ORIGINAL ARTICLE

UDC: 616.314-089.843
DOI: https://doi.org/10.2298/VSP221110032D

Cone beam computed tomography analysis of maxillary vestibular bone thickness in the aesthetic region

Debljina vestibularne koštane lamele maksile u estetskoj regiji analizirana primenom kompjuterizovane tomografije konusnog zraka

Milica Djurdjević*, Marija Bubalo[†‡], Ana Luković[§], Ana Igić[‖], Aleksandar Acović*, Tatjana Kanjevac[¶]

University of Kragujevac, Faculty of Medical Sciences, *Department of Dentistry, [§]Department of Surgery, Kragujevac, Serbia; [†]Military Medical Academy, Dental Clinic, Belgrade, Serbia; [‡]University of Defence, Faculty of Medicine of the Medical Military Academy, Belgrade, Serbia; [‖]University of Niš, Faculty of Medicine, Preventive and Pediatric Dentistry, Niš, Serbia; [¶]Institute of Dentistry, Kragujevac, Serbia

Abstract

Background/Aim. Insufficient buccal bone thickness (thickness less than 2 mm) frequently leads to fenestration and dehiscence, and their consequences are additional bone resorption. That represents an additional problem during implant placement. Cone beam computed tomography (CBCT) is becoming a priority in the diagnosis of bone thickness needed for implant placement since it has proven to be an accurate and largely reliable diagnostic tool in the image of morphology and buccal wall thickness. The aim of this study was to measure the vestibular bone thickness of the anterior maxillary region in the Serbian population and compare the difference between men and women, as well as between the left and right sides of the jaw. **Methods.** CBCT images of 68 patients were examined from the existing database. The length from the cementoenamel junction to the beginning of the alveolar bone was measured, followed by the thickness of the vestibular bone at various clinically relevant locations. The data were statistically processed and analyzed. **Results.** A total of 373 teeth of the frontal region of the upper jaw, including 128 central incisors, 124 lateral incisors, and 121 canines, were analyzed. The thickness of the buccal bone in more than 88% of cases was less than 1.5 mm at all reference points, with mean values from 0.72 to 1.02 mm. **Conclusion.** A very small number of maxillary teeth have a vestibular bone thickness greater than 2 mm; therefore, the criterion to provide at least 2 mm of thickness needed for implant placement is difficult to meet. That increases the use of auxiliary methods of bone augmentation during immediate implant placement.

Key words:
alveolar bone loss; cone-beam computed tomography; dental implantation; maxilla; serbia.

Apstrakt

Uvod/Cilj. Nedovoljna debljina bukalne kosti (debljina manja od 2 mm) često dovodi do fenestracije i dehiscencije, a njihove posledice su dodatna resorpcija kosti. To predstavlja dodatni problem prilikom ugradnje implantata. Kompjuterizovana tomografija konusnog zraka (KTKZ) postaje prioritet prilikom dijagnostikovanja debljine kosti i planiranju ugradnje implantata, jer se u pogledu morfologije i debljine vestibularne lamele pokazala kao precizan i u velikoj meri pouzdan dijagnostički alat. Cilj rada bio je da se izmeri debljina vestibularne koštane lamele prednjih maksilarnih zuba u populaciji Srbije i uporedi razlika između muškaraca i žena, kao i između leve i desne strane vilice. **Metode.** Analizirani su snimci KTKZ 68 ispitanika, iz postojeće baze podataka. Izmerena je udaljenost gleđno-cementne granice od vrha alveolarnog grebena, a zatim i debljina vestibularne lamele na različitim, klinički relevantnim tačkama. Podaci su statistički obrađeni i analizirani. **Rezultati.** Analizirano je ukupno 373 zuba frontalne regije gornje vilice, uključujući 128 centralnih sekutića, 124 lateralnih sekutića i 121 očnjak. Debljina vestibularne lamele kod više od 88% slučajeva bila je manja od 1,5 mm na svim referentnim tačkama, sa srednjim vrednostima od 0,72 do 1,02 mm. **Zaključak.** Veoma mali broj maksilarnih frontalnih zuba ima debljinu vestibularne lamele veću od 2 mm; stoga je teško ispuniti kriterijum da se obezbedi najmanje 2 mm debljine kosti potrebne za implantaciju. Ovim se povećava potreba za primenom pomoćnih metoda uvećanja kosti prilikom neposredne ugradnje implantata.

Ključne reči:
alveolna kost, gubitak; kompjuterizovana tomografija konusnog zraka; implantacija, stomatološka; maksila; srbija.

Correspondence to: Aleksandar Acović, University of Kragujevac, Faculty of Medical Sciences, Department of Dentistry, Svetozara Markovica 69, 34 000 Kragujevac, Serbia. E-mail: dr.acovic115@gmail.com

Introduction

The anterior maxillary region is the segment of the maxilla in which the four upper incisors and two canines are located. It encompasses the area between the right to the left first premolars and is also often referred to as the "aesthetic zone" [1]. The thickness of the cortical bone of both the maxilla and mandible varies; palatally and lingually, it is usually thicker compared to the vestibular areas [2]. Previous studies have noted that insufficient bone thickness (thickness less than 2 mm) leads to frequent fenestration and dehiscence [3]. The immediate implant placement has primacy when placing teeth in the "aesthetic zone", considering that implants serve as replacements for frontal teeth, and the therapeutic approach is most influenced by the factors examined in this study, but also the shape of the face, the inclination of the teeth, and the type of malocclusion [3, 4].

There is an increasing interest in immediate implant placement [5, 6]. The existing vestibular cortical bone will determine the application technique, more precisely, the thickness and height of the bone itself [6–8]. As previously mentioned, at least 2 mm of buccal bone (BB) thickness is necessary after the formation of the implant bed to achieve gum support and reduce additional bone resorption [9]. Bone augmentation procedures are recommended to obtain adequate bone contour when it is impossible to provide sufficient BB thickness [9, 10].

Up to now, several retrospective studies analyzed the thickness of the BB; in the majority of studies, the data show that this thickness is below 1 mm, in some cases even less than 0.5 mm, while the tooth is still present in the alveolus [11–13]. Loss of teeth will lead to additional bone resorption. Many authors suggest placing the implant at a greater distance from the BB to prevent changes in dimension [3].

Since its introduction, cone beam computed tomography (CBCT) has found a place in many branches of dentistry due to its advantages over conventional radiographic techniques [14]. CBCT is becoming a priority in the diagnosis and planning of oral and maxillofacial surgeries, as well as implant placement. Besides the three-dimensional representation and noninvasiveness, CBCT has a low radiation dose and high resolution. It has proven to be an accurate and largely reliable diagnostic tool in the image of morphology and buccal wall thickness [15]. Therefore, the CBCT is suitable for this type of research. The aim of this study was to measure the vestibular (buccal) bone thickness of anterior maxillary teeth in the Serbian population and compare the difference between men and women, as well as between the left and right sides of the jaw.

Methods

Sample selection

Images of 68 patients (36 women and 32 men, mean age 42 years, range 20–70 years) were examined with CBCT from the existing database. All recordings were made at the Department of Dentistry at the Medical Faculty of the University of Kragujevac, Serbia from October 25, 2014, to December 20, 2019. Ethical approval was obtained from the local Ethics Committee (No. 01-8735).

Patients were subjected to recording only in indicated cases, not for analysis of recordings for research purposes. The inclusion criteria were CBCT scans made during the diagnosis, therapy planning, and treatment in the cases of prosthetic, surgical, or orthodontic indications. The exclusion criteria were pregnancy, patients on chemotherapy, and radiation therapy. Patients with advanced periodontitis or a history of periodontitis were also excluded from the study. Teeth with large fillings, metal and ceramic crowns, endodontic treatment, and chronic inflammatory diseases of the periapex were not analyzed. Images that did not show the frontal teeth completely, on which the region of the examined teeth was cut or distorted for technical reasons, were excluded from the analysis.

Image analysis

The scans were done on an Orthophos XG 3D device (Sirona Dental Systems GmbH, Bensheim, Germany). All measurements were analyzed on a standard monitor (Philips LED monitor, 23 inches, 1,920 × 1,080 pixels); the analyzed field size was 8 × 8 cm. In the frontal region (the area of central incisors, lateral incisors, and canines), the thickness of the BB was analyzed, and the images were placed so that the cross-section of the sagittal and transversal plane passes through the longitudinal axis of the tooth, while the vertical plane adjusts to the set sections. The length from the cementoenamel junction (CEJ) to the beginning of the alveolar bone was measured, followed by the thickness of the BB at various clinically relevant locations. Two researchers analyzed the collected data. Using the "measure distance" tool and "measure along path" tool on the sagittal section, the following values were measured: 1) the distance of the CEJ from the beginning of the bone crest (BC), CEJ-BC; 2) the thickness of the facial plate at the beginning of BC; 3) the thickness of the facial plate at 2, 5, and 8 mm from BC (BC-2, BC-5, BC-8) (Figure 1).

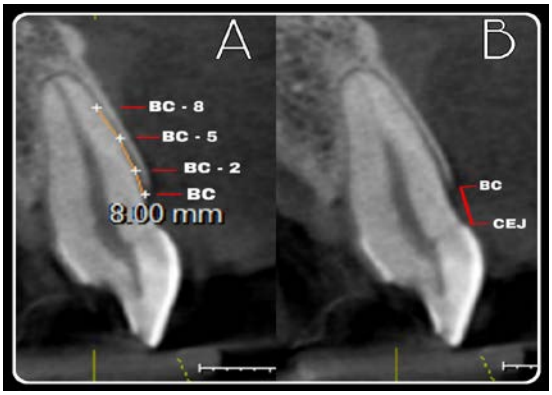

Fig. 1 – A) "Measure along path" tool was used to make points at the bone crest (BC), 2 mm, 5 mm, and 8 mm from BC. B) The distance of the cementoenamel junction (CEJ) from the beginning of BC ("measure distance" tool was used).

Statistical analysis

All the data were statistically analyzed with both descriptive and analytical tests using the software SPSS v20.0 (SPSS Inc., Chicago, IL, USA). Mann–Whitney *U* test, Friedman's test, and Wilcoxon signed-rank test were used to compare differences between measurements. The significance level was set at $p \leq 0.05$.

Results

The data from 68 patients were statistically processed, analyzing a total of 373 maxillary teeth of the frontal region, including 128 central incisors, 124 lateral incisors, and 121 canines. The mean value of the distance of the CEJ from the beginning of the bone was 2 mm, with the highest value observed on the lateral incisors, without a statistically significant difference between the groups (Table 1).

Table 2 shows the mean values of the distance of the CEJ from the beginning of the alveolar bone and the thickness of the BB of each analyzed tooth on the left and right sides. A significantly higher value between the left and right sides was observed on the left central incisors at BC ($p = 0.000$), BC-2 mm ($p = 0.001$), and BC-5 mm ($p = 0.003$). No statistically significant difference in BB thickness or the distance of the CEJ from the beginning of the alveolar bone was observed on the remaining teeth.

Table 3 shows the number and percentage of teeth in three categories (< 1.5 mm, 1.5–2.0 mm, and > 2 mm) concerning the BB thickness at defined reference points. The largest number of teeth (86–93%) had a BB thickness of less than 1.5 mm at all reference levels. The lowest prevalence of central incisors, lateral incisors, and canines was observed in the group > 2 mm, with the largest number of teeth within the group having a buccal wall thickness greater than 2 mm at the reference point BC-8 mm on lateral incisors (7.3%) and canines (3.3%).

In all groups (central incisors, lateral incisors, and canines), a significantly smaller thickness of the buccal wall on the BC point was shown compared to other measurement points ($p < 0.05$). At the BC-2 mm reference point, significantly less BB thickness was observed compared to BC-5 mm and BC-8 mm on the central incisors, and BC-5 mm on the lateral incisors (Table 4).

A comparison between the genders showed that the thickness of the buccal wall at all reference points was greater in men. The statistically most significant difference between men and women ($p = 0.000$) was present at BC-5 mm on the lateral incisors and BC-8 mm on the canines (Table 5).

Table 6 shows the values of Pearson and Spearman correlation coefficients. No correlation was found between the age of the subjects and the thickness of the buccal lamella of the upper jaw in the area of the front teeth.

Table 1

Distance between cementoenamel junction (CEJ) and bone crest (BC) and results of comparison between groups

Parameter	Central incisors	Lateral incisors	Canines
Number of teeth used	128	124	121
CEJ-BC, mm	2.04 ± 0.80	2.05 ± 0.88	2.1 ± 0.81

Values are presented as mean ± standard deviation.
***Statistically not significant ($p > 0.05$, *t*-tests).**

Table 2

The buccal bone thicknesses of the upper anterior teeth and results of comparison between the left and right side

Parameter	Central incisors		Lateral incisors		Canines	
	left side	right side	left side	right side	left side	right side
Tooth number	11	21	12	22	13	23
Number of teeth used	65	63	63	61	63	58
CEJ-BC distance	1.98 ± 0.92	2.04 ± 0.77	2.15 ± 0.92	2.01 ± 0.81	2.16 ± 0.88	2.07 ± 0.72
BC	0.63 ± 0.20	0.81 ± 0.39*	0.7 ± 0.35	0.81 ± 0.39	0.78 ± 0.35	0.81 ± 0.28
BC-2 mm	0.75 ± 0.30	0.86 ± 0.26*	0.97 ± 0.42	1.08 ± 1.09	0.91 ± 0.4	0.96 ± 0.5
BC-5 mm	0.76 ± 0.36	0.87 ± 0.35*	0.81 ± 0.44	0.87 ± 0.46	0.86 ± 0.38	0.92 ± 0.6
BC-8 mm	0.94 ± 0.57	1.00 ± 0.5	0.93 ± 0.52	1.04 ± 0.64	0.85 ± 0.36	0.95 ± 0.61

CEJ – cementoenamel junction; BC – bone crest. Values (in mm) are presented as mean ± standard deviation.
***Statistically significant difference between right and left side, $p \leq 0.05$ (Mann–Whitney *U* test).**

Table 3

The buccal bone thickness within three categories at different levels

Parameter	Central incisors			Lateral incisors			Canines		
	< 1.5	1.5–2	> 2	< 1.5	1.5–2	> 2	<1.5	1.5–2	> 2
BC	125 (97.7)	2 (1.6)	1 (0.8)	120 (96.8)	1 (0.8)	3 (2.4)	119 (98.3)	1 (0.8)	1 (0.8)
BC-2 mm	125 (97.7)	3 (2.3)	0 (0)	110 (88.7)	12 (9.7)	2 (1.6)	108 (89.3)	10 (8.3)	3 (2.5)
BC-5 mm	119 (93)	8 (6.1)	1 (0.8)	110 (88.7)	11 (8.9)	3 (2.4)	111 (91.7)	9 (7.4)	1 (0.8)
BC-8 mm	119 (93)	8 (6.1)	1 (0.8)	107 (86.3)	8 (6.5)	9 (7.3)	109 (90.1)	8 (6.0)	4 (3.3)
Total	122 (95.3)	6 (4.4)	0 (0)	116 (93.4)	6 (4.4)	2 (1.6)	116 (95.9)	4 (3.3)	1 (0.8)

BC – bone crest. < 1.5 – less than the required thickness; 1.5–2 – minimally required thickness; > 2 – preferable required thickness. All values (in mm) are expressed as numbers (percentages).

Table 4

Results of comparison between buccal bone thickness at different levels

Parameter	Central incisors	Lateral incisors	Canines
Number of teeth used	128	124	121
BC	0.72 ± 0.32[a]	0.76 ± 0.37[a]	0.79 ± 0.32[a]
BC-2 mm	0.81 ± 0.29[b]	1.02 ± 0.83[b]	0.94 ± 0.45[b]
BC-5 mm	0.82 ± 0.36[c]	0.86 ± 0.43[c]	0.89 ± 0.50[b]
BC-8 mm	0.99 ± 0.54[d]	0.97 ± 0.59[b]	0.90 ± 0.50[b]
**p*-value	≤ 0.001	≤ 0.001	≤ 0.005

BC – bone crest. Values (in mm) are presented as mean ± standard deviation.
***Significant at $p \leq 0.05$ (Friedman's test, Wilcoxon signed-rank test, Bonferroni's correction). Different letters in the same column represent statistically significant differences among groups (BC, BC-2, BC-5, BC-8). A statistically significant difference exists between the groups for each tooth when they are labeled with distinct letters in the table. If the groups are marked with the same letter, there is no statistically significant difference between them.**

Table 5

Thickness of buccal plate of maxillary anterior and results of comparison between males and females

Parameter	Females	Males	*p*-value
Central incisors			
number of teeth used	66	62	
BC	0.67 ± 0.20	0.78 ± 0.41	0.217
BC-2 mm	0.80 ± 0.31	0.82 ± 0.27	0.539
BC-5 mm	0.79 ± 0.37	0.86 ± 0.34	0.044*
BC-8 mm	0.94 ± 0.55	1.03 ± 0.52	0.299
Lateral incisors			
number of teeth used	68	56	
BC	0.70 ± 0.33	0.83 ± 0.41	0.013*
BC-2 mm	0.86 ± 0.30	1.22 ± 1.15	0.002*
BC-5 mm	0.70 ± 0.30	1.06 ± 0.49	0.000*
BC-8 mm	0.83 ± 0.48	1.14 ± 0.66	0.001*
Canines			
number of teeth used	63	58	
BC	0.77 ± 0.35	0.83 ± 0.28	0.084
BC-2 mm	0.83 ± 0.41	1.05 ± 0.47	0.002*
BC-5 mm	0.81 ± 0.57	0.99 ± 0.39	0.001*
BC-8 mm	0.78 ± 0.51	1.03 ± 0.45	0.000*

BC – bone crest. Values (in mm) are presented as mean ± standard deviation.
***Significant at $p \leq 0.05$ (Mann-Whitney *U* test).**

Table 6

Correlation coefficients between age and the buccal bone thickness of the alveolar bone measurement points in the maxillary anterior teeth

Measurement points	Age	
	Spearman's rho	*p*-value*
Central incisors		
BC	0.69	0.733
BC-2 mm	0.128	0.475
BC-5 mm	0.59	0.914
BC-8 mm	-0.201	0.112
Lateral incisors		
BC	0.372	0.497
BC-2 mm	0.247	0.090
BC-5 mm	0.131	0.324
BC-8 mm	0.11	0.673
Canines		
BC	-0.13	0.898
BC-2 mm	0.33	0.909
BC-5 mm	-0.003	0.969
BC-8 mm	-0.62	0.737

BC – bone crest. *Pearson correlation is significant at 0.01 level.

Discussion

It is known that in 80% of cases, the tooth roots are located next to the buccal plate, in the anterior maxillary region, and in 87% of cases, its thickness is less than 1 mm (average value is 0.8 mm), while in only 3% of cases, the thickness is 2 mm. Dehiscence or fenestration of the buccal plate due to vertical root fracture, endodontic complications, or tooth extraction is common. A thin or damaged buccal plate, 0.5–0.6 mm thick, is predominantly present in the extraction sockets of the anterior maxillary region [3, 16–18]. In patients where immediate implants should be placed, the buccal plate is missing in 24–57% of cases, which correlates with a greater gingival recession [3].

Since the buccal plate is essential for the long-term stability of the gingival margin, placing the implant in sockets with an insufficient buccal plate, without bone augmentation, would result in a gingival recession [19].

Regardless of the diversity of the implant system, the correct three-dimensional position is the most important in terms of the aesthetic outcome of the treatment. Satisfactory height and width of facial bones can ensure the implant's long-term stability [20, 21]. In addition to stability, the height and the width of the buccal alveolar bone have an impact on the soft tissues that cover them, especially the interdental papilla [22–26]. A better aesthetic effect and lower frequency of gingival recession were observed after implantation in sockets with higher alveolar bone height and in thicker bone biotypes [27].

According to the results of this study, the distance of the CEJ from the beginning of the alveolar bone was 2–3 mm, confirming the statement that the head of the implant should be placed 3 mm below the imaginary line that joins the CEJ of adjacent teeth [28, 29].

The analysis of this study showed that the thickness of the BB in the anterior maxilla, in more than 88% of cases, was less than 1.5 mm at all reference points, with mean values from 0.72 to 1.02 mm. Similar results were found by Sheerah et al. [3], wherein the group of less than 1.5 mm were 88.7% of central incisors, 83.3% of lateral incisors, and 95.2% of canines. Slightly lower values were shown by Rangari et al. [10], who found 32–53% of central and lateral incisors and 36–58% of canines in the group < 1 mm.

BB thickness of less than 1 mm was observed in the area of central incisors, lateral incisors, and canines on all teeth except at reference point BC-8, where the value was slightly above 1 mm. Similar values were observed in other studies, and, in these cases, placing the implant more palatal is suggested, as the BB plate is thin. It is important to place the implant shaft to match the incisal edges of adjacent teeth or to place it more palatal in relation to the mentioned landmark, which leads to the possibility of bone perforation [28, 29].

In this study, the analysis showed that thicker BB (mean thickness of > 2 mm) was present in only 0–0.8% of central incisors, 1.6–2.4% at all reference points except BC-8 where thicker bone was found in as much as 7.3%, while on the canines it occurred in 0.8–3.3%. Similar results have been shown in other studies [6, 30]. Compared to the available literature, a higher prevalence was observed in the study of Fuentes et al. [31] in central incisors (14.4%), lateral incisors (6.2%), and canines (9%); Ghassemian et al. [32] presented similar results. Different results may be due to differences in the surveyed populations, the number of respondents, and many other factors. On the other hand, a minimum buccal plate thickness of 2 mm proved to be an essential feature for maintaining the vertical dimension after tooth extraction [33]. Studies examining gender and age differences have shown that these factors might be important when planning immediate implant placement [34, 35], while the effect of systemic diseases was not statistically significant at the reference point 8 mm from the alveolar bone crest [36]. In this study, a statistically significant difference between men and women was also confirmed, and the women had a significantly smaller BB plate thickness than males.

A statistically significant difference between the left and right sides was present between the central incisors at the alveolar bone crest and the distance of 2 mm and 5 mm from it. There were no statistically significant differences between the left and right sides of the remaining teeth, which coincides with the data from the literature [6, 37]. Similar to the results of other studies, there was no correlation between age and buccal plate thickness of the aesthetic region [6, 30].

A limitation in the present study, and one common to similar studies using CBCT measurements, is the unreliability of the images when measuring bone plate thinner than 1 mm. Behnia et al. [38] evaluated that CBCT is very accurate when measuring bone thickness greater than 1 mm, while radiographic measurement of smaller dimensions more often overestimates bone thickness compared to direct measurement using calipers. Another potential limitation is the small sample size. A larger number of patients is needed to obtain more valid results, considering that a certain number of patients did not have all the teeth in the aesthetic region.

Conclusion

This study shows that a very small number of maxillary teeth have a BB thickness > 2 mm, and thus, it can be concluded that the bone in the area of the anterior maxillary teeth is mostly thin. Therefore, the criterion to provide at least 2 mm of thickness is difficult to meet, which increases the use of auxiliary methods of bone augmentation during immediate implant placement. Consequently, CBCT scans are highly recommended for implantation planning to minimize complications and observe the critical dimensions of the BB before starting surgical therapy.

R E F E R E N C E S

1. *Trevizan M, Consolaro A.* Premaxilla: an independent bone that can base therapeutics for middle third growth! Dental Press J Orthod 2017; 22(2): 21–6.
2. *Garib DG, Yatabe MS, Ozawa TO, da Silva Filho OG.* Alveolar bone morphology under the perspective of the computed tomography: Defining the biological limits of tooth movement. Dental Press J Orthod 2010; 15(5): 192–205.
3. *Sheerah H, Othman B, Jaafar A, Alsharif A.* Alveolar bone plate measurements of maxillary anterior teeth: a retrospective cone beam computed tomography study, AlMadianh, Saudi Arabia. Saudi Dent J 2019; 31(4): 437–44.
4. *Morad G, Behnia H, Motamedian SR, Shahab S, Gholamin P, Khosraviani K,* et al. Thickness of labial alveolar bone overlying healthy maxillary and mandibular anterior teeth. J Craniofac Surg 2014; 25(6): 1985–91.
5. *Naghibi N, Fatemi K, Hoseini-Zarch SH, Sadeghi B, Fasihi Ramandi M.* CBCT evaluation of buccal bone thickness in the aesthetic zone of menopausal women: A cross-sectional study. Clin Exp Dent Res 2022; 8(5): 1076–81.
6. *London RM.* The esthetic effects of implant platform selection. Compend Contin Educ Dent 2001; 22(8): 675–82; quiz 683.
7. *Zhou Z, Chen W, Shen M, Sun C, Li J, Chen N.* Cone beam computed tomographic analyses of alveolar bone anatomy at the maxillary anterior region in Chinese adults. J Biomed Res 2014; 28(6): 498–505.
8. *Zhang X, Li Y, Ge Z, Zhao H, Miao L, Pan Y.* The dimension and morphology of alveolar bone at maxillary anterior teeth in periodontitis: a retrospective analysis-using CBCT. Int J Oral Sci 2020; 12(1): 4.
9. *Becker W, Sennerby L, Bedrossian E, Becker BE, Lucchini JP.* Implant stability measurements for implants placed at the time of extraction: a cohort, prospective clinical trial. J Periodontol 2005; 76(3): 391–7.
10. *Rangari P, Singh U, Singh N, Dewangan A.* A Retrospective Study Evaluating the Anterior Bone Wall Thickness Using Cone Beam Computed Tomography Images with a Three Dimensional Software. J Med Sci Clin Res 2018; 6(4): 849–54.
11. *Arango E, Plaza-Ruíz SP, Barrero I, Villegas C.* Age differences in relation to bone thickness and length of the zygomatic process of the maxilla, infrazygomatic crest, and buccal shelf area. Am J Orthod Dentofacial Orthop 2022; 161(4): 510–8. e1.
12. *El Nahass H, N Naiem S.* Analysis of the dimensions of the labial bone wall in the anterior maxilla: a cone-beam computed tomography study. Clin Oral Implants Res 2015; 26(4): e57–61.
13. *Al-Haj Husain A, Stadlinger B, Özcan M, Schönegg D, Winklhofer S, Al-Haj Husain N,* et al. Buccal bone thickness assessment for immediate anterior dental implant planning: A pilot study comparing cone-beam computed tomography and 3D double-echo steady-state MRI. Clin Implant Dent Relat Res 2023; 25(1): 35–45.
14. *Venkatesh E, Elluru SV.* Cone beam computed tomography: basics and applications in dentistry. J Istanb Univ Fac Dent 2017; 51(3 Suppl 1): S102–21.
15. *Khoury J, Ghosn N, Mokbel N, Naaman N.* Buccal Bone Thickness Overlying Maxillary Anterior Teeth: A Clinical and Radiographic Prospective Human Study. Implant Dent 2016; 25(4): 525–31.
16. *Braut V, Bornstein MM, Belser U, Buser D.* Thickness of the anterior maxillary facial bone wall- a retrospective radiographic study using cone beam computed tomography. Int J Periodontics Restorative Dent 2011; 31(2): 125–31.
17. *Vera C, De Kok IJ, Reinhold D, Limpiphipatanakorn P, Yap AK, Tyndall D,* et al. Evaluation of buccal alveolar bone dimension of maxillary anterior and premolar teeth: a cone beam computed tomography investigation. Int J Oral Maxillofac Implants 2012; 27(6): 1514–9.
18. *Chen ST, Darby I.* The relationship between facial bone wall defects and dimensional alterations of the ridge following flapless tooth extraction in the anterior maxilla. Clin Oral Implants Res 2017; 28(8): 931–7.
19. *Kuchler U, Chappuis V, Gruber R, Lang NP, Salvi GE.* Immediate implant placement with simultaneous guided bone regeneration in the esthetic zone: 10-year clinical and radiographic outcomes. Clin Oral Implants Res 2016; 27(2): 253–7.
20. *Belser UC, Buser D, Hess D, Schmid B, Bernard JP, Lang NP.* Aesthetic implant restorations in partially edentulous patients - a critical appraisal. Periodontol 2000 1998; 17: 132–50.
21. *Buser D, von Arx T.* Surgical procedures in partially edentulous patients with ITI implants. Clin Oral Implants Res 2000; 11(Suppl 1): 83–100.
22. *Tarnow DP, Magner AW, Fletcher P.* The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol 1992; 63(12): 995–6.
23. *Choquet V, Hermans M, Adriaenssens P, Daelemans P, Tarnow DP, Malevez C.* Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. J Periodontol 2001; 72(10): 1364–71.
24. *Ryser MR, Block MS, Mercante DE.* Correlation of papilla to crestal bone levels around single tooth implants in immediate or delayed crown protocols. J Oral Maxillofac Surg 2005; 63(8): 1184–95.
25. *Palmer RM, Farkondeh N, Palmer PJ, Wilson RF.* Astra Tech single-tooth implants: an audit of patient satisfaction and soft tissue form. J Clin Periodontol 2007; 34(7): 633–8.
26. *Lops D, Chiapasco M, Rossi A, Bressan E, Romeo E.* Incidence of inter-proximal papilla between a tooth and an adjacent immediate implant placed into a fresh extraction socket: 1-year prospective study. Clin Oral Implants Res 2008; 19(11): 1135–40.
27. *Le BT, Borzabadi-Farahani A.* Labial Bone Thickness in Area of Anterior Maxillary Implants Associated with Crestal Labial Soft Tissue Thickness. Implant Dent 2012; 21(5): 406–10.
28. *Langer B, Sullivan DY.* Osseointegration: its impact on the interrelationship of periodontics and restorative dentistry. Part 3. Periodontal prosthesis redefined. Int J Periodontics Restorative Dent 1989; 9(4): 240–61.
29. *Lee SL, Kim HJ, Son MK, Chung CH.* Anthropometric analysis of maxillary anterior buccal bone of Korean adults using cone-beam CT. J Adv Prosthodont 2010; 2(3): 92–6.
30. *Nowzari H, Molayem S, Chiu CH, Rich SK.* Cone beam computed tomographic measurement of maxillary central incisors to determine prevalence of facial alveolar bone width ≥2 mm. Clin Implant Dent Relat Res 2012; 14(4): 595–602.
31. *Fuentes R, Flores T, Navarro P, Salamanca C, Beltrán V, Borie E.* Assessment of buccal bone thickness of aesthetic maxillary region: a cone-beam computed tomography study. J Periodontal Implant Sci 2015; 45(5): 162–8.
32. *Ghassemian M, Nowzari N, Lajolo C, Verdugo F, Pirronti T, D'Addona A.* The thickness of facial alveolar bone overlying healthy maxillary anterior teeth. J. Periodontol 2012; 83(2): 187–97.
33. *Belser U, Martin W, Jung R, Hämmerle C, Schmid B, Morton D,* et al. Implant therapy in the esthetic zone: single-tooth replacements. In: *Buser D, Belser U, Wismeijer D*, editors. ITI Treatment Guide Series, Volume 1. Berlin (DE): Quintessence Publishing Co. Ltd.; 2006. p. 268.
34. *Boskey AL, Coleman R.* Aging and bone. J Dent Res 2010; 89(12): 1333–48.

35. *Kelly PJ, Twomey L, Sambrook PN, Eisman JA*. Sex differences in peak adult bone mineral density. J Bone Miner Res 1990; 5(11): 1169–75.
36. *Farahamnd A, Sarlati F, Eslami S, Ghassemian M, Youssefi N, Jafarzadeh Esfahani B*. Evaluation of Impacting Factors on Facial Bone Thickness in the Anterior Maxillary Region. J Craniofac Surg 2017; 28(3): 700–5.
37. *Zekry A, Wang R, Chau AC, Lang NP*. Facial alveolar bone wall width - a cone-beam computed tomography study in Asians. Clin Oral Implants Res 2014; 25(2): 194–206.
38. *Behnia H, Motamedian SR, Kiani MT, Morad G, Khojasteh A*. Accuracy and reliability of cone beam computed tomographic measurements of the bone labial and palatal to the maxillary anterior teeth. Int J Oral Maxillofac Implants 2015; 30(6): 1249–55.

Received on November 10, 2022
Revised on May 12, 2023
Accepted on May 23, 2023
Online First June 2023