Evaluation of Cortical Thicknesses and Bone Density Values of Mandibular Canal Borders and Coronal Site of Alveolar Crest

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ABSTRACT

Objectives: The objectives of this retrospective study are to measure the amount of the alveolar crest cortication and cortication around the mandibular canal, and to evaluate bone density values of alveolar crest, cortication around mandibular canal, and possible implant placement area for edentulous sites.
Material and Methods: Six hundred forty-two cone-beam computed tomography scans from 642 subjects were evaluated in four centers. Cortical thicknesses of alveolar crest and mandibular canal cortical borders (buccal, lingual, apical, and coronal) in each mandibular posterior teeth region were measured. Bone density of alveolar crest and mandibular canal cortical borders (buccal, lingual, apical, and coronal) in each mandibular posterior teeth region were recorded. The correlations between numeric variables were investigated using Pearson's correlation test.
Results: The largest cortical border of the canal was measured 1.1 (SD 0.71) mm at the left second molar area and in coronal side of the mandibular canal (MC). Left and right first premolar regions showed higher bone density values compared to the other sites in all bone density values evaluations. The buccal side of the canal at the right first premolar region showed the highest bone density values (832.32 [SD 350.01]) while the coronal side of the canal at the left second molar region showed the lowest (508.75 [SD 225.47]). The bone density of possible implant placement area at the both left (692.25 [SD 238.25]) and right (604.43 [SD 240.92]) edentulous first premolar showed the highest values. Positive correlations between the bone density values of alveolar crest and the coronal side of MC were found in molar and left second premolar regions ($P < 0.05$).
Conclusions: Results may provide information about the amount of cortication and bone densities tooth by tooth for posterior mandible to surgeons for planning the treatment precisely.

Keywords: bone density; dental implants; mandibular canal; tomography.

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INTRODUCTION

Recently, dental implants become the most preferred treatment options for partially or fully edentulous patients. They not only restore the quality of life and also boost the self-confidence of the patients. But from the point of therapeutic standpoint, there are clinical cases, can be called as a difficult, like especially severe atrophic sites that is neighbor to the crucial anatomic landmarks [1].

Placement of dental implants in the posterior region of the mandible represent a zone of higher risk due to the presence of mandibular canal (MC) [1]. The MC that carries inferior alveolar neurovascular bundle [2] is a bilateral, intraosseous opening, begins in mandibular foramen on the medial surface of the ascending mandibular ramus and runs obliquely downward and forward in the ramus, then horizontally forward in the body till mental foramen [3]. The inferior alveolar nerve (IAN) is a branch of the mandibular nerve, which is itself the third branch of the trigeminal nerve [4]. The IAN provides innervation of the mandibular molars and premolars and adjacent parts of the gingiva [4,5]. There are also anatomical variations of the MC, as bifid canal configuration and an anterior loop of the mental nerve [6,7]. In addition, the diameter of the MC can become smaller over time depending on mandibular remodeling after dental extractions and the course of the canal in the mandibular body alters [8]. If these vital structures are not properly identified specially for the patient, the complications like altered sensation, numbness, and pain often occur [9]. Generally, in most of the cases, paresthesia decreases over time but also it may be irreversible. In addition, damage of blood vessels may trigger undesired, excessive bleeding pre and post operatively. Thus, in order to avoid aforementioned complications, the MC should be precisely determined especially using cone-beam computed tomography (CBCT) imaging while planning implant surgeries [10].

CBCT is an accurate non-invasive method used to evaluate anatomical structures and abnormalities including detailed information about MC [4,11]. Although CBCT is mostly used for planning surgeries prior to dental implant placement, in some cases especially in single tooth loss, surgeons may decide to plan the operation using panoramic radiographies. Due to the well-known limitations of panoramic radiographies [12], in these cases, surgeon's professional experience, knowledge and tactile sense during surgery get involved.

The cortication of MC is a natural barrier for vital structures it contains. To the best of authors knowledge, there are no articles published in English comparing this natural barrier with alveolar ridge cortication. Thus, the objectives of this retrospective study are to measure the amount of the alveolar crest cortication and cortication around the mandibular canal, and to evaluate bone density values of alveolar crest, cortication around mandibular canal, and possible implant placement area for edentulous sites.

MATERIAL AND METHODS

Study design and participants

Six hundred forty-two CBCT scans from 642 subjects were evaluated in four centers (Hacettepe University, Sakarya University, Istanbul Aydin University, Alanya Alaaddin Keykubat University). Scans were obtained from participants who required preoperative dental implant planning during January 2019 to February 2020.

The study was approved by institutional review boards of the participated universities (Hacettepe University: GO 19/1058, Sakarya University: 71522473/050.01.04, Istanbul Aydin University: B. 30.2AYD.0.00.00-050.06.04/246, Alanya Alaaddin Keykubat University: 15-11).

In this retrospective study, the age of the subjects ranged from 18 to 99 years. Edentulous sites under healing process were not evaluated. The study consisted of the following inclusion criteria:

- CBCT images of patients no distortion or deflection.
- Images that precisely illustrated the region of mandibular premolars and molars.
- Clear visibility of MC.

Before starting the study, how to make measurements were described in an online meeting by the mentor of the study to calibrate authors. All measurements were performed independently by calibrated authors from each center with experience in analyzing CBCT images. Four study centers used two different brands of CBCT devices: KaVo OP™ 3D DVT (KaVo Dental; Biberach, Germany) and i-CAT® Model 17-19 CBCT device (Imaging Sciences International; Hatfield, PA, USA). For the first machine operating parameters were 90 kV and 9.23 mA, and scan time was 8.14 seconds and these values for the second machine were 1.4 mA and 120 kV, with a resolution of 0.2 voxels, the thickness of 0.1 mm. For the second machine, images were obtained at 110 mm field of view, 26.9 seconds exposure cycle, 1.4 mA and 120 kV, with a resolution of 0.2 voxels, the thickness of 0.1 mm. Digital Imaging and Communications in Medicine format was used to save the images of the scans. Images were viewed in a dimmed room on a 24-inch

Dell Precision display with a resolution of 1920 x 1200 pixels (Dell Inc.; Round Rock, Texas, USA).
As a protocol in every research center, all CBCT scans were made according to a strict standardized scanning protocol; patients were placed in a stand-up vertical position, stabilized with head band and chin support, and monitored to ensure that they remained motionless throughout the duration of the scan.

CBCT image analysis

For visualizing the cases, SimPlant® Pro version 17.01 software (Dentsply Implants NV; Research Campus 10, Hasselt 3500, Belgium) was used by the whole study centers. The software acquires images in axial and reconstructs in coronal and sagittal views; it also provides at three-dimensional reconstructed model of the area of interest. The brightness and contrast of the images were adjusted, if required, to optimize image quality. The information about age and gender of the subjects were obtained from the study centers records. The following parameters were measured and/or recorded by calibrated clinicians from each center (E.T.A.D. - Hacettepe University, D.Y. - Sakarya University, S.G. - Istanbul Aydin University, T.Ç. - Alanya Alaaddin Keykubat University):

- Presence/absence of mandibular premolars and molars;
- Coronal cortical thickness of alveolar crest in mandibular premolar and molar regions;
- Cortical thickness of buccal, lingual, apical, and coronal sides of MC (recorded each tooth site) (Figure 1);
- Bone density of alveolar crest in mandibular premolar and molar regions (in the absence of the teeth): is performed at the top of alveolar crest with a 1 mm edged square;
- Bone density of buccal, lingual, apical, and coronal sides of MC (recorded each tooth site): is performed around the MC with a 1 mm edged square;
- Bone density of the possible implant placement area: is recorded an area between the top of alveolar crest with a 1 mm edged square and coronal part of the MC with a 1 mm edged square (Figure 2).

All the measurements were performed in the center part of edentulous sites. Measurement of the thickness was recorded in millimeters (mm) and bone density measurements were obtained in Hounsfield units derived from CBCT (CBCT-HU). CBCT scans were excluded if radiopaque border of MC and/or alveolar crest could not be defined clearly. Inter-class correlation coefficients were performed to assess intra-observer reliability for the measurements of randomly selected 10 CBCT scans. Intra-observer coefficients values were calculated 90%.

Statistical analysis

Numeric variables were presented as mean and standard deviation values. Number of event and percentage were used for categorical variables.

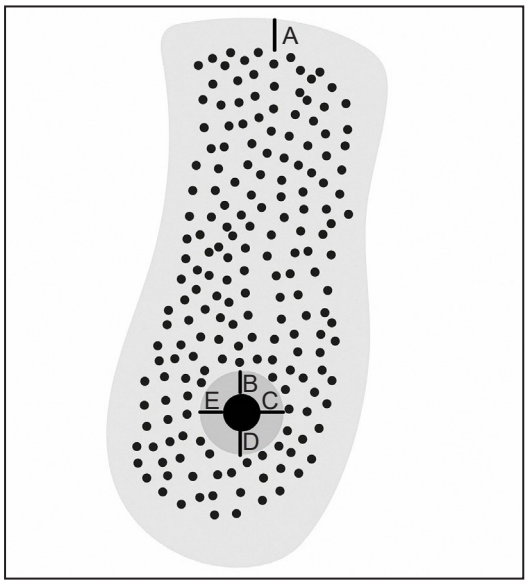

Figure 1. Illustration for demonstrating linear measurements.
A = coronal cortical thickness of alveolar crest; B = coronal cortical thickness of mandibular canal; C = lingual cortical thickness of mandibular canal; D = apical cortical thickness of mandibular canal; E = buccal cortical thickness of mandibular canal.

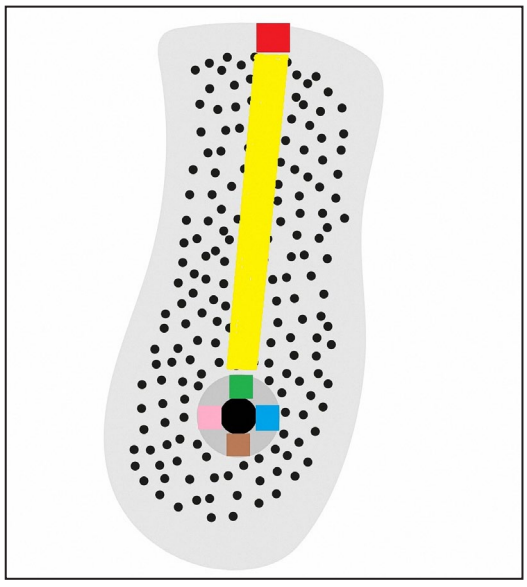

Figure 2. Illustration for demonstrating bone density values records.
Red = coronal cortical thickness of alveolar crest; green = coronal cortical thickness of mandibular canal; blue = lingual cortical thickness of mandibular canal; brown = apical cortical thickness of mandibular canal; pink = buccal cortical thickness of mandibular canal; yellow = possible implant placement area.

Statistical data were processed using IBM SPSS Statistics for Windows version 24.0 (IBM Corp., Armonk, New York, USA). Parametric data were expressed as mean and standard deviation (M [SD]). The correlations between numeric variables were evaluated using Pearson's correlation test. Statistical significance level was defined at P = 0.05.

RESULTS

In this study, a total of 642 CBCT images were evaluated. Mean age of subjects was 43.94 (14.96) years. According to absence of mandibular posterior teeth, 373 edentulous sites were recorded for right second molar. There were 254 edentulous sites for right first molar, 386 edentulous sites for right second premolar, and 388 edentulous sites for right first premolar. For the left side, data was recorded from 358 edentulous sites in second molar, 276 edentulous sites in first molar, 390 edentulous sites in second premolar, and 398 edentulous sites in first premolar regions.

The cortical thicknesses of alveolar crest were demonstrated in Table 1. When the alveolar crest cortication of the posterior mandibular teeth was evaluated, cortical bone was mostly seen in the right second premolar area. According to the study's results there was a tendency to increase the amount of cortication towards the premolar region at the right side of the subjects. The largest cortical border of the canal was measured 1.1 (0.71) mm at the left second molar area and in coronal side of the MC.

On the contrary, the lowest cortication was noted at the right first molar region and in lingual aspect of the MC (0.65 [0.33] mm) (Table 1).

Table 2 presents the bone density values (CBCT-HU) of aforementioned structures. When the distribution of bone density values of alveolar crest both left and right mandibular posterior region were considered together, both left and right first premolar regions showed higher CBCT-HU values compared to the other sites. When comparing the bone density values around the MC, the buccal side of the canal at the right first premolar region showed highest CBCT-HU values (832.32 [350.01]) while the coronal side of the canal at the left second molar region showed the lowest (508.75 [225.47]). There was a tendency to increase bone density values of buccal and coronal side of the canal towards the premolar region at the both right and left sides. When the bone density of possible implant placement area considered, as the bone density of alveolar crest, it was shown the higher values at the both left and right edentulous first premolar area. While comparing CBCT-HU values of possible implant placement area and MC coronal side, MC coronal sides showed higher CBCT-HU values than possible implant placement area in every tooth region, separately (Table 2). In addition, positive correlations between the bone density values of alveolar crest and the coronal side of MC were found in right first molar region ($r = 0.152$, $P = 0.008$), right second molar region ($r = 0.155$, $P = 0.034$), left second premolar region ($r = 0.183$, $P = 0.041$), left first molar region ($r = 0.15$, $P = 0.011$), and left second molar region ($r = 0.224$, $P = 0.002$). Any correlation in premolar regions except left second premolar regions was detected ($P > 0.05$) (Table 3).

DISCUSSION

Due to highly vascularization and location of the relevant anatomical structures around the mouth floor

Table 1. Cortical thicknesses (mm) of mandibular canal (MC) and crest

Tooth position	N	Cortical thickness (mm)				
		Crest	Apical side of MC	Buccal side of MC	Coronal side of MC	Lingual side of MC
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
#47	**373**	1.57 (0.72)	0.86 (0.21)	0.67 (0.43)	0.78 (0.64)	0.85 (0.81)
#46	**254**	1.63 (0.78)	0.71 (0.3)	0.72 (0.67)	0.9 (0.37)	0.65 (0.33)
#45	**386**	1.77 (0.97)	0.75 (0.36)	0.69 (0.3)	0.7 (0.29)	0.67 (0.25)
#44	**388**	1.77 (0.85)	0.81 (0.26)	0.77 (0.26)	0.76 (0.25)	0.75 (0.26)
#34	**398**	1.67 (0.74)	0.77 (0.21)	0.72 (0.22)	0.75 (0.38)	0.71 (0.23)
#35	**390**	1.74 (0.81)	0.74 (0.32)	0.7 (0.46)	0.68 (0.29)	0.68 (0.3)
#36	**276**	1.71 (0.75)	0.7 (0.36)	0.94 (0.11)	0.78 (0.42)	0.72 (0.66)
#37	**358**	1.73 (0.74)	0.73 (0.49)	1.01 (0.72)	1.1 (0.71)	0.68 (0.37)

SD = standard deviation; N = number of events.
World Dental Federation FDI (French: Fédération Dentaire Internationale) tooth numbering system was used.

Table 2. Bone density (CBCT-HU) values of mandibular canal (MC) and crest

Tooth position	N	Bone density values (CBCT-HU)					
		Crest	Apical side of MC	Buccal side of MC	Coronal side of MC	Lingual side of MC	Possible implant placement area
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
#47	**373**	811.56 (260.93)	637.4 (275.93)	538.28 (242.06)	512.1 (218.87)	679.95 (270.99)	440.15 (249.3)
#46	**254**	742.80 (252.93)	647.93 (266.87)	601.11 (282.69)	522.90 (217.16)	679.35 (295.02)	449.90 (242.99)
#45	**386**	841.63 (240.77)	688.48 (283.44)	770.15 (671.92)	614.57 (252.93)	624.49 (271.78)	496.27 (256.63)
#44	**388**	907.2 (296.03)	817.27 (309.3)	832.32 (350.01)	723.65 (284.34)	744.16 (314.11)	604.43 (240.92)
#34	**398**	960.24 (271.78)	772.41 (275.76)	820.73 (321.1)	706 (255.82)	714.22 (304.6)	692.25 (238.25)
#35	**390**	864.67 (247.44)	670.03 (289.93)	745.72 (353.51)	613.72 (247.64)	603.52 (274.36)	494.69 (242.19)
#36	**276**	800.18 (241.46)	631.34 (269.19)	580.88 (289.73)	524.85 (232.64)	669.82 (290.44)	471.26 (251.76)
#37	**358**	830.33 (255.59)	622.01 (267.84)	535.37 (250.4)	508.75 (225.47)	653.1 (257.48)	462.58 (252.39)

CBCT-HU = Hounsfield units derived from CBCT; SD = standard deviation; N = number of events.
World Dental Federation FDI (French: Fédération Dentaire Internationale) tooth numbering system was used.

Table 3. r values of correlation between values of alveolar crest bone density and mandibular canal coronal side bone density for each posterior tooth region

	Tooth position	Mandibular canal coronal side bone density values							
		#47	#46	#45	#44	#34	#35	#36	#37
Alveolar crest bone density value	**#47**	0.155[a]	-	-	-	-	-	-	-
	#46	-	0.152[a]	-	-	-	-	-	-
	#45	-	-	0.091	-	-	-	-	-
	#44	-	-	-	0.039	-	-	-	-
	#34	-	-	-	-	0.258	-	-	-
	#35	-	-	-	-	-	0.183[a]	-	-
	#36	-	-	-	-	-	-	0.15[a]	-
	#37	-	-	-	-	-	-	-	0.224[a]

[a]Positive correlation was detected by using Pearson's correlation test ($P < 0.05$).
World Dental Federation FDI (French: Fédération Dentaire Internationale) tooth numbering system was used.

in patients with atrophic mandibles, posterior mandibular region is susceptible to the injury in case of implant placement [1]. Furthermore failure to identify site specific landmarks can cause irremediable iatrogenic damage especially injuries of IAN and such injuries can result in paresthesia of the jaw and lips along with neuropathic acute/chronic pain, in turn instigating difficulty in routine activities as eating and talking [9]. Thus, preoperative planning must be very carefully performed. Besides, the experience and tactile sensitivity of the clinician during surgery are also important factors. This study presents the cortication (mm) in alveolar crest of posterior mandibular teeth and around the MC and the bone density in these areas and also possible implant placement area for edentulous sites.

In the present study, the alveolar crest cortication of the posterior mandibular teeth was evaluated and cortical bone was mostly seen in the right second premolar area (1.77 [0.97]). In the literature, cortical bone thickness of the second premolar and first molar teeth were examined and they were noted 2.38 and 1.72 mm, respectively. As in the present study, there is a tendency for cortication in the second premolar region [13]. Ko et al. [14] examined the crestal cortical bone thickness in the posterior mandible and noted this value as 1.22 (0.52) mm, while Sugiura et al. [15] reported the total thickness of the alveolar crest of the posterior mandible as 1.5 (0.7) mm. As the literature was evaluated, none of the studies carried out to examine the crestal cortical bone thickness tooth by tooth. Besides, according to the present study's results there was a tendency to increase the amount of cortication at the right side of the subjects. This may due to the asymmetry of the two halves of the face [16].

In order to avoid injury to the IAN, it is important

to know the amount of bone cortication and density around the MC. In the present study, the amount of cortical bone around the MC was measured at four sites. The largest cortical border of the canal was measured 1.1 (0.71) mm at the left second molar area and in coronal side of the MC. On the contrary, the lowest cortication was noted at the right first molar region and in lingual aspect of the MC (0.65 [0.33] mm). Başa et al. [17] measured the bone cortication only at coronal site of the canal for premolar and molar regions and they found the amount of cortication 0.87 (0.18) and 0.86 (0.18) mm for premolar and molar regions, respectively. The values found in present study are compatible with the literature. To best our knowledge, there is no study that measures the amount of bone cortication from four regions of the MC (coronal, buccal, apical, and lingual) and tooth by tooth.

With the use of CTs, clinicians have begun to measure HU values that provide information about bone density and is particularly guiding for primary stabilization of implants. HU values, a standardized and accepted scale, consists of X-ray attenuation measures and varies according to the density of the tissues (-1000 to 1000 HU) [18]. In the present study, CBCT-HU values for alveolar crest, around the MC and possible implant placement areas for posterior mandible were measured. The cortical bone density of anterior and posterior mandible ranges from 1000 to 1800 HU [19,20]. In a more recent study, Sugiura et al. [15] was noted this value 1292 (231) HU for posterior mandible. In the present study, CBCT-HU values were measured for posterior mandible tooth by tooth and noted maximum 960.24 (271.78) CBCT-HU for left first premolar region and minimum 742.8 (252.93) CBCT-HU for right first molar region. The difference between present study and the literature could be caused by different ethnicity of the patients. According to present study's results, there was a tendency to increase bone density values of buccal and coronal side of the canal towards the premolar region at the both right and left side of the subjects. There is only one study in the literature evaluating bone density around MC. Başa et al. [17] measured the bone density only in the coronal region of the MC for the premolar and molar regions and noted these values as 649.18 (241.42) for the premolar region and 584.44 (222.73) for the molar region. The values found in the present study are compatible with the literature. According to the bone density of possible implant placement area, it was shown the higher values at the both left and right edentulous first premolar area in the present study. When the literature is evaluated, there are studies with different results. It was found 359 (150) CBCT-HU for possible implant placement area in posterior mandible while this measurement was noted as 455 (228) CBCT-HU in another study [15,21]. Shapurian et al. [18] and de Oliveira et al. [22] measured 321 (132) CBCT-HU and 306.3 (187.15) CBCT-HU for posterior mandible, respectively. On the contrary, Turkyılmaz et al. [23] presented this value as 721 (291) CBCT-HU. Differences in measurements are likely to come from the distribution of regions selected and from patient-related factors (i.e. age, gender, and ethnicity) and also the bone densities reported in most of the studies were lower than those found in the present study due to the inclusion of trabecular portion and the outer cortical shell.

Assessing bone density through grey scale values obtained from CBCT appears to lack the accuracy and stability exhibited by Hounsfield Units (HU) acquired from computed tomography (CT) [24,25]. Nonetheless, a compelling observation was the emergence of a robust correlation between the grey scale data extracted from the CBCT scan and the Hounsfield Units (HUs) measured in the CT scan [26]. In contrast, contrary to the aforementioned notion, the recent publication suggests that CBCT-HU can effectively evaluate bone density through the utilization of the 'HU' feature within the SimPlant software [27].

While comparing CBCT-HU values of possible implant placement area and MC coronal side, MC coronal sides showed higher CBCT-HU values than possible implant placement area in every tooth region, separately. This data gives information to the surgeons doing dental implant surgeries without CBCT about natural barrier of the MC and importance of tactile sense during surgery.

To our knowledge, there are no published articles in the literature in English on the comparison of bone density of the alveolar ridge and bone density of the coronal side. According to the present study, positive correlations were detected in molar and left second premolar regions ($P < 0.05$). This data is important to show the surgeon the presence of natural bone barrier in a harmony of alveolar crest bone density value. The limitations of this study are being a retrospective study and not distinguishing the subjects as partial and total edentulism. However, to reduce the risk of IAN injury, evaluating the bone thicknesses and density values in each posterior tooth region is crucial prior to dental implant surgeries. In the guidance of this retrospective radiological study, further clinical studies are needed.

CONCLUSIONS

According to the study results, there is a tendency to increase the amount of cortication towards the premolar region for both sides. While considering the bone density, there is a tendency to increase on values of buccal and coronal side of the mandibular canal towards to the premolar region for both sides. In every posterior tooth region, bone density values of mandibular canal coronal sides were higher than possible implant placement area's bone density values. These findings may provide information about the amount of cortication and bone densities tooth by tooth for posterior mandible to the surgeons for planning the treatment precisely. Results about differences in bone density values (alveolar crest, around the mandibular canal, and possible implant placement areas) will also assist the surgeon in tactile sensitivity that can avoid to damage mandibular canal during surgery.

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The authors report no conflict of interest related to this study.

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