

# The Radiological Evaluation of Mandibular Canal Related Variables in Mandibular Third Molar Region: a Retrospective Multicenter Study

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## ABSTRACT

**Objectives:** The aim of this retrospective study was to investigate anatomical structure of mandibular canal and the factors those increase the possibility of inferior alveolar nerve damage in mandibular third molar region of Turkish population.

**Material and Methods:** Overall 320 participants with 436 mandibular third molars were included from four different study centers. Following variables were measured: type and depth of third molar impaction, position of mandibular canal in relation to third molars, morphology of mandibular canal, cortication status of mandibular canal, possible contact between the third molars and mandibular canal, thickness and density of superior, buccal, and lingual mandibular canal wall, bucco-lingual and apico-coronal mandibular canal diameters on cone-beam computed tomography scans.

**Results:** Lingual mandibular canal wall density and thickness were decreased significantly as the impaction depth of mandibular third molar was increased ( $P = 0.045$ ,  $P = 0.001$  respectively). Highest buccal mandibular canal wall density and thickness were observed in lingual position of mandibular canal in relation to mandibular third molar ( $P = 0.021$ ,  $P = 0.034$  respectively). Mandibular canal with oval/round morphology had higher apico-coronal diameter in comparison to tear drop and dumbbell morphologies ( $P = 0.018$ ). Additionally, mandibular canals with observed cortication border and no contact with mandibular third molar had denser and thicker lingual mandibular canal wall ( $P = 0.003$ ,  $P = 0.001$  respectively).

**Conclusions:** Buccal and lingual mandibular canal wall density, thickness and mandibular canal diameter may be related with high-risk indicators of inferior alveolar nerve injury.

**Keywords:** mandible; radiology; surgery; tomography.

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## INTRODUCTION

Third molar teeth are most commonly impacted. Independent from eruption status they may cause caries, periodontal lesions of second molar, and cystic or neoplastic conditions [1]. Extraction of mandibular third molar (MTM) is a common procedure performed in oral cavity by both dentists and oral-maxillofacial surgeons. Likewise, any other surgical intervention, extraction of MTM may cause complications. Inferior alveolar nerve (IAN) damage is one of the most significant and unpleasant condition both for the patient and the clinician [2].

The percentage of disturbances of the IAN is ranged between 0.4 and 9.4% for temporary, and 0.5 to 1% for permanent injuries [3]. Preoperative radiologic examination is an important step to reduce IAN related injuries. Panoramic radiographs are the first choice for the clinicians to make assessment of diagnosis and treatment plans related on MTM. Rood and Shebab [4] indicated seven radiologic diagnostic signs, which may be related to high risk of IAN injury during MTM surgeries. On the other hand, cone-beam computed tomography (CBCT) is recommended if three of seven signs exist in panoramic radiographs or close relations between MTM and mandibular canal (MC) are suspected [5]. CBCT scan enables clinicians to assess IAN by direct visualization from both multiple planes and three-dimensional views. Studies have suggested that the additional information provided by CBCT could change the surgical approach and thus prevent injury to the IAN also pathologies associated with the MTM is more often observed in CBCT than in panoramic radiographs [6,7]. For preoperative evaluation of MTMs, several classifications have been proposed. Among them the Winter [8] and the Pell and Gregory classifications [9] are the most predominant systems used for predicting the difficulty of the surgical procedures. The Winter system [8] is based on the inclination of the impacted third molar tooth to the long axis of the second molar. The Pell and Gregory system [9] considers level A, B, and C for third molars according to the relative depth of the impacted tooth in the bone. Significant association between the type of tooth impaction using the Winter [8] and the Pell and Gregory classification [9] systems and the position of the third molar teeth in relation to the cortical plates and MC morphology have been demonstrated [10-12]. In the literature, studies also demonstrated that several morphological and anatomical features such as MC shape [13], position [14-16], cortication status [13,17,18] and MC contact status between MTM [19] are associated with

increased risk of IAN damage.

Anatomically, IAN locates in MC which is a pathway starting from mandibular foramen and surrounded by MC wall which is an important anatomical and radiological landmark in order to avoid injury of IAN in dental implant and MTM surgeries. Bone mineral density and microstructure of the alveolar bone are the strongest features for bone strength [20]. The bone quality of MC wall has been reported more trabecular than cortical in mandibular premolar and molar regions [21]. Despite the anatomy of canal has been well documented through anatomical and radiological studies, data related on MC wall is limited [22-25].

To best of authors' knowledge MC wall (superior, buccal and lingual) in third molar region in relation to possible risk indicators for IAN injuries has not been examined. The aim of this retrospective study was to investigate anatomical and radiological structure of mandibular canal and the factors that increase the possibility of inferior alveolar nerve damage in third molar region of Turkish population.

## MATERIAL AND METHODS

### Study design and participants

This retrospective study was conducted in four centers (Sakarya University, Istanbul Aydin University, Hacettepe University and Alanya Alaaddin Keykubat University) which were in different regions of Turkey. Ethical approval was waived by the local Ethics Committees of Sakarya University: 71522473/050.01.04, Istanbul Aydin University: B.30 .2AYD.0.00.00-050.06.04/246, Hacettepe University: GO 19/1058 and Alanya Alaaddin Keykubat University: 15-11, in view of the retrospective nature of the study and all the procedures being performed were part of the routine care. Scans were obtained from participants whose third molars classified to be at high risk of nerve injury in panoramic radiographs [4] or from participants who required preoperative dental implant planning during January 2019 to February 2020.

Following inclusion criteria were enrolled:

- Participants were older than 18 years of age.
- MTMs with completely developed roots.
- Distinct radiographic images with no distortion or deflection.
- Images that clearly illustrated apical region of MTM and MC.

Participants with mandibular lesions (cyst, tumour, fracture, etc.) around MTM and/or MC were excluded. Four study centers had two different kinds of CBCT apparatus. The CBCT mandibular scan

was acquired using by KaVo OP™ 3D DVT (KaVo Dental; Biberach, Germany) and i-CAT® Model 17-19 CBCT device (Imaging Sciences International; Hatfield, PA, USA). Operating parameters for the first machine were 90 kV and 9.23 mA, and scan time was 8.14 seconds. 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 0.100 mm. Digital Imaging and Communications in Medicine format was used to save the images of the scans. 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.

### Study variables

Demographic variables including age and gender were obtained from data bank of the study centers. One observer from each center with at least five years of experience in periodontology and/or oral radiology also were experienced in the assessment of CBCT and panoramic images (DY - Sakarya University, ETAD - Hacettepe University, SG - Istanbul Aydin University, TÇ - Alanya Alaaddin Keykubat University) executed all measurements. Images were viewed in a dimmed room on a Dell Precision display with a resolution of 1920 × 1200 pixels (Dell Inc.; Round Rock, TX, USA). 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. Before starting, observers (DY, ETAD, SG, TÇ) discussed about study protocol by using schematic diagrams and agreed on the methods for achieving the associated data. Training on using the software and interpreting the CBCT scans were provided over several sessions. If there was a doubt in the measurements or in the selection of the case, the observer shared the relevant case with other observers and the consensus decision has been made. Then, intraclass-interclass correlation coefficients (ICC) and kappa statistics were performed to assess intra-observer and inter-observer reliability for the measurements of 10 subjects. Following measurements were performed:

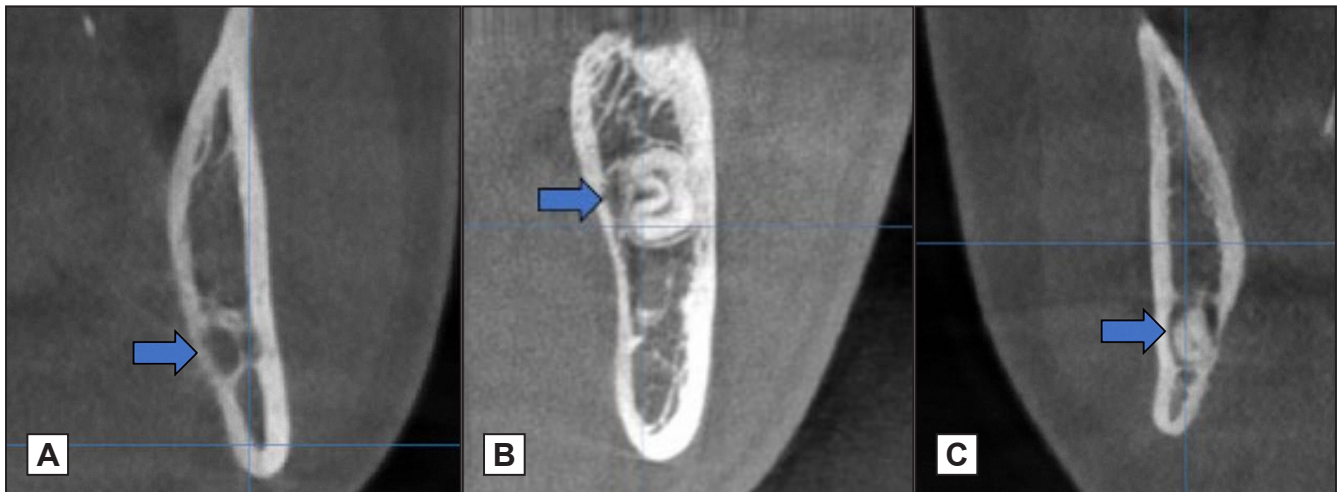
- Type and depth of third molar impaction.
- Position of MC in relation to third molars.
- Morphology of MC.
- Cortication status of MC.
- Possible contact between the third molars and MC.

MC wall related measurements including:

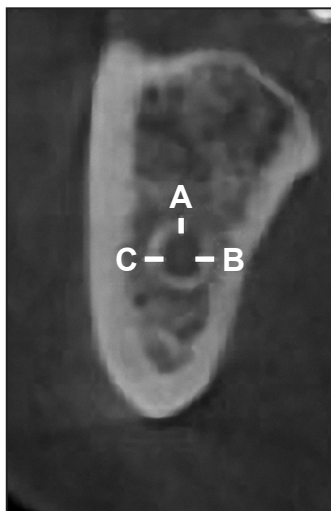
- Thickness of superior, buccal and lingual canal wall.
- Bucco-lingual and apico-coronal canal diameters.
- Radio-density measurements of superior, buccal and lingual canal wall were performed.

In present study, according to Winter classification [8], MTMs were impacted in vertical (n = 227 [52.06%]), mesioangular (n = 170 [38.99%]), horizontal (n = 31 [7.11%]), and distoangular (n = 8 [1.38%]) position. The depth and the position of MTM in relation to occlusal surface of second molar were defined by Pell and Gregory classification [9] and our findings demonstrated that Type A was the most common impaction depth with n = 268 (73.22%); Followed by type B = 68 (18.58%), and type C = 30 (8.3%). 70 MTMs were excluded in Pell and Gregory classification [23] due to missing second molars. Winter [8] and Pell and Gregory [9] classifications were determined from panoramic views of CBCT images and remaining measurements were performed in the plane perpendicular to dental arch in cross-sectional sagittal view of CBCT scans. The position of MC in relation to MTM was identified as Ghaemina classification [14], based on that buccal, lingual, inferior or inter-radicular positions were defined. Of 292 (66.97%) cases MC was located inferior in relation to MTM followed by lingual 75 (17.2%), buccal 53 (12.16%), and inter-radicular 16 (3.67%) locations. The morphology of MC in coronal plane was classified into three subtypes: round/oval, teardrop, and dumbbell, as reported by Ueda et al. [13]. According to our study, 334 of MC had round/oval morphology (76.6%); followed by teardrop (n = 67 [15.37%]) and dumbbell subtypes (n = 35 [8.03%]) which illustrated in Figure 1. Regarding cortication status of MC and the possible contact between third molars and MC were recorded as yes or no. Of 392 (89.91%) cases the cortication around MC was observed. However, there was no contact between MC and MTM in 328 (75.23%) cases.

Figure 2 demonstrated MC wall thickness measurements. Briefly, in the most distal section of CBCT scans, which third molar and MC were clearly identified, buccolingual sections with 1-mm thickness were obtained to measure the thickness of the superior, buccal, and lingual wall of the bone



**Figure 1.** The morphology of mandibular canal in coronal plane according to Ueda et al [13] classification: A = round/oval; B = teardrop; C = dumbbell.



**Figure 2.** Mandibular canal wall thickness measurements were illustrated.

- A = superior wall thickness of mandibular canal.
- B = lingual wall thickness of mandibular canal.
- C = buccal wall thickness of mandibular canal.

that surrounds the MC on the cross-sectional plane. Measurement of the thickness was expressed in millimetres. In case of unclear images, panoramic scans were appointed in addition to cross-sectional views. CBCT scans were excluded whether radiopaque border of MC could not be defined clearly or any contact between MC and retromolar canal was exist. The length between superior to inferior and between buccal to lingual radiopaque border of MC wall was defined as apico-coronal (AC) and bucco-lingual (BL) diameter of MC respectively. The radio-density measurements were performed through Hounsfield units (HU) option of the SimPlant® software by choosing targeted square in the image with a 1mm edge square around each included side of MC wall. A high CBCT-HU value indicated high bone density.

**Statistical analysis**

Number of event and percentage were used for categorical variables. Student’s t-test was performed while comparing the average of independent pairs. For evaluating more than two independent groups, one-way ANOVA test was utilized. Chi-square test was used to evaluate gender effect on groups. Statistical data were processed using IBM SPSS 24.0 software (IBM Corp.; Armonk, New York, USA) for Windows. Parametric data were expressed as mean and standard deviation (M [SD]). Statistical significance level was defined at P = 0.05.

**RESULTS**

ICC values were calculated > 90% and kappa values were > 0.8 for all the observers. Overall, full mouth mandibular CBCT scans of 320 participants with 436 MTMs (225 right and 221 left side location) were included in the present study. Gender distribution was 171 females (53.44%) and 149 males (46.56%). Mean age of participants was 38.138 (13.459) years (female: 37.026 [12.784]; male: 39.414 [14.118]; P = 0.065). No significant difference was observed in demographic variables. Any significant difference was detected in relation to gender and location (left vs. right) between MTM angulation, MTM impaction depth, MC morphology, cortication status of MC and contact status between MTM and MC measurements (P > 0.05).

MC wall related variables were summarized in Table 1. According to the findings, buccal and superior MC walls were thicker and denser in left side in comparison to right side (P = 0.013,



**Table 1.** Mandibular canal related variables

	Overall	Left (I)	Right (II)	I vs II	Female (III)	Male (IV)	III vs IV
				P-value			P-value
<b>Buccal wall thickness (mm)</b>	1.05 (0.57)	1.45 (1.01)	0.68 (0.57)	0.013 <sup>a</sup>	1.39 (0.49)	0.62 (0.25)	0.023 <sup>a</sup>
<b>Buccal wall bone density (CBCT-HU)</b>	542.29 (311.2)	631.27 (206.23)	516.19 (297.29)	0.027 <sup>a</sup>	648.83 (218)	501.24 (137.02)	0.019 <sup>a</sup>
<b>Superior wall thickness (mm)</b>	1.06 (0.83)	1.51 (1.36)	0.65 (0.24)	0.01 <sup>a</sup>	0.98 (0.8)	1.17 (0.91)	0.519
<b>Superior wall bone density (CBCT-HU)</b>	563.27 (289.95)	642.18 (207.33)	530.76 (228.34)	0.018 <sup>a</sup>	571.33 (219.37)	594.36 (275.36)	0.627
<b>Lingual wall thickness (mm)</b>	0.66 (0.29)	0.66 (0.28)	0.66 (0.31)	0.873	0.67 (0.27)	0.66 (0.33)	0.84
<b>Lingual wall bone density (CBCT-HU)</b>	630.54 (273.09)	641.28 (244.18)	612.19 (218.84)	0.725	624.38 (218.77)	640.33 (243.11)	0.887
<b>Apico-coronal diameter (mm)</b>	2.8 (0.65)	2.91 (0.66)	2.85 (0.63)	0.382	2.73 (0.57)	3.06 (0.69)	0.013 <sup>a</sup>
<b>Bucco-lingual diameter (mm)</b>	2.22 (0.49)	2.22 (0.5)	2.23 (0.48)	0.792	2.15 (0.5)	2.31 (0.46)	0.067

<sup>a</sup>P < 0.05 significant differences between subgroups according to Student's t test.  
CBCT = cone-beam computed tomography; HU = Hounsfield units.

P = 0.01 and P = 0.027, P = 0.018 respectively). Female participants had thicker and denser buccal MC wall than males (P = 0.023 and P = 0.019 respectively), while AC diameter of MC was high in male participants in comparison to females (P = 0.013).

MTM impaction depth according to Pell and Gregory classification [9] in relation to MC wall variables were demonstrated in Table 2. As the impaction rate increased, lingual MC wall thickness and density were decreased significantly (P = 0.001 and P = 0.045 respectively). On the other hand, there was not significant relation between MTM impaction in respect to Winter classification [8] and MC wall

related variables. Relation between the position of MC and MC wall related variables were illustrated in Table 3. Highest buccal MC wall thickness and density were observed in lingual position of MC in relation to MTM (P = 0.034 and P = 0.021 respectively). The relation between the morphology of the MC and MC wall related variables were presented in Table 4. Canals with oval/round morphology had higher AC diameter in comparison to tear drop and dumbbell morphologies (P = 0.018). Additionally, MCs with observed cortication border and no contact with MTM had thicker and denser lingual MC walls (P = 0.003 and P = 0.001 respectively).

**Table 2.** Mandibular third molar teeth impaction depth according to Pell and Gregory classification [9] in relation to mandibular canal variables

	A	B	C	P-value
<b>Buccal wall thickness (mm)</b>	1 (0.77)	0.61 (0.24)	0.51 (0.32)	0.936
<b>Buccal wall bone density (CBCT-HU)</b>	571.20 (337.12)	541.28 (221.07)	536.71 (207.55)	0.125
<b>Superior wall thickness (mm)</b>	1.34 (0.41)	0.57 (0.23)	0.50 (0.27)	0.824
<b>Superior wall bone density (CBCT-HU)</b>	591.18 (301.89)	561.07 (241.19)	553.36 (207.19)	0.069
<b>Lingual wall thickness (mm)</b>	0.69 (0.29)	0.55 (0.25)	0.44 (0.16)	0.001 <sup>a</sup>
<b>Lingual wall bone density (CBCT-HU)</b>	662.73 (207.33)	629.27 (198.27)	611.37 (190.75)	0.045 <sup>a</sup>
<b>Apico-coronal diameter (mm)</b>	2.92 (0.63)	2.77 (0.7)	3.06 (0.77)	0.178
<b>Bucco-lingual diameter (mm)</b>	2.23 (0.47)	2.25 (0.54)	2.47 (0.69)	0.198

<sup>a</sup>P < 0.05 significant differences between subgroups according to One-Way ANOVA tests.  
A = the occlusal plane of the impacted tooth is at the same level as the occlusal plane of the second molar.  
B = the occlusal plane of the impacted tooth is between the occlusal plane and the cervical margin of the second molar.  
C = the impacted tooth is below the cervical margin of the second molar.  
CBCT = cone-beam computed tomography; HU = Hounsfield units.

**Table 3.** Relation between the position of mandibular canal and mandibular canal related variables

	Buccal	Lingual	Inferior	Inter-radicular	P-value
<b>Buccal wall thickness (mm)</b>	0.66 (0.28)	3.1 (1.68)	0.65 (0.52)	0.61 (0.11)	0.034 <sup>a</sup>
<b>Buccal wall bone density (CBCT-HU)</b>	539.27 (244.18)	631.09 (281.6)	524.96 (216.75)	510.27 (223.08)	0.021 <sup>a</sup>
<b>Superior wall thickness (mm)</b>	0.66 (0.27)	1.78 (0.72)	0.99 (0.62)	0.61 (0.41)	0.853
<b>Superior wall bone density (CBCT-HU)</b>	557.37 (219.18)	571.11 (227.19)	562.37 (209.34)	551.29 (245.33)	0.182
<b>Lingual wall thickness (mm)</b>	0.7 (0.34)	0.75 (0.33)	0.64 (0.28)	0.55 (0.11)	0.06
<b>Lingual wall bone density (CBCT-HU)</b>	629.88 (217.35)	638.75 (285.44)	620.14 (241.01)	612.79 (118.3)	0.092
<b>Apico-coronal diameter (mm)</b>	2.79 (0.7)	2.9 (0.69)	2.9 (0.63)	2.64 (0.54)	0.442
<b>Bucco-lingual diameter (mm)</b>	2.31 (0.53)	2.09 (0.53)	2.25 (0.46)	2.14 (0.65)	0.055

<sup>a</sup>P < 0.05 significant differences between subgroups according to One-Way ANOVA tests.  
CBCT = cone-beam computed tomography; HU = Hounsfield units.

**Table 4.** Morphology of the mandibular canal in relation to mandibular canal related variables

	Oval/round	Teardrop	Dumbbell	P-value
<b>Buccal wall thickness (mm)</b>	1.18 (0.89)	0.64 (0.17)	0.66 (0.16)	0.883
<b>Buccal wall bone density (CBCT-HU)</b>	545.11 (283.66)	532.22 (213.65)	542.38 (201.09)	0.731
<b>Superior wall thickness (mm)</b>	1.2 (0.68)	0.61 (0.16)	0.66 (0.15)	0.877
<b>Superior wall bone density (CBCT-HU)</b>	571.05 (219.83)	558.1 (191.35)	562.07 (200.44)	0.667
<b>Lingual wall thickness (mm)</b>	0.68 (0.32)	0.6 (0.16)	0.62 (0.16)	0.261
<b>Lingual wall bone density (CBCT-HU)</b>	655.27 (203.51)	614.51 (211.55)	629.07 (183.67)	0.337
<b>Apico-coronal diameter (mm)</b>	2.93 (0.64)	2.66 (0.63)	2.84 (0.64)	0.018 <sup>a</sup>
<b>Bucco-lingual diameter (mm)</b>	2.2 (0.49)	2.31 (0.48)	2.28 (0.52)	0.205

<sup>a</sup>P < 0.05 significant differences between subgroups according to One-Way ANOVA tests.  
CBCT = cone-beam computed tomography; HU = Hounsfield units.

## DISCUSSION

In the present study, relationship between possible IAN damage indicators and MC wall related variables were demonstrated. To best of authors' knowledge in MTM area, MC related variables including superior, buccal, and lingual canal wall thickness, diameters and density of MC has not been elucidated.

IAN damage and subsequent neurosensory disturbances is rare but serious complication [2]. Panoramic radiography is routinely utilized to initially assessment of possible IAN damage with advantages including common availability and low cost however has several mis interpretation regarding with image quality [26]. CBCT scans can provide diagnostic information in different planes without overlap anatomical structures [26]. In the literature,

it was reported that preoperative CBCT scan did not decrease IAN damage risk in comparison to panoramic radiograph [27]. Additionally, due to relatively high radiation dose and cost, CBCT should be suggested if any possibility exists to change treatment or the treatment outcome for the patient [27]. In the present study, we did not seek to compare the accuracy and utility of CBCT and panoramic radiographs. CBCT was appointed to investigate anatomical details of MC and related measurements due to superiority in precise assessment. Here, we focused on the coronal plane of CBCT because it clearly and comprehensively demonstrated the whole positional and anatomical relationship MC with MTM and morphology, cortication and dimensions of MC. The study had limitations including the lack of clinical data, regarding IAN injury after MTM extraction and the usual limitations of retrospective

study design. Despite, the cautions have been taken with the training of investigators and the Intraclass-interclass correlation coefficients (ICC), measurements may be done in several times to increase accuracy of the present study. Future studies with more participants and including their clinical data are required to be strengthened the present findings those we found.

In the literature, MTM angulation and impaction depth, position of MC in relation to MTM, morphology of MC, cortication status and possible contact with MC and MTM were defined as risk indicators of IAN injury in MTM surgeries [10-19]. According to our results, 52.06% of participants had vertical impaction of MTM followed by mesioangular (38.99%) and horizontal (7.11%) positions in respect to Winter classification [8]. Studies revealed that greater number of mesioangular, horizontal and vertical type of MTM impactions in their studied population and there is no consensus related on this issue in literature [28,29]. Discrepancy be attributed to the differences in ethnicity. 268 (%73.22) cases were classified as type A according to Pell and Gregory classification [9] which was the most common impaction depth type in our study and this finding was in accordance with a study that performed in 954 participants with 1304 MTMs of Chinese population [29]. The most prevalent position of MC was inferior the roots of MTM (66.97%) followed by lingual (17.2%) and buccal (12.16%) positions and similar findings were confirmed by several authors [14,19]. However, some studies have reported that the canal was located most often buccal or lingual to MTM were also exist [15,16]. There is significant anatomical variation in the position of the MC. Oval/round MC morphology was the most detected shape in our study (76.6%) that compatible with previous studies [13,30]. It was hypothesis that MC morphology is closely associated with the MTM root and according to literature dumbbell and tear-drop morphologies is significantly associated with direct contact of MTM with MC and absence of cortication line of MC [13,30].

There are some other factors that could be influenced to identify the morphology of MC in this area such as retromolar and accessory canals, idiopathic bone marrow defects, salivary glands etc. [31]. However we excluded the radiographs that displaying such images. In our study, relatively low numbers of direct contact of MTM with MC (24.77%) additionally number of cases with absence of cortication line around MC (10.09%) also strengthened this hypothesis. In contrast to our findings, some studies reported high frequency of direct contact of MTM with MC and

no cortication around MC [17,18]. The difference between the present and aforementioned studies may be explained by obtained CBCT scans with different indications. In the present study, cases who requested both preoperative assessment for implant and/or MTM removal were included, however only MTM related CBCT images were evaluated in cited studies.

It is important to know location, anatomical structures, and density of MC prior to MTM surgeries to prevent complications including IAN injuries. The structure of MC has been controversial owing to lack of longitudinal studies [22,23]. Visualization is the first step in MC assessment, and it highly depends on cortication status of MC wall [32]. In present study, not all the MC walls can be measured because walls are often not visible. Moreover, we excluded the CBCT scans which radiopaque border of MC could not be defined clearly and any contact between MC and retromolar canal was existed to avoid misinterpretation of the data. According to our study, the visualization rate of MC was 58.49% which is consistent with previous findings that differs widely among studies from 56% to 87% [33,34]. In our study, average AC diameter of MC was significantly larger in males comparing with female participants and this resembles the previous study which was conducted in Mongoloid racial population [35]. On the other hand, left side located buccal and superior wall of MC were thicker in comparison to right side. Further studies, including participants from different racial groups could clarify the anatomical variations across the world which could help individualized treatment planning. In the literature, studies published mostly focused on superior wall of MC however in case of impacted MTM, buccal and lingual MC walls are also crucial in order to avoid IAN damage which were evaluated in our study. Başa and Dilek [24] reported the thickness of superior wall of MC 0.87 mm for premolar region and 0.86 mm for molar region. The thickness of superior wall was 1.06 mm in our study. This difference may be related with the region of interest and MTM impaction. Koivisto et al. [25] reported that average diameter of the right and left MC in premolar/molar regions were 2.91 mm and 3.03 mm in CBCT scans. In our study, AC and BL diameter of MC were 2.88 and 2.22 mm, respectively. In addition, positive relation of AC diameter of MC with oval/round morphology was demonstrated. The disparity between the present and their findings may be related with different MC morphologies, and it can be hypothesis that MC morphology is a major determinant on MC diameter in MTM region. According to the present study, positive relation was demonstrated between decreased MC lingual wall

thickness and density with high impaction depth of MTM, direct contact of MTM with MC and no cortication borders of MC which were indicators of IAN injury according to previous studies [11,13,17-19]. It can be speculated that decreased thickness and density of lingual MC wall may be another indicator for IAN injury although it should be confirmed with future studies with clinical findings for sure. On the other hand, positive relation was also demonstrated between increased buccal MC thickness and density with lingual position of MC in relation to MTM. In the literature, MC wall thickness was differed between dentulous and edentulous jaws [21] and it could be attributable to remodelling of the wall after tooth loss however according to our result the distance between teeth and MC may be an important determinant in MC wall thickness. On the other hand, the measurement accuracy on CBCT image depends on the observation conditions, such as window level and width. To address this discrepancy, the profile of density for the MC wall was appointed. The HU value is routinely applied to determine the bone density in CT images [36]. In literature several studies also reported that HU values could be used to evaluate the bone density in CBCT images [37-40]. Regarding HU evaluations in CBCT images, some authors have found it controversial because of the enhanced scattered beam and noise [41]. The suspicion of the reliability of intensity values between different CBCT machines is another limitation. To overcome this limitation, same software was utilized in present study. CBCT-HU

can be applied to assess the bone density by using "HU" option of the SimPlant® software according to recent publications [37,38]. Therefore, our established HU values are more appropriate with mentioned CBCT machines and three-dimensional evaluation software, the results of our research cannot be considered verified values for any other CBCT model without experimental analysis. Nevertheless, some future clinical studies with micro-CT evaluations of bone biopsies to explore the correlation with HU values in CBCT are needed.

## CONCLUSIONS

Mandibular canal related variables should be carefully examined before mandibular third molar surgeries in addition to previously determined risk indicators. In accordance with the results of the present study, buccal and lingual mandibular canal wall thickness, density and mandibular canal diameter may be related with high risk of inferior alveolar nerve injury.

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

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