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CONE-BEAM COMPUTED TOMOGRAPHY ASSESSMENT OF THE BUCCAL BONE THICKNESS IN ANTERIOR MAXILLARY AND MANDIBULAR TEETH

PROCENA DEBLJINE BUKALNE LAMELE MAKSILE I MANDIBULE U PREDELU PREDNJIH ZUBA POMOĆU KOMPJUTERIZOVANE TOMOGRAFIJE KONUSNOG SNOPA

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Summary

Introduction. The aim of this study was to assess the buccal bone thickness in anterior maxillary and mandibular teeth and to provide information important during immediate implant placement. **Material and Methods**. The study included 245 cone-beam computed tomography scans. The buccal bone thickness was measured in the sagittal plane of the maxillary and mandibular anterior teeth at five points (M1 - M5) (2 mm apart), starting 2 mm from the cementoenamel junction in the coronal to apical position along the roots. **Results**. The lowest mean buccal bone thickness was observed at M1 point in all teeth in both jaws while the highest mean buccal bone thickness was observed at M4 (maxilla) and M5 (mandible). An increase of the buccal bone thickness was established at every subsequent measurement point perpendicular to the long axis of the tooth ($p < 0.001$). The buccal bone thickness was less than 1 mm in more than 60% of all teeth in the maxilla and mandible at all measurement points. A statistically significant difference in the thickness of the buccal bone in relation to the patients' age was found at all measurement points, except at M4 point of the anterior teeth of the maxilla ($p = 0.456$) and mandible ($p = 0.109$). **Conclusion**. The buccal bone thickness in anterior maxillary and mandibular teeth is less than 1 mm in more than 60% at all measurement points. The buccal bone thickness tends to increase from a coronal to apical position along the roots.

Key words: Cone-Beam Computed Tomography; Alveolar Process; Incisor; Esthetics, Dental; Immediate Dental Implant Loading; Alveolar Bone Loss; Bone Resorption; Gingival Recession

Sažetak

Uvod. Cilj istraživanja je bio izmeriti debljinu bukalne lamele u predelu prednjih zuba gornje i donje vilice i obezbediti informacije koje su značajne prilikom imedijatne ugradnje implantata. **Materijal i metode.** U istraživanju je analizirano 245 snimaka urađenih pomoću konusnog snopa kompjuterizovane tomografije. Merenje debljine bukalne lamele je obavljeno na sagitalnom preseku maksilarnih i mandibularnih prednjih zuba na pet tačaka (M1-M5) (udaljenih 2 mm jedna od druge), počevši 2 mm od cementno-gleđne granice u koronarno-apikalnom pravcu duž korena zuba. **Rezultati.** Najniža srednja vrednost debljine bukalne lamele uočena je na M1 mernoj tački na svim zubima u obe vilice, dok su najveće srednje vrednosti bile na M4 (maksila) i M5 (mandibula). Sa svakom sledećom tačkom merenja uzdužno uz osu zuba dolazi do povećanja vrednosti debljine bukalne lamele ($p < 0,001$). Debljina bukalne lamele je manja od 1 mm u više od 60% tačaka merenja, na svim prednjim zubima maksile i mandibule. Statistički značajna razlika debljine bukalne lamele u odnosu na starost pacijenta je bila na svim mernim tačkama osim na tački M4 prednjih zuba maksile ($p = 0,456$) i mandibule ($p = 0,109$). **Zaključak.** Maksilarni i mandibularni prednji zubi imaju debljinu bukalne lamele manju od 1 mm u više od 60% svih tačaka merenja. Debljina bukalne lamele ima tendenciju povećanja debljine u koronarno-apikalnom pravcu duž korena zuba.

Ključne reči: kompjuterizovana tomografija sa konusnim snopom; alveolarni nastavak; sekutić; dentalna estetika; imedijantno opterećenje implantata; gubitak alveolarne kosti; resorpcija kosti; povlačenje desni

Introduction

Immediate implant placement, defined as the placement of dental implant immediately into fresh extraction socket site after tooth extraction, has advantages over early and delayed placement. In addition to the reduction of treatment time, number of interventions, and patient discomfort, the main advantages include soft and hard tissues conservation after tooth extraction [1, 2]. Furthermore, there is no difference in the survival rates between implants placed with immediate placement protocol and other protocols [3].

However, lack of success in achieving desirable esthetic outcomes due to recession of buccal mucosa is still one of the most common complications when it comes to immediate implant placement. Adequate

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Abbreviations

BBT – buccal bone thickness
CBCT – cone-beam computed tomography
CEJ – cementoenamel junction

buccal bone and soft tissue thickness are essential for long-term esthetic outcomes [4].

Soft tissue thickness has been shown to be dependent on the thickness of the underlying bone. The presence of minimum buccal bone thickness (BBT) of 2 mm is critical for the maintenance of the vertical dimension of the alveolar crest after tooth extraction and soft tissue stability [5–7]. Also, thin buccal bone may cause a local risk associated with significantly greater vertical bone resorption over time and subsequent gingival recession [8].

The bone resorption is rapid in the three-month period compared to the following nine months [9]. Both buccal and palatal bone plates show bone loss after tooth extraction. The buccal bone plate is more affected since the resorption is more severe where the walls are initially thinner and composed mainly of bundle bone. There is more reduction in the width than in the height of the residual alveolar ridge after tooth extraction [10, 11].

Various techniques have been proposed to overcome the limitations of a thin buccal bone. The bone resorption may be reduced by using bone graft barrier membranes when the BBT is less than 2 mm [12]. The socket shield technique has positive effects on the changes in width and height of buccal bone plate and may be a good alternative in terms of alveolar bone maintenance [13, 14].

Despite immediate implant placement, the remodeling of the alveolar bone is an inevitable process. However, the resorption degree is in correlation with initial BBT and, therefore, the treatment outcomes [15, 16].

Considering the significance of the buccal cortical bone thickness as one of the risk factors for esthetic outcome after immediate implant placement, it is of great importance to perform a precise bone assessment prior to performing any surgical procedure. Cone beam computed tomography (CBCT) offers high-resolution and cross-sectional imaging. This is an imaging technique that enables accurate bone structure measurements and comprehensive preoperative implant site assessment. Nowadays, CBCT has become a method of choice in dental implant treatment planning [17, 18].

In this study, CBCT images were used to evaluate the BBT in the anterior maxillary and mandibular teeth. The objective was to find the correlation between the BBT in regard to patients' age and gender. The study aimed to provide more quantitative information about maxillary and mandibular anterior area thickness in order to help immediate implantation planning.

Material and Methods

After the study was approved by the Scientific Ethics Committee of the Faculty of Medicine, University of Banja Luka (18/4.6/20), CBCT scans were collected and analyzed using the Planmeca ProMax 3D Classic (Planmeca, Finland) with a voxel size (VS) of 0.2 mm and maximum field of view (FOV) 110 × 80 mm. The study was designed as a retrospective study to evaluate BBT of the anterior maxillary and mandibular teeth. The CBCT scans were done for various clinical reasons between January 2018 and December 2018.

The inclusion criteria for the study were: high-resolution images, presence of maxillary and mandibular anterior teeth (left canine to right canine), no severe periodontal bone loss, and no periapical diseases.

The exclusion criteria were: scans with poor image definition, presence of severe periodontal bone loss, periapical diseases, previous apical surgery, root resorption. Supernumerary, misaligned and crowded teeth in the anterior region were excluded, since accurate measurements could not be obtained.

The measurement of BBT was conducted in the buccal-oral direction of the maxilla: right side - central incisor (11), lateral incisor (12), canine (13) and left side: central incisor (21), lateral incisor (22), canine (23); and mandibula: left side - central incisor (31), lateral incisor (32), canine (33) and right side - central incisor (41), lateral incisor (42), canine (43).

For each tooth, measurements were taken at five points (M1 - M5), starting 2 mm from the cementoenamel junction (CEJ). Every subsequent measurement point was recorded with a 2 mm distance from the previous measurement point perpendicular to the long axis of the tooth **(Figures 1** and **2)**. The measurement of the BBT was performed in the sagittal plane.

All CBCT images were analyzed by two trained observers. If differences in measurements were found, an average of two measurements was calculated.

The statistical analysis was performed using Statistical Package for the Social Sciences (IBM SPSS statistics 25.0, IBM Corporation, New York, United States) at a 5% significance level. The data were presented with descriptive statistics. The normality of distribution was assessed using Shapiro-Wilks test. Kruskal Wallis and Mann-Whitney tests were used for quantitative and continuous variables.

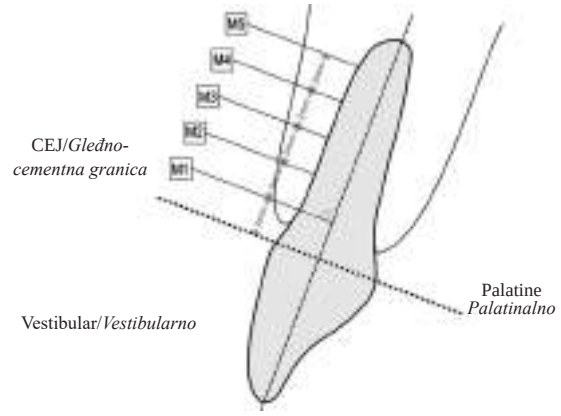

Figure 1. Representation of BBT measurements of the anterior maxillary teeth. Measurements were done at five points (M1 – M5), starting 2 mm from CEJ
Slika 1. *Prikaz merenja debljine bukalne lamele maksilarnih prednjih zuba. Merenja su beležena na pet tačaka (M1 – M5), počevši 2 mm od cementno-gleđne granice*

Results

A total of 245 CBCT scans were included in this study, 131 (53.47%) males and 114 (46.53%) females. The mean age of all patients was 45.5 years (mean age for males 47.00 ± 13.68; mean age for females 45.00 ± 14.42).

Table 1 and **Table 2** present descriptive statistics for BBT per tooth at M1, M2, M3, M4 and M5. The lowest mean BBT was observed at the M1 measurement point in all teeth in both jaws (maxilla and mandible). There was an increase in BBT perpendicular to the long axis of the tooth with every subsequent measurement point ($p < 0.001$). The highest mean BBT was at M4 (maxilla) and M5 (mandible) measurement points **(Table 1)**.

Table 2 shows that BBT was thinner than 1 mm in more than 60% of all teeth in the maxilla and mandible at all measurement points. Furthermore, BBT was thinner than 1 mm in more than 90% at measurement points M1 and M2. In the maxilla, the incidence of BBT thicker than 1 mm was more than 25% only at the M3 measurement point. This incidence was even lower in the mandible. The incidence of BBT thicker than 2 mm was very rare, and it was found mostly at the M5 measurement point **(Table 2)**.

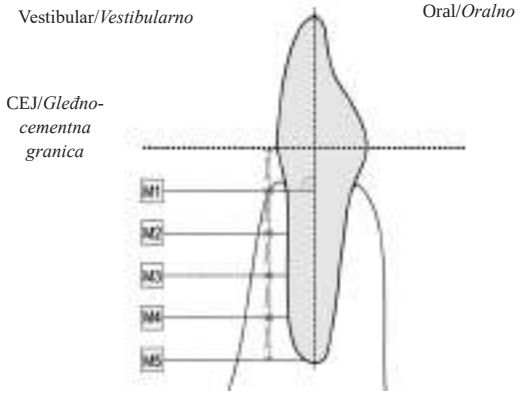

Figure 2. Representation of BBT measurements of the anterior mandibular teeth. Measurements were done at five points (M1 – M5), starting 2 mm from CEJ
Slika 2. *Prikaz merenja debljine bukalne lamele mandibularnih prednjih zuba. Merenja su beležena na pet tačaka (M1-M5), počevši 2 mm od cementno-gleđne granice*

Table 1. BBT of maxillary and mandibular anteriror teeth at each point of measurement
Tabela 1. *Debljina bukalne lamele maksilarnih i mandibularnih prednjih zuba na svim tačkama merenja*

Tooth *Zub*	M1			M2			M3			M4			M5			p/*p*
	Mean/ *Srednja* ± SD	Min *Minimun*	Max *Maksimum*	Mean/ *Srednja* ± SD	Min *Minimun*	Max *Maksimum*	Mean/ *Srednja* ± SD	Min *Minimun*	Max *Maksimum*	Mean/ *Srednja* ± SD	Min *Minimun*	Max *Maksimum*	Mean/ *Srednja* ± SD	Min *Minimun*	Max *Maksimum*	
11	0.034 ± 0.172	0.000	1.170	0.219 ± 0.421	0.000	1.520	0.758 ± 0.504	0.000	1.810	0.915 ± 0.375	0.000	2.040	0.911 ± 0.384	0.000	2.510	<**0.001**
12	0.024 ± 0.168	0.000	1.610	0.191 ± 0.431	0.000	2.210	0.731 ± 0.597	0.000	2.610	0.885 ± 0.475	0.000	2.210	0.861 ± 0.385	0.000	2.200	<**0.001**
13	0.016 ± 0.113	0.000	0.800	0.168 ± 0.450	0.000	3.620	0.671 ± 0.661	0.000	4.420	0.892 ± 0.535	0.000	3.690	0.818 ± 0.440	0.000	2.600	<**0.001**

Legenda: SD – standardna devijacija
*Shows significantly higher proportion at 5% level of significance/**Pokazuje značajno veće vrednosti na nivou značajnosti od 5%*

Table 2. Distribution of BBT (%) for maxillary and mandibular anterior teeth
Tabela 2. *Raspodela debljine bukalne lamele u procentima za maksilarne i mandibularne prednje zube*

Tooth *Zub*	< 1 mm					1 – 2 mm					> 2 mm				
	M1 (%)	M2 (%)	M3 (%)	M4 (%)	M5 (%)	M1 (%)	M2 (%)	M3 (%)	M4 (%)	M5 (%)	M1 (%)	M2 (%)	M3 (%)	M4 (%)	M5 (%)
11	99.35	91.03	65.20	60.30	64.10	0.65	8.97	37.8	39.1	34.62	0.00	0.00	0.00	0.64	1.28
12	99.26	94.07	64.44	62.22	73.33	0.74	5.19	34.82	36.3	25.19	0.00	0.74	0.74	1.48	1.48
13	100.00	95.94	68.92	59.46	68.92	0.00	3.38	27.03	37.84	29.73	0.00	0.68	4.05	2.7	1.35
21	100.00	92.76	69.08	65.79	67.11	0.00	7.24	28.95	34.21	30.92	0.00	0.00	1.97	0.00	1.97
22	100.00	94.80	65.19	61.48	73.89	0.00	5.20	34.07	34.07	22.39	0.00	0.00	0.74	4.44	3.73
23	100.00	95.27	70.95	70.27	72.00	0.00	4.73	27.03	26.35	26.00	0.00	0.00	2.03	3.38	2.00
31	99.08	95.41	89.91	88.07	70.64	0.92	4.59	9.17	10.09	27.52	0.00	0.00	0.92	1.84	1.84
32	99.12	95.57	87.61	86.73	82.15	0.88	4.43	12.39	13.27	16.96	0.00	0.00	0.00	0.00	0.89
33	100.00	94.02	89.74	88.89	91.45	0.00	5.98	8.55	10.26	7.69	0.00	0.00	1.71	0.86	0.86
41	100.00	96.23	83.02	88.07	70.64	0.00	3.77	15.09	10.09	27.52	0.00	0.00	1.89	1.84	1.84
42	100.00	98.26	87.83	84.35	83.48	0.00	1.74	12.17	15.65	16.52	0.00	0.00	0.00	0.00	0.00
43	98.26	94.78	83.48	91.30	85.09	1.74	5.22	16.52	8.70	14.91	0.00	0.00	0.00	0.00	0.00

Table 3. Relationship between patients' age and mean BBT at each point of measurement
Tabela 3. *Odnos između godina pacijenata i prosečnih srednjih vrednosti debljine bukalne lamele na svim tačkama merenja*

Age/*Godine*	<18	18–30	30–50	50–70	>70	p/*p*
Maxilla *Gornja vilica*	Mean *Srednja* ± SD	Mean *Srednja* ± SD	Mean *Srednja* ± SD	Mean *Srednja* ± SD	Mean *Srednja* ± SD	
M1	0.122 ± 0.301	0.017 ± 0.116	0.015 ± 0.123	0.009 ± 0.090	0.000 ± 0.000	**<0.001**
M2	0.655 ± 0.489	0.398 ± 0.464	0.179 ± 0.434	0.095 ± 0.286	0.000 ± 0.000	**<0.001**
M3	0.911 ± 0.327	0.881 ± 0.433	0.890 ± 0.736	0.591 ± 0.558	0.435 ± 0.555	**<0.001**
M4	0.908 ± 0.351	0.895 ± 0.341	0.948 ± 0.533	0.863 ± 0.458	0.778 ± 0.594	0.456
M5	1.042 ± 0.528	0.840 ± 0.321	0.901 ± 0.449	0.848 ± 0.415	0.745 ± 0.507	**0.001**
Manidible/*Donja vilica*						
M1	0.067 ± 0.231	0.081 ± 0.293	0.020 ± 0.137	0.004 ± 0.059	0.000 ± 0.000	**0.004**
M2	0.686 ± 0.322	0.461 ± 0.481	0.177 ± 0.356	0.102 ± 0.292	0.000 ± 0.000	**<0.001**
M3	0.733 ± 0.231	0.512 ± 0.459	0.565 ± 0.478	0.454 ± 0.517	0.144 ± 0.320	**0.007**
M4	0.752 ± 0.244	0.625 ± 0.629	0.731 ± 0.358	0.613 ± 0.434	0.485 ± 0.478	0.109
M5	1.028 ± 0.310	0.866 ± 0.656	0.794 ± 0.412	0.725 ± 0.379	0.848 ± 0.371	**0.001**

Legenda: SD – standardna devijacija
*Shows significantly higher proportion at 5% level of significance/**Pokazuje značajno veće vrednosti na nivou značajnosti od 5%*

Table 4. Relationship between patients' gender and mean BBT at each point of measurement
Tabela 4. *Odnos između pola pacijenata i prosečnih srednjih vrednosti debljine bukalne lamele na svim tačkama merenja*

Sex/*Pol*	Males/*Muškarci*	Females/*Žene*	
Maxilla/*Gornja vilica*	Mean/*Srednja* ± SD	Mean/*Srednja* ± SD	p/*p*
M1	0.009 ± 0.084	0.029 ± 0.165	0.036
M2	0.186 ± 0.390	0.204 ± 0.437	0.620
M3	0.740 ± 0.694	0.726 ± 0.562	0.972
M4	0.942 ± 0.505	0.864 ± 0.451	**0.001**
M5	0.924 ± 0.458	0.831 ± 0.398	**0.000**
Manidible/*Donja vilica*			
M1	0.017 ± 0.128	0.013 ± 0.112	0.697
M2	0.139 ± 0.332	0.184 ± 0.362	0.066
M3	0.512 ± 0.522	0.470 ± 0.462	0.214
M4	0.698 ± 0.428	0.597 ± 0.415	**0.001**
M5	0.785 ± 0.415	0.740 ± 0.410	**0.060**

Legenda: SD – standardna devijacija
*Shows significantly higher proportion at 5% level of significance/**Pokazuje značajno veće vrednosti na nivou značajnosti od 5%*

Kruskal-Wallis test was conducted to examine the differences in BBT in regard to age. This test showed that there were significant differences at every measurement point, except at M4 in both jaws (p = 0.456 maxilla, p = 0.109 mandible) **(Table 3)**.

A statistically significant difference among groups was assessed using the Man-Whitney U test for two independent variables: between males and females in maxilla at measuring points M1 (p = 0.036), M4 (p = 0.001), M5 (p = 0.000) and in mandible at measuring point M4 (p = 0.001) **(Table 4)**.

Discussion

This retrospective study evaluated BBT in the anterior maxillary and mandibular teeth using CBCT images over a one-year period. It also investigated the impact of age and gender on BBT.

Regarding the maxilla, the buccal bone was thinner at M1 than at M2 – M5 in all teeth. The highest mean BBT was found at M4, which is not in accordance with Gakonoyo et al. study [19], where the thickest measurement point was the furthest from the bone crest. This could be attributed to the different proximity of the measurement points. In our study, all measurement points were close to each other (2 mm apart), while in Gakonoyo et al. study, the first measurement point was 4 mm apical to the CEJ and the second was located in the middle of the root. According to the literature, the thinnest alveolar ridge is in the region of lateral central incisor compared to other anterior teeth regions of the maxilla. It is probably due to the presence of lateral fossa and concavity adjacent to lateral incisor [20].

In our study, the lowest BBT was mainly in the region of canines, with the exception of the region of teeth 21 at M1 (0.012 ± 0.102), 22 at M1 (0.006 ± 0.073), 12 at M4 (0.885 ± 0.475) and 21 at M4 (0.880 ± 0.357) and at M5 (0.867 ± 0.374) **(Table 1)**. The reason is probably the anatomical upright position of the canine root in the maxilla.

In the mandible, the lowest BBT was at M1, and the highest at M5. The values of BBT among the groups of teeth are variable, although the canines have thinner BBT than the central and lateral incisors at measurement points M4 and M5. Tsai et al. [21] investigated the risks for labial bone perforation in the anterior mandibular region using a virtual immediate implant placement procedure. They found that the prevalence of labial bone perforation is significantly higher at the mandibular canine site than at the central and lateral incisor sites.

In our study, the measured BBT in both jaws was very thin. More than 60% of all measurement points showed BBT less than 1 mm. The BBT from 1 – 2 mm was found rarely (22.39 – 39.1% in the maxilla only at measurement points M3 – M5). This is in accordance with Gakonoyo et al. [19] study results, where BBT in the maxillary anterior teeth was predominantly thinner at measurement points near the bone crest. The incidence of BBT thicker than 2 mm was very low and mostly found at measurement point M5 (1.28 – 3.73%). This incidence is even lower in the mandible **(Table 2)**. Al Tarwneh et al. [22] reported that teeth with a bone thickness of more than 2 mm account for no more than 3% at their best. Lack of sufficient buccal bone in the anterior region of the maxilla may lead to recession of the marginal peri-implant mucosa and adversely effect the final esthetic outcome [23]. Connective tissue grafting has a beneficial effect on the peri-implant mucosa and esthetic outcome [24]. However, Zuiderveld et al. [25] found that the application of connective tissue in the esthetic zone of immediately placed implants may lead to BBT decrease after 1 year. This may be due to disrupted vascularization between the mucosa and periosteum during connective tissue grafting.

The relationship between the patient age and BBT is still unclear. Some studies found that the patient age was associated with the BBT [26, 27], while others have failed to find a correlation [28]. We found a statistically significant difference in average mean values at every measurement point, except M4 in the maxilla ($p = 0.456$) and M4 in the mandible ($p = 0.109$). The highest BBT was found in younger patients in both jaws compared to other groups. Our results are in correlation with the Santos et al. findings [26].

Comparing average BBT at all measurement points in men and women, we found that males had greater BBT the closer we got to the apical direction. The results showed that males had higher values at M3, M4 and M5 measurement points and females at M1 and M2. A statistically significant difference was found in the maxilla at M1 ($p = 0.036$), M4 ($p = 0.001$) and M5 ($p < 0.001$) and in the mandible only at M4 ($p = 0.001$). The literature indicates that males have a greater BBT [22]. Although there are no significant differences between the values, there is a trend of greater BBT in males [29, 30]. Additionally, Zhang et al. [20] compared the width of the alveolar ridge in males and females in the anterior maxillary teeth. The results showed a wider alveolar ridge in males at all measurements.

The limitations of this study should be mentioned. The complete comprehensive patient medical history was unavailable, and the effect of the medical status on the BBT was not determined since the CBCTs used in this study were taken as a diagnostic adjunct to dental medicine and oral surgery therapy. Further studies with larger sample sizes would be needed to validate our findings.

Conclusion

Based on our results, the buccal bone plate is generally thin in the maxillary and mandibular anterior area. The buccal bone thickness was lower than 1 mm in more than 60% of all measurement points in all teeth in the maxilla and mandible. In the maxilla, more than 90% of patients presented with bone plate thickness under 1 mm at measurement points M1 and M2. This is even lower in the mandible. These findings could affect successful implant treatment in the esthetic zone. Precise buccal bone thickness measurement is crucial in implant treatment planning, especially in the maxillary and mandibular anterior area.

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