Cone Beam Computed Tomography Assessment of the Buccal Bone Thickness in Anterior Maxillary Teeth: Relevance to Immediate Implant Placement

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Purpose: Peri-implant bone thickness is an important local factor that could influence esthetic outcomes in immediate implant therapy. The aim of this study was to assess the thickness of the buccal bone overlying the anterior maxillary teeth in Kenyans. Materials and Methods: A total of 184 cone beam computed tomography (CBCT) scans that met the inclusion criteria were retrospectively studied. Buccal bone thickness of all maxillary anterior teeth was assessed, resulting in a total of 1,104 teeth. Measurements were taken on sagittal views at a point 4 mm below the cementoenamel junction (M1) and at the mid-root level (M2). The data were analyzed using SPSS software (version 20, IBM), and statistical significance was set at P ≤ .05.

Results: Mean buccal bone thickness of the teeth studied was 0.55 ± 0.38 mm at M1 and 0.60 ± 0.30 mm at M2. Missing buccal bone wall was observed in 31.61% (349 teeth) of all teeth at M1 and in 21.38% (236 teeth) of all teeth at M2. The majority of the teeth had a thin buccal bone wall (< 1 mm) at M1 (56.34%) and at M2 (68.48%), whereas a thick buccal bone (≥ 1 mm) was only observed in 12.05% of teeth at M1 and in 10.14% of teeth at M2. Thin buccal bone was mainly found in central incisors, while thick buccal bone wall was found mainly in canines. The thickness of buccal bone at M1 decreased with an increase in age.

Conclusion: Contour augmentation would be necessary in most of these cases, as the buccal bone was typically thin. The thickness at the cervical portion was inversely correlated with age. One in every four of the cases would not be ideal for flapless immediate implant placement due to a missing buccal bone wall. Preoperative CBCT analysis of the buccal wall is recommended for appropriate treatment planning. Int J Oral Maxillofac Implants 2018;33:880–887. doi: 10.11607/jomi.6274

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Immediate dental implants have been shown to have a high survival rate.1,2 Compared with implants placed in healed sites, no difference in the success rate has been established.3,4 Reduced chair time, less economic burden, reduced morbidity, and the number of surgeries involved are the main advantages of this treatment method.5 However, one of the most common complications after immediate implant treatment is recession of the buccal mucosa leading to adverse esthetic outcomes, especially in sites with a thin peri-implant gingival biotype.2,6–8

Even when implants are placed into healed sites, a significant decrease in tissue height of up to 0.6 mm has been observed within the first 6 months.9 In the anterior maxilla, soft tissue thickness has been shown to be dependent on the thickness of the underlying bone.10 For long-term esthetic soft tissue stability, adequate horizontal and vertical bone volume is a prerequisite.11 A thin buccal bone at the time of immediate implant placement is a local risk factor that has been associated with significantly greater vertical resorption of bone over time and subsequent gingival recession.2,6 One way of preventing this complication is by ensuring that at least 2 mm of buccal bone surrounds the implant.12

It is now clear that there is invariable resorption of the maxillary alveolar ridge with diminished width and height following tooth extraction, which may sometimes preclude optimum implant placement.
and restorative esthetics. Clinical and radiographic analyses showed that there is more reduction in the width than in the height of the residual ridge after tooth extraction. In addition, since the crest of the buccal bone wall is mainly composed of bundle bone, it tends to resorb more than the palatal bone. Botticelli et al reported that up to 56% of the horizontal dimension of the buccal bone was lost following immediate implant placement. A later study confirmed that implant placement into the extraction socket did not stop this resorption. However, when the buccal bone thickness is less than 2 mm, horizontal resorption may be reduced to 25% of the original buccal dimension with the use of bone grafts and/or barrier membranes. It has also been demonstrated that extraction sockets with thick bony walls (> 1 mm) have more bone fill in the gap between the implant and the inner aspect of the socket wall (also referred to as horizontal defect dimension [HDD]) than sites with thin socket walls (≤ 1 mm). Considering that a thin or missing buccal bone presents a local esthetic risk factor, it is critical for the clinician to have an idea of its thickness prior to tooth removal to decide on the best treatment approach for predictable outcomes. Cone beam computed tomography (CBCT) is a noninvasive modality offering cross-sectional imaging and three-dimensional reconstruction of the maxillofacial skeleton at lower radiation doses than medical computed tomography. Previous studies based on CBCT scans have reported that the buccal bone found in most maxillary anterior teeth is typically thin (< 1 mm). A similar finding was reported in an earlier related study that involved direct measurement of the buccal bone thickness at extraction sites.

There is a paucity of information in the literature on buccal bone thickness. Continuous variables were calculated. Accuracy was limited to the inherent voxel size (0.3 mm) of the CBCT machine used in acquiring the scans. Measurements of the thickness of the buccal bone for each tooth were taken at two points (Fig 1) as reported earlier: 4 mm apical to the cementoenamel junction (M1) and at the middle of the root (M2). To check whether there was reproducibility of measurements, the investigators repeated the morphometric measurements after 1 month to prevent recall bias. Where the second measurements differed from the earlier ones, an average of the two measurements was calculated.

**Study Designs**

The study was designed as a retrospective radiographic study to document the thickness of the facial bone of anterior maxillary teeth (left canine to right canine). A total of 184 CBCT scans of adult (≥ 18 years of age) patients who for various reasons attended a busy private dental clinic in Nairobi, Kenya, were included. All images had been obtained between January 2014 and December 2016 and were analyzed by a single calibrated examiner (A.M.) and confirmed by a second examiner (J.G.). Any image that showed signs of trauma, supernumerary teeth, crowding, marked loss of both buccal and palatal alveolar bones, previous apical surgery, or root resorption in the region of interest and any images that presented with lack of clarity or too much scattering were excluded. Thus, a total of 1,104 teeth that met the inclusion criteria were studied. The study protocol was approved by the Kenyatta National Hospital/University of Nairobi Ethics Committee (Protocol number: UP925/12/2016).

**Image Acquisition and Measurements**

A Galileos Comfort Plus (Sirona Dental Systems) CBCT unit with an image intensifier (II) detector and a charge-couple device camera was used to take all the radiographs. The exposure volume was to display a spherical field of view of 15 cm (resulting in a scan volume of 15 × 15 × 15 cm) and voxel size (slice thickness = 0.3 mm) at 0.3 × 0.3 × 0.3 mm. The tube voltage and current were fixed at 85 kV and 7 mA, as recommended by the manufacturer. A bite block was utilized while scanning in addition to the x-ray unit height being adjusted to ensure that the occlusal plane was perfectly horizontal. The detector unit completes a 200-degree rotation around the patient’s head in 14 seconds.

Sidexis XG software (Sirona Dental Systems) is used to capture, process, and store reconstructed 3D data together with the original two-dimensional projection views. A sagittal view for each tooth was reconstructed and analyzed by a computer using Galaxis/Galileos (Sirona Dental Systems) three-dimensional (3D) visualization and measurement software.

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**Statistical Methods**

Demographics and other baseline characteristics were collected for each patient and were presented by way of descriptive statistics (frequencies, means, and standard deviations [SDs]). Subcategories were created to determine the effect of sex, age, and side of mandible on buccal bone thickness. Continuous variables were presented by way of number of observations (n), minimum (min), median, maximum (max), mean, and SD and discrete variables by frequency and percentage.
Intergroup comparisons were performed using the Student t test. The data were analyzed statistically using SPSS software (version 20, IBM), and a two-sided P value of .05 or less was considered statistically significant. Independent-samples t test, Levene’s test of homogeneity of variances, Pearson product-moment correlation coefficient, Spearman’s rank-order correlation coefficient, and Linear Regression tests were performed.

RESULTS

Descriptive Statistics
A total of 184 CBCT scans belonging to 85 (46.2%) men and 99 (53.8%) women with an age range from 18 to 81 years (mean = 39.28, SD = 14.04) and a mode of 34 years were enrolled in this study. An independent-samples t test revealed a non–statistically significant difference in age between sexes with the mean age of men (mean = 40.21 years, SD = 15.06) being higher than women (mean = 38.47 years, SD = 13.12, t[182] = 0.836, P = .404).

Table 1 presents the mean buccal bone thickness of central incisors, lateral incisors, and canines on the left and right sides of the maxilla at M1 and M2. In total, 1,104 teeth were analyzed (368 central incisors, 368 lateral incisors, and 368 canines). The mean buccal bone thickness for all the teeth studied was 0.55 ± 0.38 mm at M1 and 0.60 ± 0.30 mm at M2. This difference was found to be statistically significant (P = .004).

There was a positive correlation between the buccal bone thickness of the teeth on the right side when compared with the same teeth on the left side specifically corresponding to M1 and M2 as presented in Table 2. The only exception was in the canine teeth, where this correlation was significant at both M1 and M2.

Figure 2 presents a frequency distribution of buccal bone thickness among the tooth sites studied. A clear majority (62%) of the tooth sites exhibited a thin buccal bone wall (< 1 mm), while only 11% exhibited a thick buccal wall (≥ 1 mm). In more than a quarter (26%) of the tooth sites, there was a missing buccal bone wall (thickness = 0 mm), especially at M1. Thin buccal bone was mainly found in central incisors, while thick and missing buccal bone walls were found mainly in canines.

Difference in Buccal Bone Thickness Between Men and Women
An independent sample t test only elicited a statistically significant difference with regard to the buccal bone thickness between the two sexes in the canine teeth at M2 with the mean for men (mean = 0.64 ± 0.44 mm) being higher than that for women.
(mean = 0.50 ± 0.41 mm, t [182] = 2.189, P = .030) (Table 3). Spearman’s rank-order correlation coefficient test of association only elicited a statistically significant correlation between the buccal bone thickness of the left canine at M2 when both sexes were compared ($r_s [182] = –0.176, P = .017$).
Influence of Age on Buccal Bone Thickness

Figure 3 presents a curve estimation linear regression model showing a statistically significant negative correlation between the buccal bone thickness at M1 and age in all the teeth studied. However, at M2, age was not a statistically significant factor.

DISCUSSION

Immediate implant placement into extraction sockets has become a common procedure in many parts of the world, as it compares well to placement in healed sites.4 Due to bone resorption following tooth removal, the soft tissue that makes up the gingival margin subsequently recedes, as the two have been shown to be strongly associated.10 This is especially of great aesthetic concern in the anterior maxillary region if a high smile line exists, as the dark color of the implant collar may become visible. It is recommended that if the buccal bone is intact, contour augmentation should be done whenever treating patients with a thin gingival biotype to minimize the risk of buccal plate resorption and marginal tissue recession.22 Further, when the buccal plate integrity is lost, implant placement should be delayed.22 Prior knowledge of the thickness of the facial bone is therefore critical during treatment planning.

There are no published studies known to the authors that have documented the thickness of the buccal bone in Africans; yet this is an important dimension to clinicians all over the world. As a baseline, the present study documented that the mean thickness of the facial bone of all teeth examined in the maxillary region was thin (range: 0.48 ± 0.40 mm to 0.70 ± 0.31 mm). These results corroborate the findings of previous CBCT studies, where it was established that the buccal bone in the anterior maxilla of other populations was mainly thin (range: 0.5 to 0.8 mm).19,21,23 The buccal bone in the present study was also significantly thicker at M2 than at M1 (P = .004). This contradicts the findings of a previous study where the bone thickness at 1, 3, and 5 mm apical to the bone crest was invariable.23 This could be attributed to the proximity (2 mm) of the measurement points in that study, which were all near the crest of the buccal bone. In other words, the thickness of the buccal bone of anterior maxillary teeth may be said to be generally thin in most people irrespective of their ethnicity or geographic location. These findings would help underscore the necessity of contour augmentation at the time of immediate implant placement in the anterior maxillary region to minimize the inevitable loss of buccal bone dimensions that follows tooth loss.

In the present study, a thin buccal bone (< 1 mm) was mainly observed in the central incisors, while a thick buccal bone was identified around the canines. A trend toward a decreasing thickness of buccal bone from the posterior teeth toward the anterior teeth was also reported in earlier studies.19,24 Just as in those studies, more missing buccal bone walls were observed at the level of M1 than at the level of M2 in the present study. These findings could point toward the need to use implants with a narrow crest in the maxillary anterior region for an immediate placement protocol. Older adults of black descent have been shown to have a higher prevalence of periodontal disease,25 which may be the cause of bone loss of especially the thin marginal buccal plates. A decrease in the thickness of the buccal bone with an increase in age was noted at the level of M1 in all the teeth included in the present study. This trend confirms the findings of a similar study by Braut et al19 and those by Wang et al.24 It could be speculated that immediate implant
Fig 3  Plot model of the correlation between buccal bone thickness and age of patients. (a) Left central incisor M1. (b) Left lateral incisor M1. (c) Left canine M1. (d) Right central incisor M1. (e) Right lateral incisor M1. (f) Right canine M1.
placement in the maxillary anterior area in patients of advanced age poses a higher risk of esthetic complications than in younger patients.

Some authors have recommended that to reduce bone loss, atraumatic extraction of teeth for immediate implant placement should involve minimal flap elevation to spare blood supply to the buccal bone. The assumption in this approach is that the extraction socket has intact bone walls. From the standpoint of the data presented in the present study, at least one in every four (26%) of the tooth sites studied had a missing buccal bone wall. This situation would have implications on the success of guided bone regeneration, as there would be no barrier to give preference to bone cells to repopulate the HDD created during immediate implant placement. Furthermore, in healing of immediate implant sites with thick bony walls (> 1 mm), they exhibit more bone fill of the HDD than sites with a thin alveolar crest (< 1 mm). A thick buccal bone was only observed in approximately 12% of the teeth at point M1 and in 10% of the teeth at point M2 in the present study. As such, most of the tooth sites would be at risk of developing esthetic complications following immediate implant placement due to the well-known reduction in ridge dimensions after tooth loss. An early placement protocol (4 to 8 weeks after tooth extraction) would be favored in these cases, as it is associated with a lower frequency of mucosal recession compared with immediate implant placement.

The medical status of the patients whose CBCT scans were included in the present study was unknown since they were referred purely for imaging reasons, and therefore, no comprehensive medical history was available. It is therefore worth noting that the effect of the medical status on the buccal bone thickness was not determined. Overestimation of the quantity of bone and the inherent 0.3-mm slice thickness of the CBCT system used in the present study may be viewed as potential limitations. The present findings are, however, corroborated by those from a direct measurement study where the mean width of the buccal wall was also found to be 0.8 mm in the anterior maxillary tooth sites. Cone beam computed tomography is therefore reliable in determining the thickness of the buccal bone around teeth.

**CONCLUSIONS**

Within the scope of this study, the following conclusions may be drawn. The buccal alveolar bone walls on the anterior maxillary teeth in this population were generally thin (< 1 mm), with the thickness decreasing with an increase in age. One in every four of the cases would not be ideal for flapless immediate implant placement due to a missing buccal bone wall. To cater for the inevitable dimensional loss following tooth extraction and to provide a convex contour of the facial tissues for a successful esthetic outcome, 87% of the cases would require contour augmentation. CBCT analysis is informative to clinicians about the presence or absence and quantity of the buccal bone wall for appropriate treatment selection.

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