
Maxillary Posteriors	44 (48.4)	47 (51.6)	1.525 (0.774-3.006)	0.221
Canines and Incisors	10 (32.3)	21 (67.7)	3.277 (1.238-8.671)	0.017*

*Modeling the probability of having thin (≥2mm) crestal soft tissue, $p < 0.05$

Abbreviation: CI, Confidence interval

Discussion

The crestal soft tissue thickness of sites planned for implant placement were evaluated in the present study. In 189 edentulous sites, the mean crestal soft tissue thickness was 2.09 ± 0.73 mm and the median thickness was 2.01 mm, ranging from 0.62 to 4.39 mm. If we use 2.0 mm as a cutoff point to divide between thin and thick tissue as in some other clinical studies,^{13,24} the current study indicated that about 50% of the population had relatively thick crestal soft tissue. Linkevičius, T. estimated that 30% to 80% of patients might have thin crestal soft tissue,²⁵ but the range was wide, and the estimation was not supported by any epidemiologic study. One previous systematic review compared mean crestal soft tissue thicknesses reported in different clinical studies. The thinnest mean tissue thickness reported was 1.53 ± 0.07 mm, and the thickest mean tissue thickness reported was 3.32 ± 0.76 mm.²⁶ The mean crestal soft tissue thickness measured in the current study fell between those two groups. Systematic reviews of clinical studies have concluded that there is moderate certainty of the evidence that implants placed with an initially thicker peri-implant soft tissue (or supracrestal tissue attachment) have less radiographic marginal bone loss in the short term.^{12,27} In contrast, one recent clinical study found excessive vertical soft tissue thickness around implants in patients with a history of periodontitis had an

adverse influence on health of the peri-implant tissue.²⁸ The mean crestal soft tissues reported in that study was 3.32 ± 0.76 mm. The current study was the first one that reported the variations of crestal soft tissue thickness using non-invasive radiographic method, indicating more than half of implant patients may have relatively thick initial crestal soft tissue. The clinical significance of crestal soft tissue to long-term health of peri-implant tissue is still inconclusive.

The results of our study showed that the thickness of crestal soft tissue varied among different sites, with anterior sites (incisors and canines) demonstrating greater values than those of mandibular and maxillary posterior sites. The mean crestal soft tissue thickness of anterior sites was 2.51 ± 0.91 mm and could be considered thick. While mean crestal soft tissue thicknesses of maxillary posterior sites and mandibular posterior sites were 2.03 ± 0.91 mm and 1.98 ± 0.74 mm, respectively. Anterior sites also had higher chances of presenting ≥ 2.0 mm thickness of soft tissue at alveolar crest than mandibular posterior sites. Since the present study did not measure the attachment level or soft tissue thickness of adjacent teeth, it was hard to explain the exact reason why anterior sites showed significantly thicker crestal soft tissue. The anterior sites (31 sites) included in this study were relatively less compared with the number of maxillary and mandibular posterior sites (158 combined). To our knowledge, no previous study has reported the differences of thickness of crestal soft tissue between different sites. More studies and larger sample sizes are needed to confirm this finding.

Previous studies evaluated buccal bone thickness and have found a thin (< 1.0 mm) bone wall usually presented in anterior regions of both jaws.²⁹⁻³¹ Several studies have focused on the thickness of the buccal cortical plate and its correlation between facial tissue thickness, especially in the anterior area. Younes et al. studied the relationship between buccal bone and soft tissue thickness at teeth in the premaxilla.³² They included 21 patients, measured buccal bone thickness on CBCT scans and used an ultrasonic device to measure the gingival thickness. Their results showed a thin buccal bone wall (< 1.0 mm) in over half of the central incisors and canines, and there was a moderately positive correlation between buccal bone and soft tissue thickness. Esfahanizadeh et al. measured buccal bone and soft tissue thicknesses of 330 maxillary incisors using CBCT scans and their results were consistent with Younes et al. They reported that the mean thickness of buccal bone and soft tissue in the anterior maxilla was < 1.0 mm and there was a mild linear correlation between them.³³ Fu et al. found that the mean labial soft tissue thickness of the maxillary anterior teeth at 2.0 mm below the bone crest was 0.57 mm (0.2 to 1.86 mm) on CBCT scans and the thickness of the gingival tissue had a moderate association with the underlying labial alveolar bone.³⁴ In contrast, Kim et al. found that the correlation between buccal bone thickness and soft tissue thickness of anterior teeth was generally not significant.³⁵ Most of the studies mentioned above measured the facial bone wall thickness at different levels from the bone crest. Among the different levels, 5 mm apical to the bone crest was selected in all these studies. Another study reported that the mean values of facial bone thickness for the different levels fluctuated in a very small range.³⁶ Because the primary focus of our study was crestal soft tissue thickness, we decided only to evaluate the thickness of buccal plates 5 mm apical to the alveolar crest. In the 122 sites from our study, the mean thickness of buccal cortical plate was 1.14 ± 0.68 mm, indicating relative thick (> 1.0 mm)

buccal cortical plates existed in sites that were ready for implant placement. Male patients and mandibular posterior sites had significantly thicker buccal cortical plates. However, most sites from the present study were posterior sites, and previous studies reported thickness of bone around teeth while our study only focused on edentulous sites. It is difficult to compare the results of the present study with other studies. According to our results, most of the hard tissue measurements were positively correlated to each other while the correlation between hard tissue measurements and crestal soft tissue thickness was not significant. More investigation will be needed to evaluate the correlation between hard tissue measurements, crestal soft tissue thickness, and buccal soft tissue thickness.

Crestal cortical bone thickness and lingual cortical plate thickness 5 mm apical to the alveolar crest were also measured in this study. The mean $\pm$ SD values of the crestal cortical bone thicknesses at the dental implant sites of the present study were as follows: posterior mandible (0.99 ± 0.67 mm), posterior maxilla (0.86 ± 0.34 mm), anterior mandible and maxilla (1.09 ± 0.58 mm). Our study did not find a significant difference in crestal cortical bone thicknesses among different site groups. However, Ko et al. measured 661 implant sites using CBCT and reported that the crestal cortical bone thicknesses at dental implant sites in the four regions decreased in the following order: posterior mandible (1.07 ± 0.47 mm) > anterior mandible (0.99 ± 0.36) > anterior maxilla (0.82 ± 0.30 mm) > posterior maxilla (0.75 ± 0.35 mm).¹⁷ These results were consistent with those reported by Gupta et al., who measured 218 patients' CBCT scans of implant sites, with the thickness of crestal cortical bone in the posterior mandible, anterior mandible, anterior maxilla, and posterior maxilla being 1.18 ± 0.48 , 1.08 ± 0.30 , 0.82 ± 0.32 , and 0.76 ± 0.28 mm, respectively.³⁷ The present study grouped maxillary and mandibular anterior sites together due to limited sample size. This might be one of the reasons why there was no significant difference detected among the site groups. However, the mean crestal cortical bone thickness in general was consistent with the previous studies. Our study found that the thickness of the lingual cortical plate and width of alveolar ridge decreased in the following order: posterior mandible > posterior maxilla > anterior. The mean thickness of the lingual cortical plate was 1.56 ± 0.76 mm, which was consistent with the finding reported by Srebrzyńska-Witek et al.³⁸ They measured 100 CBCT scans of anterior mandible and found the mean thickness of the lingual alveolar cortex was $1.51 \text{ mm} \pm 0.35 \text{ mm}$.

CBCT scans were used in this study to measure crestal soft tissue thickness. Even though the soft tissue of the lips and cheeks were not retracted when taking CBCTs, and the lips and cheeks did collapse on the buccal gingiva in most cases, a clear visualization of the crestal soft tissue was achieved in most cases. The advantages of CBCT included high resolution, more precision in linear measurements of both soft and hard tissues than traditional X-rays, and measurement of tissue thickness prior to the surgical procedure. Fu et al. did not find statistically significant differences between the clinical and CBCT measurements of both soft tissue and bone thickness when measuring tissue biotypes.³⁴ The current study also indicated that CBCT can be used as an objective and non-invasive method to assess crestal soft tissue thickness.

The present study has some limitations. One limitation is the small sample size of anterior sites. We had to combine maxillary and mandibular anterior sites together into one group in order to compare the

measurements to posterior groups. Additional studies are needed to compare the crestal soft tissue thickness between maxillary and mandibular anterior sites. The present study only focused on the edentulous sites and did not measure the periodontal condition of adjacent teeth. Studies that included both edentulous sites and adjacent teeth may be needed to evaluate the effects of periodontal condition of adjacent teeth to the edentulous sites. The present retrospective study evaluated the correlation between crestal soft tissue thickness and hard tissue measurements but did not evaluate buccal soft tissue thickness and its relationship to crestal soft tissue. Further prospective studies with a larger sample size and longer follow-up period are needed to investigate crestal soft tissue changes before and after implant placement and its long-term effect on implant success.

Conclusions

According to the results of our study, crestal soft tissue of more than half of the edentulous sites which were ready to receive implant placement was found to be relatively thick (>2.0 mm). Crestal soft tissue thickness was not significantly associated with hard tissue measurements. Edentulous anterior sites may present with thicker soft tissue at the alveolar crest than mandibular posterior sites. Gender and age did not appear to have a significant influence on crestal soft tissue thickness.

List Of Abbreviations

CBCT: Cone beam computed tomography;

FOV: Field of view;

ICC: Intraclass correlation co-efficient;

SE: Standard error;

OR: Odds Ratio;

CI: Confidence interval

Declarations

Ethics approval and consent to participate

This study was approved by East Carolina University (ECU) institutional review board (UMCIRB 20-000945).

Consent for publication

Not applicable.

Availability of data and material

The datasets used during the current study are available from the corresponding author on reasonable request. All data analyzed during this study are included in this published article in the form of tables and figures.

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Competing interests

Xiaoxi Cui, Tyler Reason, Vanessa Pardi, Qiang Wu and Acela Martinez Luna declare that they have no competing interests.

Authors' contributions

Categories of the authors' contribution are as follows: concept/design (XC and AML), data collection (XC and TR), data analysis/interpretation (XC, VP and QW), drafting of the article (XC), critical revision of the article (XC, VP, QW and AML), and approval of the article (XC, TR, VP, QW and AML).

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Figures

Figure 1

Measurements evaluated on CBCT images

- (a) Crestal soft tissue thickness measured in red and cortical bone of alveolar crest measured in yellow.
- (b) 5 mm apical to alveolar crest shown in orange. Lingual cortical plate (A) and buccal cortical plate (B) thickness measured in red.
- (c) 5 mm apical to alveolar crest shown in orange. Alveolar ridge thickness measured in blue (including thickness of buccal and lingual cortical plates).