Received: 12 October 2022 | Revised: 20 December 2022 | Accepted: 24 December 2022

DOI: 10.1111/cid.13175

ORIGINAL ARTICLE

WILEY

Buccal and palatal alveolar bone dimensions in the anterior maxilla: A micro-CT study

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Funding information

Ministarstvo Prosvete, Nauke i Tehnološkog Razvoja, Grant/Award Number: 451-03-68/2022-14/200129

Abstract

Objective: Anterior maxillary immediate implant placement has become a popular procedure. It has aesthetic and functional risks. A prerequisite for success is sufficient alveolar bone for primary stability. Many cone-beam computed tomography (CBCT) studies have assessed alveolar bone dimensions in the anterior maxilla, with varying results. More accurate information on the alveolar bone dimensions in the anterior maxilla is required. The objective of the present study was to evaluate bone dimensions in the anterior maxilla using micro-CT, a high-resolution imaging tool.

Materials and Methods: Seventy-two human skulls were scanned using micro-CT at the South African Nuclear Energy Corporation. Specialized software was used for 3-D rendering, segmentation, and visualization of the reconstructed volume data. Axial planes were created over each alveolus/tooth from canine to canine. Buccal and palatal bone dimensions were measured at crestal, 3 mm, 6 mm, and 9 mm levels.

Results: Buccal bone rarely exceeded 0.5 mm, consisting of bundle bone only for all investigated teeth at all levels. Up to a third of teeth showed buccal fenestrations. Alveolar bone on the palatal side was thicker than buccal and increased from <1 mm at crestal level up to 3.77 mm, 4.56 mm, and 5.43 mm for centrals, laterals, and canines at the 9 mm level, respectively.

Conclusions: Immediate implants in the anterior maxillae has anatomical risks. Alveolar bone on the buccal aspect is very thin, with fenestrations in certain positions. Therefore, a thorough planning and individual approach are needed to avoid possible complications and achieve stable aesthetic and functional results in the long-term.

KEYWORDS

dental implants, maxillary bone, x-ray micro-CT

Summary Box

What is known so far

- Sufficient buccal and palatal alveolar bone dimensions are of utmost importance for successful immediate implant placement.
- Many studies have assessed almost only buccal bone in the anterior maxilla using CBCT imaging, offering varying results.
- CBCT methodology has been provenly not reliable for evaluation of thin bone plates.

How present study advance the knowledge

- Micro-CT is superior imaging modality compared to CBCT, offering the possibility of exact measurements of thin bone plates. However, it should be realized that micro-CT can only be used in laboratory conditions, due to the high radiation dose.
- Overall evaluation of the alveolar bone in the anterior maxilla (buccal and palatal), provides clear information on available bone dimensions, will raise the awareness of existing anatomical limitations.

1 | INTRODUCTION

Dental implants have become the standard of care for the replacement of lost teeth. This practice is especially popular in the anterior maxilla where aesthetic demands of patients can be very high.[1] Prerequisites for successful implant surgery and an aesthetic outcome are ideal three-dimensional implant positioning and maintenance of adequate buccal bone over the implant surface.[2]

Immediate implant placement in the anterior maxilla has become popular but remains controversial and carries a high risk for complications.[1] It is one of the most difficult areas to manage successfully as it is associated with variable outcomes and high frequency of gingival recession.[1,3] The most important obstacle encountered is the thin buccal bone and the resorption of bundle bone after tooth loss,[3–8] which increases the risk of bone fenestration, dehiscence, and soft tissue recession.[7,9]

Immediate implant placement in the anterior maxilla area is done with a flapless approach in most cases. The flapless technique is preferred as the elevation of surgical flaps affects the integrity of the underlying alveolar bone.[2] This technique requires the placement of the implant toward the palatal bone wall to achieve adequate primary stability and to not engage the buccal bone wall.[6,10] If the bone dimensions on the palatal side are insufficient, it may perforate into the maxillary incisive canal[5,11] or into palatal soft tissue, which may result in implant failure.[6,10] Flapless surgery does not reveal the dimensions of available bone thickness and two-dimensional (2D) radiological findings are not satisfactory to assess the bone.

A minimal width of 1–2 mm of buccal bone is advocated to maintain stable dimensions of the alveolar crest[3,12,13] and for successful implant placement.[9,13–15] It has been shown that the recommended 2 mm thickness of buccal bone occurred only in 3% of cases[9] and a value of less than 1 mm is a common finding.[3,8,16,17]

Cone-beam computed tomography (CBCT) has become the standard for bone assessment in implant planning. However, many clinicians, especially in remote locations, do not have access to CBCT and rely on intra-oral 2D radiography and clinical assessment for immediate implant planning in the anterior maxilla. Furthermore, most dental CBCT scanners have a voxel size of 0.3–0.4 mm resulting in a spatial resolution of 0.7 mm. It has been shown that this spatial resolution is not adequate to properly visualize thin bone such as in the anterior maxilla.[18] Even though it has been reported that CBCT may underestimate the thickness of alveolar bone in the anterior maxilla,[18,19] most scientific studies have used this imaging modality to assess the availability of buccal or palatal bone in the anterior maxilla.[8,9,13,17,20,21]

Investigations using a high-resolution tool, such as micro-focus computed tomography (micro-CT), provide the ability for thorough assessment of thin bone plates for example, the buccal bony wall.[19] It has to be noted that micro-CT is not intended for clinical use and is beneficial for research purposes only. One study, where CBCT and micro-CT were compared for alveolar bone measurements using alveolar blocks obtained from pigs, concluded that regions of thin bone tissue were not visible on CBCT, but could however be delineated using micro-CT. Bone measurements were underestimated when using CBCT.[19] Superiority of the micro-CT over the CBCT imaging has been shown and can be observed in Figure 1.[22]

Few studies using micro-CT have been conducted. Kim and associates[10] used micro-CT to elucidate the relationship between anterior maxillary teeth and surrounding alveolar bone. However, only used a small number of samples (19 maxillae) were analyzed and the surrounding alveolar bone was only measured at the apex of each tooth.[10] Other limitations in the literature reviewed include a limited sample number.[2,10,13,14,20,21] Dimensions of the alveolar bone surrounding the anterior teeth are either reported as a pooled value for all anterior teeth[14] or only a few tooth locations are investigated.[9,23] Many researchers have reported on the buccal bone wall dimensions only.[3,7–9,13,17,20]

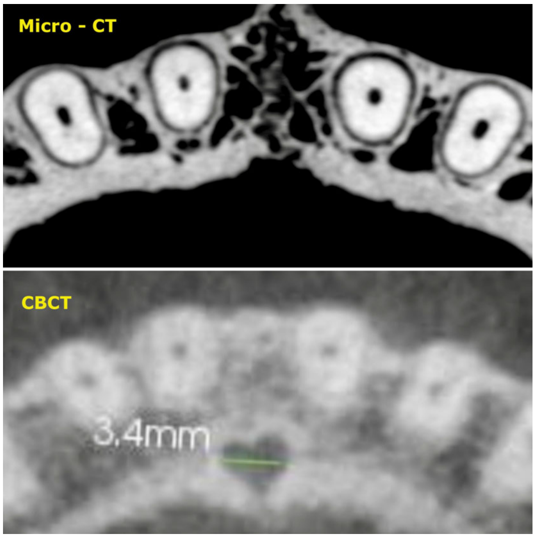

FIGURE 1 Comparison of micro-CT versus CBCT imaging

It is necessary to obtain more detailed information on the buccal and palatal alveolar bone in the anterior maxilla using a high-resolution imaging tool such as micro-CT. The primary objective of this study was to assess the available palatal and buccal alveolar bone for immediate implant placement in the anterior maxilla using micro-CT.

2 | MATERIALS AND METHODS

A total of 123 dry human skulls were obtained from Pretoria Bone Collection (University of Pretoria, South Africa), representing two South African population subgroups and both genders. According to the inclusion criteria only skulls that contained all six anterior maxillary teeth and had no signs of bone loss that could be attributed to periodontal disease were included in the study. After the exclusion process, study sample was defined to 72 skulls. The age at death of the decedents from whom skulls were obtained ranged from 22 to 86 years (mean age, 51.97 years). In terms of the skeletal material, this study falls under the auspices of the National Health Act (No. 61 of 2003) of South Africa. Therefore, permission for research was given either by family members in the case of donations or in the case of unclaimed bodies, was protected by the act stated above. All identities of the individuals used will be kept protected. Ethics approval was granted by the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria, South Africa (Ethics approval No. 111_2013) and the Helsinki Declaration was signed.

The skulls were scanned with a micro-focus CT unit (Nikon XTH 225 ST, Nikon Metrology SARL, Lisses, France) at the Micro-Focus X-ray Tomography Facility (MIXRAD) of the South African Nuclear Energy Corporation (NECSA). Micro-focus x-ray tomography is based on the same principle as CBCT. It utilizes the same amount of energy as CBCT, but the spatial resolution obtained is shifted to 1–3 μm instead of 300 μm due to the focal spot size of 0.001–0.003 mm versus 1–3 mm for CBCT. To obtain a high-quality three-dimensional

FIGURE 2 Three-dimensional view of scull scanned with micro-CT

(3D)-virtual image at this high spatial resolution, the number of 2D projections increases from 375 to up to 8000 (1000 projections for this study). Due to the size of the samples in this study, a spatial resolution of 40 and 90 microns for the respective tomograms of the maxillae were achieved which resulted in a higher quality tomogram (3D image) than for CBCT and from which more accurate quantitative analyses could be made. Each of the 2D digitized radiographs per specimen, taken at different angles, consists of an array of 2048 $\times$ 2048 pixel elements (maximum for the current detector at the micro-CT system) and each element with a 16-bit gray scale (65 535 gray levels). The reconstruction into 2D slices (for each row of the of 2048 $\times$ 2048 pixel array), is performed through Nikon CT-Pro 3D software, a commercial tomography reconstruction package for micro-CT, which creates a single virtual 3D volume file by reconstructing all the 2D slices together with all the information of the sample imbedded (dimensional and density related). This volume file is then imported into VGStudioMAX visualization software (Volume Graphics GmbH, Heidelberg, Germany) for the 3D rendering, segmentation and visualization of the reconstructed volume data (Figure 2). For quantitative analysis of the virtual volume, a menu of analytical functions is available for example, sectioning and measurement of distances in 3D space by integrating the information provided by the 3D image together with the axial, sagittal and frontal views which showed the additional xy, yz, and xz slices, respectively. The specimen is defined through a density map of constituents of the sample as the virtual volume is being defined by 3D voxel elements, each with a different voxel value (up to 56 535) representing its density and thus makes porosity quantification throughout the sample possible.

On the 3D-reconstructed images of the skull, a reference axial plane was created at the deepest points of the socket on the buccal and palatal aspect of the alveolar bone over each of the anterior maxillary teeth/alveolar socket: canines, lateral and central incisors (teeth 13, 12, 11, 21, 22, 23) (Figure 3). Axial planes of the 3D-reconstructed images of the maxillary alveolar bone were made to enable measurements of distances in mm to the nearest second decimal. Axial sections were made at the crestal level, 3 mm, 6 mm, and 9 mm (where possible) by scrolling toward apical from the reference plane of each of the 6 upper teeth, as demonstrated in Figure 4. The thickness of the buccal alveolar bone was measured over the most anterior aspect of the tooth root perpendicular to the anterior edge of the buccal aspect of the alveolar bone. The palatal thickness of the alveolar bone was measured over the most palatal aspect of the tooth root perpendicular to the palatal aspect of the alveolar bone. Most often this was near the middle of the root in the buccal and palatal aspects as seen in Figure 5. All measurements were performed by a single examiner (the first author) and rounded off to two decimal places.

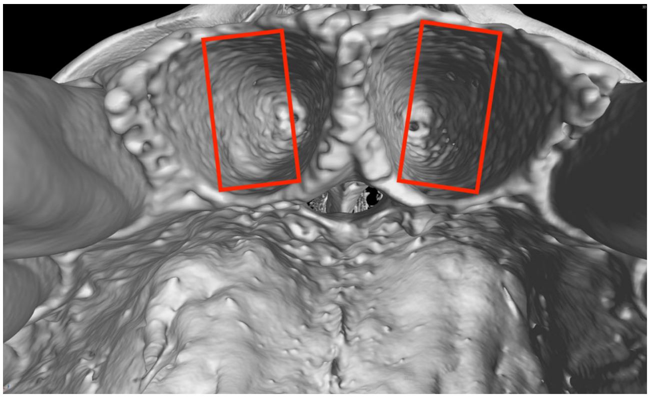

FIGURE 3 Axial planes created over alveolar socket on the 3D model

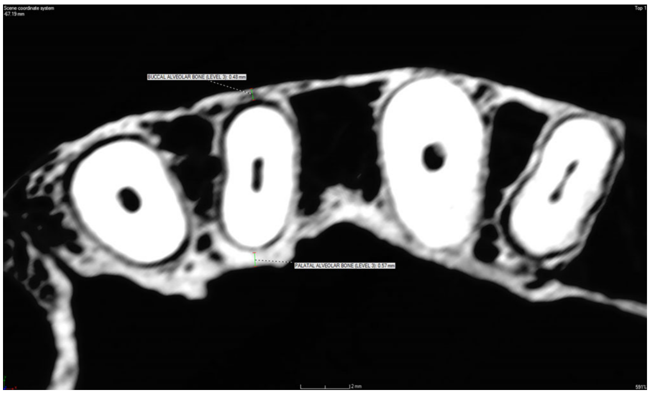

FIGURE 4 Axial section of the lateral incisor (3 mm level)

2.1 | Statistical analysis

The main statistical calculations were carried out using SPSS 24.0 (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). Alveolar bone measurements were subjected to the Kolmogorov–Smirnov test (KST) to determine the normality of data. This was followed by descriptive analysis including univariate analysis, where applicable. Comparisons of alveolar bone measurements were done between males and females and between White and Black subjects using *T*-tests (and the Mann–Whitney *U* test for non-parametric variables). Alveolar bone thickness on different levels was compared with age using the Pearson correlation test. Significance was set at $p < 0.05$. Ten measurements were repeated for each tooth type on various heights on both the buccal and palatal sides. The intraclass correlation coefficient (ICC) was used to measure intra-examiner consistency.

TABLE 1 Demographic data

Race and sex	*n*	Average age (years)
Black men	34	45.81 (±14.86)
Black women	8	41.50 (±14.81)
White men	18	57.67 (±14.18)
White women	12	64.00 (±8.85)
Total	72	51.97 (±16.14)

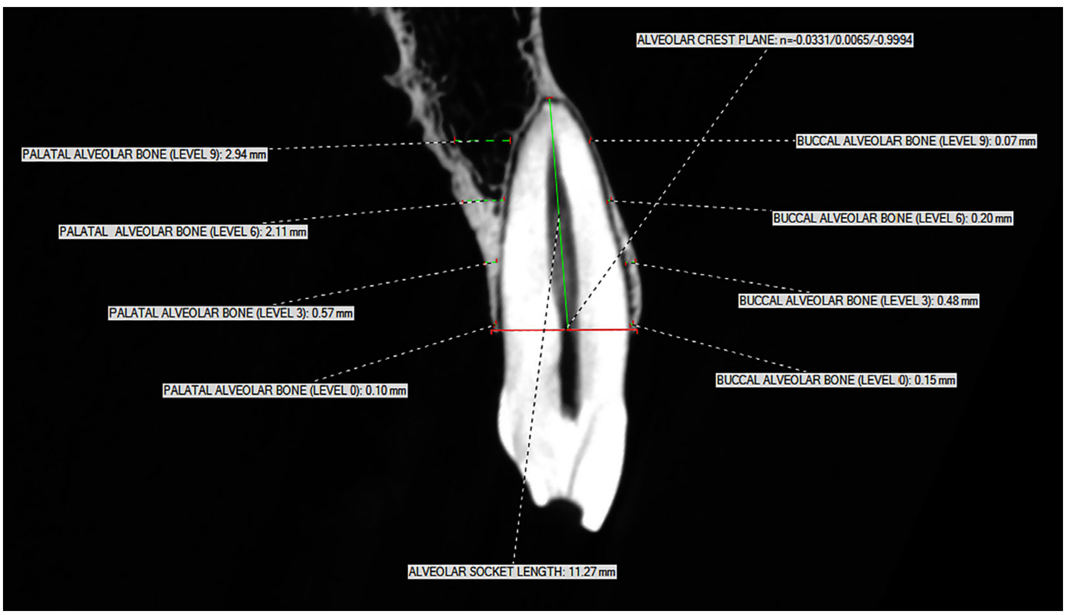

FIGURE 5 All measurements performed (sagittal view)

3 | RESULTS

The ICC varied between 0.93 and 1.00 for all comparisons, indicating good reliability for the repeated measures. The mean age of the study population was 51.97 years (SD: 16.14; SE: 1.92; 95% CI 48.15–55.79 [$n = 72$]) with 72.2% ($n = 52$) being male and 27.8% ($n = 20$) female. Table 1 displays the demographic data of the subjects included in the study. Age did not demonstrate any significant

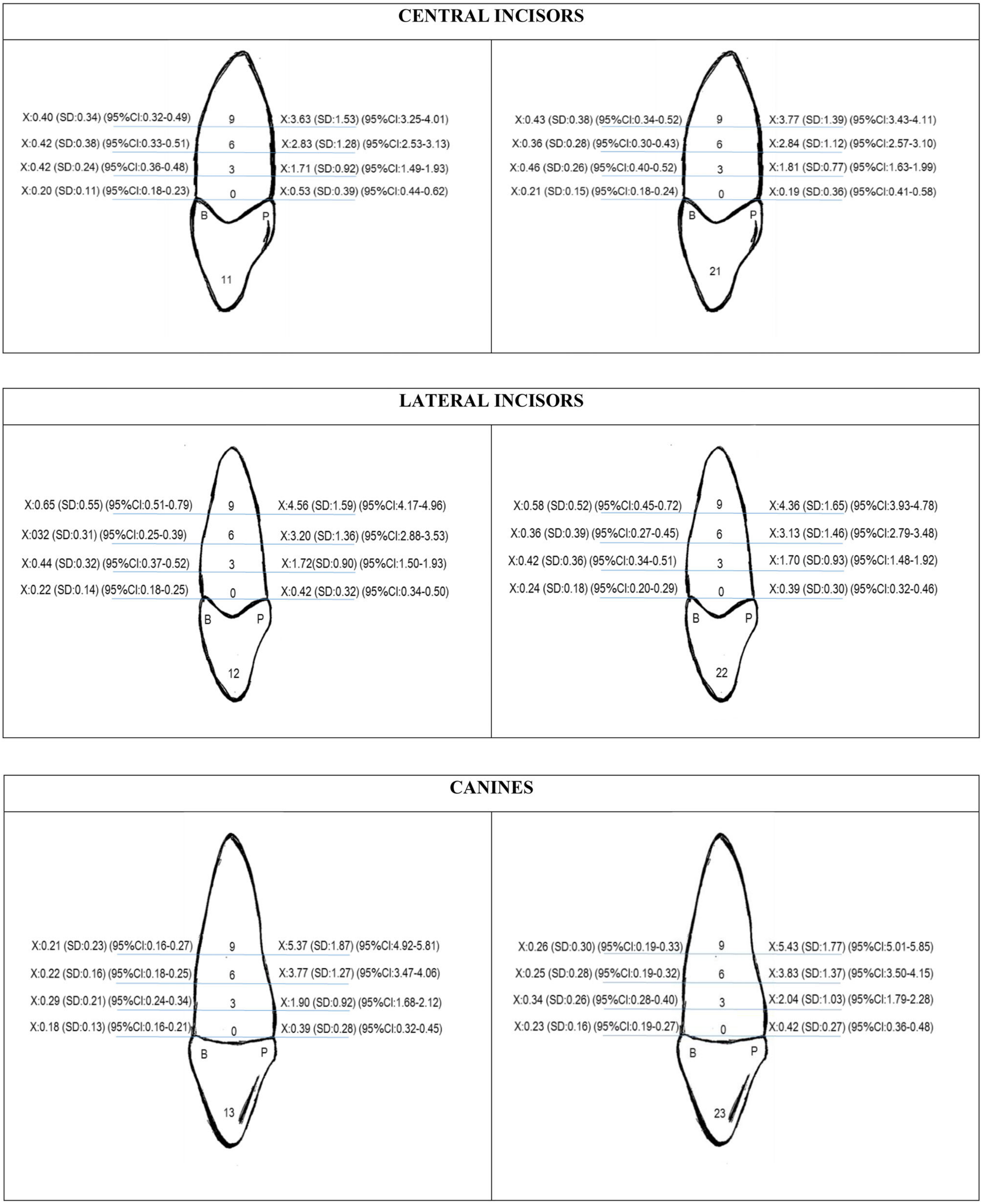

FIGURE 6 Alveolar bone thickness buccal and palatal on different levels. X: mean, SD: Standard Deviation; 95%CI: 95% Confidence Interval

TABLE 2 Prevalence of alveolar bone fenestrations at different horizontal levels

	13			12			11			21			22			23		
	Sites	*n*	%	Sites	*n*	%	Sites	*n*	%	Sites	*n*	%	Sites	*n*	%	Sites	*n*	%
B0	72	15	20.83	71	7	9.86	72	10	13.89	72	12	16.67	71	7	9.86	71	12	16.90
P0	72	0	0.00	71	0	0.00	72	0	0.00	72	0	0.00	71	1	1.41	71	1	1.41
B3	72	6	8.33	71	3	4.23	72	4	5.56	72	1	1.39	71	7	9.86	71	8	11.27
P3	72	0	0.00	71	0	0.00	72	0	0.00	72	0	0.00	71	0	0.00	71	0	0.0
B6	72	13	18.06	70	9	12.86	72	5	6.94	72	8	11.11	71	16	22.54	71	15	21.13
P6	72	0	0.00	70	0	0.00	72	0	0.00	72	0	0.00	71	0	0.00	71	0	0.00
B9	71	24	33.8	64	6	9.38	63	8	12.7	67	10	14.93	61	10	16.39	70	20	28.57
P9	71	0	0.00	64	0	0.00	63	0	0.00	67	0	0.00	61	0	0.00	70	0	0.00

correlation with alveolar bone thickness, except on the palatal side (nine-level), where a very weak positive correlation was noted ($r = 0.26$, $p = 0.041$). Table A1 shows the detailed descriptive analysis at different alveolar bone locations, some with normal and others with skewed distributions (confirmed with the KST). Values ranged from zero, especially on the buccal side and several millimeters depending on the horizontal level. Figure 6 demonstrates differences between buccal and palatal measurements for the different teeth. The alveolar bone thickness was notably thicker on the palatal side for all tooth types and increased palatal from submillimeter on the crestal level to up to 3.77 mm for centrals, up to 4.56 mm for laterals and up to 5.43 mm for canines on the 9 mm level. On the buccal side, the bone thickness consistently averaged submillimeter readings, as low as 0.18 mm and rarely exceeding 0.5 mm on all levels.

Only three statistically significant different measurements were noted with females having less alveolar bone at 23P3 (mean difference (Xdif):0.61 mm, SE: 0.27, *T*-test, $p = 0.026$), 23P6 (Xdif $= -0.85$ mm, SE: 0.36, *T*-test, $p = 0.019$) and 22P9 (Xdif $= -1.03$ mm, SE: 0.48, *T*-test, $p = 0.034$). Only one statistically significant difference was noted with Whites having slightly more alveolar bone at 22B0 (Xdif $= -0.15$ mm, Mann–Whitney *U* test, $p = 0.000$) than Black subjects.

Table 2 shows the predominant alveolar bone locations where fenestrations were prevalent up to 33.8% and generally located on the buccal side. Isolated fenestrations were also observed palatal of teeth 22 and 23. Fenestrations occurred variably (from 4.23% for lateral incisors on a three-level up to 33.8% on level 9 for canines) on the buccal side with isolated fenestrations once occurring on the palatal side. Most notably, one in three canines had fenestrations on a nine-level on the buccal side.

4 | DISCUSSION

The present study assessed buccal and palatal bone dimensions in the anterior maxilla using a highly precise micro-CT imaging device. Measurements at different levels demonstrated that, in most locations of all six anterior maxillary teeth observed, the buccal bone wall was very thin, not exceeding 0.5 mm. Bundle bone or alveolar bone proper lines the tooth socket and is a tooth dependant structure with dimensions varying from 0.2 to 0.4 mm.[24] This implies that a bone wall of less than 0.5 mm is bundle bone only and will resorb after removal of the tooth. Values over threshold of 0.5 mm were only noted for lateral incisors at 9 mm level, which is in agreement with another micro-CT study of Kim et al., where laterals showed a bit thicker buccal bone plate, while rest of locations were less than 0.5 mm.[15] In most CBCT studies threshold of 1 mm was set for buccal bone thickness, as measurements of 0.5 mm and less were probably difficult to visualize using that imaging modality. However, Januário et al. assessed facial bone thickness in the anterior maxilla of 250 subjects using CBCT and reported bone wall thickness less than 0.5 mm in up to 60% of cases,[8] which is in agreement with our results. In contrary to our findings, one CT study showed a mean facial bone thickness for anterior maxillary teeth ranged from 1.41 to 1.73 mm.[7] Similarly, one recent systematic review and meta-analysis, that involved 47 studies assessed buccal bone thickness using CBCT, has also shown higher mean buccal bone thickness in the anterior maxilla, between 0.75 and 1.19 mm.[25] The literature review revealed a tendency that buccal bone wall appeared to be thicker (≥0.5 mm) in CBCT/CT studies compared to our findings. This could be explained with micro-CT being a more precise imaging modality, as the fussiness in CBCT or CT imaging may prevent such precise measurement, as it is hard to determine exact reference points. Behnia et al. investigated accuracy and reliability of CBCT for measurement of labial bone thickness in anterior teeth and concluded that it might be relatively accurate when alveolar bone is thicker than 1 mm.[26] Having abovementioned in mind, the methodology of CBCT studies could be questionable, as well as the reliability of those findings, as our results showed buccal bone thickness in the anterior maxilla to be beyond the limitations of CBCT.

In the present study, no significant difference was found regarding age, gender or race with regards to the buccal bone thickness, except for whites having slightly thicker buccal bone at the left lateral crestal level, which was not of clinical relevance. Several studies showed similar trend regarding gender independence,[9,27,28] while some authors reported males having significantly thicker buccal bone plate.[21,29] Demircan and Demircan[30] revealed males had significantly thicker bone plate only in lateral incisors, while females had significantly thicker bone at central incisors.[30] No explanation for this variation in results among studies could be given, except for a difference in sample sizes, populations and datasets. Contrary to our findings, a decrease in the thickness of the buccal bone in coronal level with increasing age was revealed in some previous research,[17,31–33] which was elucidated by local inflammatory processes, such as periodontal diseases, that may affect crestal bone plate in older subjects.[25] In our study, subjects with signs of bone loss due to periodontitis were excluded from the study. Literature review showed lack of information regarding buccal bone thickness among different ethnic groups. Only one study was found that assessed the thickness of the buccal bone in Africans using CBCT and demonstrated a thin bone plate in most subjects, though with no reference regarding race.[32]

The buccal bone thickness in the anterior maxilla is well documented in the literature, however for its counterpart on the palatal side less research interest was found. From a clinical perspective the palatal bone dimensions are equally important when placing immediate implants. It is well known that buccal bone dimensions are important for long-term soft tissue stability and aesthetic outcome, but dimensions on the palatal side are essential for possibility of immediate implant placement and achievement of sufficient primary stability. There is no consensus in the literature regarding the minimal palatal bone thickness for successful immediate implant placement in the anterior maxilla. This could be depended on the implant macro-design and length, as well as on the differences in the bone quality at the specific tooth sites. However, it could be speculated that alveolar bone on the palatal side has to be at least 4 mm thick at the alveolus level of 9 mm, to accommodate the tapered apex of the implant and gain sufficient primary stability by placing the implant in a palatal direction. Our findings revealed palatal bone being significantly thicker than the opposite buccal bone plate, with pattern of increase in thickness toward apical direction from submillimeter at the crestal level, up to 3.77 mm, 4.56 mm, and 5.43 mm at the 9 mm level for central incisors, lateral incisors and canines, respectively. No significance was found between gender or race, except that on a certain level, females had significantly less palatal bone on the left lateral incisor and canine than males. One CBCT study assessed palatal bone thickness in Asians, showing the mean thickness of 5.37 mm and 5.68 mm for centrals and laterals at the apex level, respectively, with males having significantly more bone compared to females.[34] Findings of another CBCT study revealed even thicker palatal bone plate within a Chinese population, 6.19 mm, 4.62 mm, and 6.30 mm for centrals, laterals and canines at the apical level, respectively.[35] Here again, a discrepancy between micro-CT and CBCT findings was observed in the literature, with notably higher values assessed by CBCT, which might be due to a difference in investigated populations. In many cases, the palatal bone was not thick enough to accommodate a more palatal placement of immediate implants in the anterior maxilla. Special attention should be given to the proximity of the maxillary incisive canal, as we observed large incisive canals with almost no bone on the palatal side of the central incisors. This would lead to perforation into the maxillary incisive canal if a more palatal placement protocol was followed.

In the present study, a missing buccal bone wall (fenestrations) was observed in up to 33.8% of cases. A CBCT study by Braut et al. assessing buccal bone thickness in the anterior maxillary teeth including premolars, found no existing bone wall in 25.7% of the cases. Inclusion of the premolars may explain their lower prevalence.[17] Our findings revealed up to 33% of canines had fenestrations on the buccal side at the 9 mm level, while centrals and laterals showed 10%–20%. This has clinical relevance, especially when flapless approach for immediate implants is considered.

In conclusion, clinicians performing immediate implants have to be aware of the limitations in bone dimensions in the anterior maxilla. In most cases, buccal bone thickness does not exceed 0.5 mm, often with inadequate bone thickness on the palatal side. Meticulous CBCT planning of each individual case is mandatory to achieve a satisfactory outcome. Additional bone and soft tissue augmentation procedures should be considered to avoid possible complications.

AUTHOR CONTRIBUTIONS

Vladimir S. Todorovic: design of the study, measurements of the sample, data sheets, monitoring of the study development, writing up the manuscript, approval of the manuscript for submission and submission procedure; **Thomas C. Postma**: statistical analysis of the data, interpretation of data, approval of the manuscript for submission; **Jakobus Hoffman**: preparation of the study sample, corrections of the draft before submission, approval of the manuscript for submission; **Andre W. van Zyl**: conceiving the idea, design of the study, monitoring of the study development, corrections of the draft before submission, and approval of the manuscript for submission.

FUNDING INFORMATION

The study was partially supported by the research grant No. 451-03-68/2022-14/200129 of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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How to cite this article: Todorovic VS, Postma TC, Hoffman J, van Zyl AW. Buccal and palatal alveolar bone dimensions in the anterior maxilla: A micro-CT study. *Clin Implant Dent Relat Res*. 2023;25(2):261-270. doi:10.1111/cid.13175

APPENDIX

TABLE A1 Descriptive analysis of alveolar bone measurement at different horizontal levels

Site	N	Min	Max	Median	X	SD	SE	95% CI L	95% CI U	Skew	Kur	KST Statistic	p Sig.
23P9	70	0.82	8.53	5.59	5.43	1.77	0.21	5.01	5.85	−0.15	−0.55	0.079	0.200*
23P6	71	0.80	7.97	3.77	3.83	1.37	0.16	3.50	4.15	0.20	0.40	0.057	0.200*
23P3	71	0.34	4.85	1.86	2.04	1.03	0.12	1.79	2.28	0.66	0.24	0.105	0.187
23P0	71	0.00	1.33	0.31	0.42	0.27	0.03	0.36	0.48	1.46	1.96	0.181	0.000
23B9	70	0.00	1.56	0.21	0.26	0.30	0.04	0.19	0.33	1.95	5.24	0.202	0.000
23B6	71	0.00	1.94	0.21	0.25	0.28	0.03	0.19	0.32	3.30	17.91	0.111	0.081
23B3	71	0.00	1.04	0.28	0.34	0.26	0.03	0.28	0.40	0.86	0.30	0.122	0.037
23B0	71	0.00	0.75	0.23	0.23	0.16	0.02	0.19	0.27	0.75	0.98	0.137	0.011
22P9	61	0.62	8.26	4.43	4.36	1.65	0.21	3.93	4.78	0.07	−0.50	0.069	0.200*
22P6	71	0.34	7.72	3.01	3.13	1.46	0.17	2.79	3.48	0.54	0.26	0.071	0.200*
22P3	71	0.22	4.01	1.57	1.70	0.93	0.11	1.48	1.92	0.47	−0.64	0.086	0.200*
22P0	71	0.00	1.34	0.29	0.39	0.30	0.04	0.32	0.46	1.67	2.20	0.249	0.000
22B9	61	0.00	2.47	0.47	0.58	0.52	0.07	0.45	0.72	1.15	1.79	0.129	0.021
22B6	71	0.00	2.02	0.23	0.36	0.39	0.05	0.27	0.45	1.93	4.92	0.183	0.000
22B3	71	0.00	1.88	0.30	0.42	0.36	0.04	0.34	0.51	1.59	3.42	0.172	0.000
22B0	71	0.00	1.21	0.21	0.24	0.18	0.02	0.20	0.29	2.48	11.16	0.158	0.001
21P9	67	0.48	7.30	3.94	3.77	1.39	0.17	3.43	4.11	−0.28	−0.05	0.079	0.200*
21P6	72	0.53	5.05	2.73	2.84	1.12	0.13	2.57	3.10	−0.04	−0.79	0.115	0.062
21P3	72	0.29	3.58	1.86	1.81	0.77	0.09	1.63	1.99	−0.05	−0.61	0.075	0.200*
21P0	72	0.15	1.63	0.35	0.49	0.36	0.04	0.41	0.58	1.65	2.14	0.235	0.000
21B9	67	0.00	1.89	0.37	0.43	0.38	0.05	0.34	0.52	1.48	3.25	0.129	0.022
21B6	72	0.00	1.35	0.34	0.36	0.28	0.03	0.30	0.43	1.15	1.81	0.115	0.064
21B3	72	0.00	1.26	0.43	0.46	0.26	0.03	0.40	0.52	0.89	0.86	0.139	0.009
21B0	72	0.00	0.77	0.21	0.21	0.15	0.02	0.18	0.24	1.08	2.96	0.169	0.000
13P9	71	0.24	8.89	5.16	5.37	1.87	0.22	4.92	5.81	−0.17	−0.35	0.126	0.028
13P6	72	1.04	6.45	3.74	3.77	1.27	0.15	3.47	4.06	−0.06	−0.12	0.057	0.200*
13P3	72	0.35	3.96	1.81	1.90	0.92	0.11	1.68	2.12	0.44	−0.51	0.123	0.035
13P0	72	0.11	1.48	0.28	0.39	0.28	0.03	0.32	0.45	2.13	4.70	0.256	0.000
13B9	71	0.00	1.02	0.19	0.21	0.23	0.03	0.16	0.27	1.26	1.63	0.187	0.000
13B6	72	0.00	0.65	0.21	0.22	0.16	0.02	0.18	0.25	0.67	0.06	0.100	0.0200*
13B3	72	0.00	0.97	0.25	0.29	0.21	0.02	0.24	0.34	1.21	1.44	0.210	0.000
13B0	72	0.00	0.47	0.18	0.18	0.13	0.01	0.16	0.21	0.04	−0.62	0.143	0.006
12P9	64	1.81	8.32	4.25	4.56	1.59	0.20	4.17	4.96	0.49	−0.51	0.091	0.200*
12P6	70	0.88	7.77	3.24	3.20	1.36	0.16	2.88	3.53	0.63	0.64	0.072	0.200*
12P3	71	0.25	3.51	1.62	1.72	0.90	0.11	1.50	1.93	0.29	−0.97	0.100	0.200*
12P0	71	0.08	1.52	0.30	0.42	0.32	0.04	0.34	0.50	1.72	2.56	0.197	0.000
12B9	64	0.00	3.12	0.61	0.65	0.55	0.07	0.51	0.79	1.68	5.28	0.113	0.074
12B6	70	0.00	1.79	0.23	0.32	0.31	0.04	0.25	0.39	2.11	6.60	0.161	0.001
12B3	71	0.00	1.63	0.34	0.44	0.32	0.04	0.37	0.52	1.21	1.82	0.129	0.021
12B0	71	0.00	0.87	0.22	0.22	0.14	0.02	0.18	0.25	1.60	5.93	0.131	0.017
11P9	63	0.23	7.03	3.33	3.63	1.53	0.19	3.25	4.01	−0.05	−0.65	0.101	0.200*
11P6	72	0.47	5.58	2.65	2.83	1.28	0.15	2.53	3.13	0.37	−0.58	0.083	0.200*

(Continues)

TABLE A1 (Continued)

Site	N	Min	Max	Median	X	SD	SE	95% CI L	95% CI U	Skew	Kur	KST Statistic	p Sig.
11P3	72	0.25	4.45	1.71	1.71	0.92	0.11	1.49	1.93	0.59	0.17	0.069	0.200*
11P0	72	0.14	1.81	0.36	0.53	0.39	0.05	0.44	0.62	1.31	0.99	0.238	0.000
11B9	63	0.00	1.55	0.33	0.40	0.34	0.04	0.32	0.49	1.06	1.12	0.129	0.021
11B6	72	0.00	1.76	0.32	0.42	0.38	0.04	0.33	0.51	1.65	3.11	0.135	0.013
11B3	72	0.00	1.21	0.37	0.42	0.24	0.03	0.36	0.48	0.84	1.11	0.092	0.200*
11B0	72	0.00	0.52	0.22	0.20	0.11	0.01	0.18	0.23	−0.14	0.07	0.092	0.200*

Abbreviations: CI, confidence interval; KST, Kolmogorov–Smirnov test.