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Evaluation of localisation of mandibular foramen in patients with mandibular third molar teeth using cone-beam computed tomography

O. Altun[1], Ö. Miloğlu[2], N. Dedeoğlu[1], Ş.B. Duman[1], K. Törenek[2]

[1]*Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Inonu University, Malatya, Turkey*
[2]*Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Ataturk University, Erzurum, Turkey*

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Background: *It is important to know the correct anatomical location of the mandibular foramen to obtain successful anaesthesia of inferior alveolar nerve and to prevent injury to the mandibular vessels and nerve, during a variety of oral and maxillofacial surgical procedures. The aim of this study is to evaluate localisation of the mandibular foramen in patients with the third molars using cone-beam computed tomography (CBCT).*

Materials and methods: *Cone-beam computed tomography was used to determine the location of the mandibular foramen in 67 patients (totally 99 sides) with unilateral or bilateral impacted mandibular third molars.*

Results: *The distance from the posterior border of the mandibular ramus to mandibular foramen did not differ significantly among the other angulations. But the difference between vertical and horizontal angulation of the impacted mandibular third molars according to 'fd' values (the shortest distance between mandibular foramen and the posterior border of mandibular ramus) was found to be statistically significant ($p < 0.05$).*

Conclusions: *The present study provides new information to the literature concerning relationship between the location of the mandibular foramen and the mandibular third molars.* (Folia Morphol 2018; 77, 4: 717–723)

Key words: mandibular foramen, cone-beam computed tomography, third molar teeth

INTRODUCTION

The lingula is used for defining the site for injection of local anaesthetics for inferior alveolar nerve. However, the location of mandibular foramen (MF) shows remarkable variation among several populations, in different ages and even within the same individual on two sides [20]. Variations in the form of the lingula have been reported by diverse authors [2, 8, 15], and Tuli et al. [31] classified lingula into four different types based on its form namely triangular, truncated, nodular and assimilated types. Failure to obtain adequate anaesthesia of the inferior alveolar nerve is usually caused by the lack of observance the localisation of the mandibular foramen, noticing them its variations [30]. Some researchers have estimated the failure rate of inferior alveolar nerve blocks to be about 20–25% [23]. Therefore, MF should be accurately located before initiating any surgical procedure [20].

Radiographic images are obtained to detect the location of the MF. Although the panoramic view can be used for this aim, it has the disadvantage of being less correct due to phase transformations and magnification [19]. Computed tomography (CT) can completely assign

Address for correspondence: Assistant Professor, O. Altun, DDS, PhD, Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Inonu University, Malatya, Turkey, tel: +90 4222311100, e-mail: dtaltun@yahoo.com

the position of the foramen three-dimensionally (3D) but is expensive and exposes the patient to an excessive dose of radiation. Whereas cone-beam computed tomography (CBCT) is superior to CT due to such advantages like a lower cost, a lower dose of radiation and with easier procedure, as compared with CT [3, 9, 29].

The purpose of this study is to investigate localisation of the MF in patients with the third molars according to gender, side, state of erupted or impacted third molars, and position of impacted third molars (vertical, horizontal, mesioangular), using CBCT.

MATERIALS AND METHODS

In our study, the CBCT data which were acquired in the convenient position among those taken due to the reasons such as the assessment of the patients referring to the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry of Inonu University between 2015 and 2016 before the dental implant, impacted tooth surgery, orthognathic and paranasal sinus surgery were retrospectively studied. The patients who were younger than 18 years and older than 32 years, those having trauma history in head and neck region, the patients having syndrome or congenital anomalies that give signs in the head and neck region were not included. The patients who had acquired conditions such as pathologic formation or fracture in the relevant region were excluded from the study. A total of 99 sides were measured on 67 patients with unilateral or bilateral impacted or erupted mandibular third molar teeth by using CBCT (NewTom 5G, QR, Verona, Italy).

Imaging procedure

The patient was positioned in supine position with hard palate parallel to the gantry and perpendicular to the ground in an instrument with a constant gantry angle which is perpendicular to the ground. The study was conducted by using axial sections acquired in this position. In this instrument, the study was performed in 18 × 16 or 15 × 12 centimetre field of view area with cone beam technique in 110 kVp and with maximum 20 mA as standard. Guidance images were obtained at the initial stage of the image acquisition process. The instrument had also a system (AEC, automatic exposure control system) which makes automatic dose setting with respect to the anatomic density of the head. Image acquisition was completed by ensuring the patient remained motionless until scanning was finished. Following scanning, the images were assessed with the reconstructions on the axial sections by using New NewTom (NNT) software by obtaining also the sections in other planes.

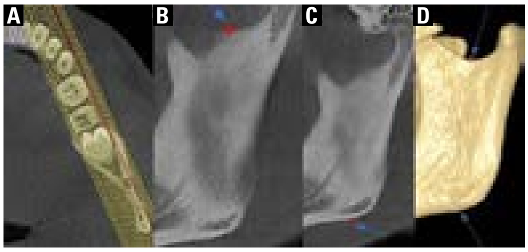

Figure 1. The axial section was selected which visualised the mandibular foramen (MF) (**A**). One-millimetre thick cross sections were taken along the MF (**B**). The middle cross-section was selected and the deepest point of the MF curvature was marked (**C**). A three-dimensional image was reconstructed to confirm marked point of MF before each measurement (**D**).

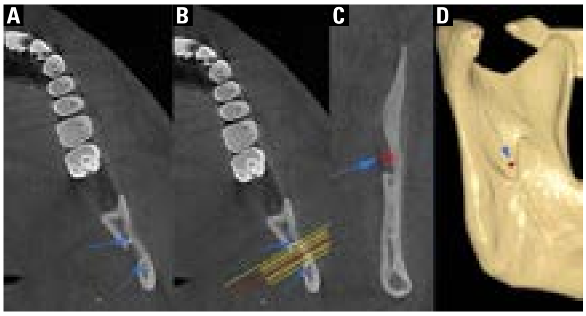

Figure 2. One-millimetre thick oblique sagittal sections were taken along the mandibular ramus (**A**). The deepest points of the mandibular incisura (**B**) and ramus (**C**) were marked. A three-dimensional image was reconstructed to confirm marked points before each measurement (**D**).

Parameters evaluated in the analysis

Marking of anatomical points

Mandibular foramen. Cross sections were taken at 1 mm thickness of the axial section where foramen was present. The deepest point of the curvature, which is located in the middle crossings section, was marked. Since the marked point would also be present in the 3D image, localisation of the point was confirmed by obtaining 3D image (Fig. 1).

The deepest point of the mandibular incisura — the lowest point of the mandibular ramus: 1-mm thick oblique-sagittal sections were taken from the mandibular ramus mandibularis. The deepest point of the mandibular incisures and the lowest point of the ramus were marked and were confirmed on 3D images (Fig. 2).

These reference points which are intended to be guides in the measurements will be seen in all CBCT sections.

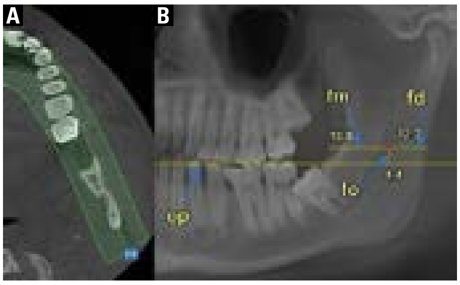

Figure 3. The panoramic radiograph was drawn passing through the mandibular foramen (MF) on the axial image (**A**). The distance between MF and anterior border of mandibular ramus (fm), MF and posterior border of mandibular ramus (fd), and MF and occlusal plane (fo) were measured (**B**).

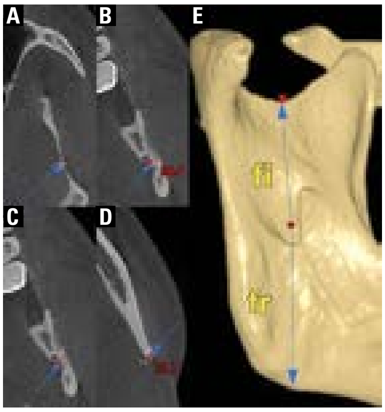

Figure 4. Using New NewTom (NNT) software three-dimensional (3D) distance tool, marked point of incisura was selected (**A**), axial sections were advanced and marked point of mandibular foramen (MF) was selected (**B**). After this process NNT measured the distance (fi) between these points. Similarly the distance between MF (**C**) and the deepest point of the ramus (**D**) was measured (fr). The fi and fr distances were symbolised on 3D image (**E**).

Measurements made on panoramic graph

The panoramic radiograph was drawn to pass through the middle of the MF. Thus, the sign of MF was seen on a panoramic graph. The occlusal plane passing through the mandibular molar teeth was drawn. The distance between the MF and the occlusal plane, ramus anterior and posterior sides was measured (Fig. 3).

3D measurements on axial sections

Distance between the mandibular foramen and the mandibular incisura. When the axial sections were examined from the top to down, the first point (deepest point of mandibular incisura) was set for the 3D measurement of the NNT programme (Fig. 4A) The axial sections were advanced and the second point (MF) was set for the 3D measurement. And NNT programme measured the distance between the two marked points (Fig. 4B).

The distance between the MF and the lowest point of the ramus. The first point of the 3D measurement was placed on the MF (Fig. 4C). The sections were advanced and the second point (deepest point of mandibular ramus) was set for the 3D measurement. And NNT programme measured the distance between the two marked points (Fig. 4D).

The distance (‘fi’, in mm) between MF and the lowest point of mandibular notch and the shortest distance (‘fr’, in mm) between MF and the inferior border of mandibular ramus were measured to compare the vertical positions of MF (Fig. 4).

The distance (‘fm’, in mm) between MF and anterior border of mandibular ramus and the shortest distance (‘fd’, in mm) between MF and the posterior border of mandibular ramus were measured to compare the anterior and posterior positions of MF (Fig. 3B).

The length (‘fo’, in mm) between MF and the occlusal plane was measured to compare the vertical position of the MF (Fig. 3B).

Reconstructed in a panoramic view from CBCT images, items were measured in the mandibular ramus. The measurements were classified into three groups as mesioangular, horizontal and vertical according to the position of the mandibular molar tooth. Distoangular positions teeth were evaluated in other group, because of deficient total number.

Reproducibility

Two different specialists performed all of the measurements and repeated 20% 1 week after. The intra- and interobserver reliability were assessed using an intraclass correlation coefficient (ICC). The intra- and interobserver reliability showed excellent agreement (ICC > 0.90) for all procedures. As a results; intra-examiner correlation coefficient was found minimum 0.93, maximum 0.99, and inter-examiner correlation coefficient was calculated minimum 0.94, maximum 0.99. The intra- and interexaminer consistency was found statistically significant ($p < 0.05$).

Statistical analysis

The data analyses were performed by using the Statistical Package for the Social Sciences (SPSS), version 20.0 (SPSS Inc., Chicago, Ill, USA). The values obtained were tabulated; the mean average and respective standard deviations were calculated for all distances studied. One-Sample Kolmogorov-Smirnov

Table 1. Distribution of evaluated patients, gender, side and average ages

Gender	Patient (n)	Side (n)	Age (mean ± SD)
Female	38	45	24.16 ± 3.612
Male	29	54	25.35 ± 4.622
Total	67	99	24.80 ± 4.215

SC — standard deviation

Table 2. Comparison of average distances (fo, fm, fd, fi and fr) according to genders

Gender		N	Mean ± SD	P
fo	Female	45	5.427 ± 1.3358	0.09
	Male	54	4.967 ± 1.3266	
fm	Female	45	18.649 ± 1.9075	0.07
	Male	54	17.950 ± 1.9603	
fd	Female	45	11.909 ± 1.7080	0.002
	Male	54	10.772 ± 1.7530	
fi	Female	45	19.536 ± 2.6841	0.001
	Male	54	17.789 ± 2.2875	
fr	Female	45	33.284 ± 3.2407	0.0001
	Male	54	29.611 ± 2.7761	

SD — standard deviation; fo [mm] — length between mandibular foramen and the occlusal plan was measured to compare the vertical position of the mandibular foramen; fm [mm] — distance between mandibular foramen and the anterior border of mandibular ramus and the shortest distance; fd [mm] — distance between mandibular foramen and the posterior border of mandibular ramus were measured to compare the anterior and posterior positions of mandibular foramen; fi [mm] — distance between mandibular foramen and the lowest point of mandibular notch and the shortest distance; fr [mm] — distance between mandibular foramen and the inferior border of mandibular ramus were measured to compare the vertical positions of mandibular foramen

test was performed to assess the normality of subgroup data distribution. To compare the impaction types according to different measurements one-way ANOVA was used. When a comparison was made between two groups, like by gender or side, an independent sample t-test was performed. The level of significance in statistical analysis was taken as $p < 0.05$.

RESULTS

The evaluated of 67 patients 29 male and 38 were female. The patients' ages ranged between 18 and 32 years. The average age was 24.8 (Table 1).

All values (fo, fm, fd, fi, and fr) were higher in women but there were no statistically significant difference in fo and fm ($p > 0.05$). However, there was statistically significant difference between male and female in fd, fi and fr ($p < 0.05$) (Table 2).

No statistically significant difference was noted between the measurements on right and left side on both mandibles (Table 3). In addition, there was no statistically significant difference between erupted and impacted groups (Table 4). Likewise, there was no statistically significant difference among impacted subgroups in the fo, fm, fi and fr ($p > 0.05$). However the difference between vertical and horizontal groups according to fd values was found to be statistically significant ($p < 0.05$) (Table 5).

Table 3. Comparison of average distances (fo, fm, fd, fi and fr) according to sides

Side		N	Mean ± SD	P
fo	Right	48	5.152 ± 1.2971	0.60
	Left	51	5.198 ± 1.3989	
fm	Right	48	18.306 ± 1.9829	0.52
	Left	51	18.231 ± 1.9535	
fd	Right	48	11.215 ± 2.0635	0.28
	Left	51	11.359 ± 1.5640	
fi	Right	48	18.402 ± 2.6241	0.66
	Left	51	18.753 ± 2.6174	
fr	Right	48	31.308 ± 3.2808	0.52
	Left	51	31.255 ± 3.7304	

Abbreviations — see Table 2

Table 4. Comparison of average distances (fo, fm, fd, fi and fr) according to impaction status

Impaction status		N	Mean ± SD	P
fo	Impacted	59	5.185 ± 1.3513	0.70
	Erupted	40	5.163 ± 1.3498	
fm	Impacted	59	18.417 ± 1.8271	0.66
	Erupted	40	18.048 ± 2.1416	
fd	Impacted	59	11.168 ± 1.9264	0.37
	Erupted	40	11.468 ± 1.6453	
fi	Impacted	59	18.685 ± 2.7081	0.75
	Erupted	40	18.433 ± 2.4927	
fr	Impacted	59	31.224 ± 3.4603	0.99
	Erupted	40	31.365 ± 3.6049	

Abbreviations — see Table 2

DISCUSSION

Manidibular foramen is not palpable intraorally; therefore, various anatomic landmarks such as occlusal plane, sigmoid notch, coronoid notch, and external and internal oblique ridges have been used for localising it [20]. These mandibular anatomic landmarks should be considered to prevent intraoperative complications such as haemorrhage and permanent neurologic damage

Table 5. Comparison of average distances (fo, fm, fd, fi and fr) according to position of impacted third molars

	fo	fm	fd	fi	fr
Vertical	5.2 ± 0.8	17.9 ± 1.7	9.8 ± 2.8	18.9 ± 2.2	29.7 ± 2.1
Mesioangular	5.2 ± 1.3	18.8 ± 1.5	11.2 ± 1.3	18.0 ± 2.5	31.9 ± 2.9
Horizontal	5.1 ± 1.6	18.1 ± 2.2	11.7 ± 2.1	19.5 ± 3.1	30.9 ± 4.3
Other	5.2 ± 1.3	18.0 ± 2.1	11.5 ± 1.6	18.4 ± 2.5	31.4 ± 3.6
Total	5.2 ± 1.3	18.3 ± 2.0	11.3 ± 1.8	18.6 ± 2.6	31.3 ± 3.5
P	0.21	0.31	0.04*	0.59	0.05*

Abbreviations — see Table 2; *$p < 0.05$ (significant)

caused by the transection of the neurovascular bundle [20]. Similarly, different conventional and advanced imaging modalities such as cephalometry, panoramic radiography, and CBCT are being used for this purpose [1].

Inferior alveolar nerve block is frequently used as a local anaesthetic method for restorative treatment and surgical treatment of mandibular molars [1, 3, 9, 12, 19, 23, 29, 30]. Malamed et al. [13] reported that this method is associated with a high clinical failure rate of up to 15% to 20% [19]. Studies performed thus far on the subject of the MF have concentrated on the race-, gender- and age-related differences [14, 17, 18].

Third molars are the teeth that most mostly follow an abortive eruption way and become impacted because of insufficient dental arch and space in which to erupt. The rate of third molar impaction appears to be increasing [5]. It has been showed that the greater the inclination, the greater the possibility of impaction [28, 32]. If a third molar has a low initial inclination and suitable space, then eruption is probable despite developed root formation [6]. Predictions of impaction or eruption of third molars before the age of 20 years may be inaccurate because of positional changes of these molars during further development [33]. The higher rate noticed in females because of the conclusion of difference between the growth of males and females [26]. Higher prevalence of impacted teeth was set in a study of Morris and Jerman [16], in a study conducted in United States on 5000 (65%) subjects, and also in a study of Quek et al. [22] on 1000 (68%) subjects of Chinese population due to higher jaw teeth size discrepancy, large teeth and smaller dental arch extent of Chinese population compared with Caucasians. The frequency of normally erupted third molars in various studies conducted on Afro-American population (58%) [10] and Indian population (65%) [25], which suggests racial and ethnic factors contributing to impaction of third molars. Olasoji Rajasuo et al. [24] reported impacted third molars are up to 7 times more common in the urban than rural areas in Nigeria and also, when it occurred, third molar impactions affected all the four third molars much more frequently in urban than in rural population. In this study using CBCT, a total of 99 sides (45 female, 54 male) were evaluated on 67 patients (38 females, 29 males) who have unilateral or bilateral, impacted or erupted mandibular third molar teeth in mandible.

Diverse methods have been used to classify impaction, in which impaction is defined based on the level of impaction [21], the angulations of the third molars [34], and the intercourse to the anterior border of the ramus of the mandible [21]. Winter's [34] and Pell and Gregory [21] classifications are most frequently preferred to classify impacted mandibular third molars. The angulation of impaction of the mandibular third molar is detected by the angle formed between the intersected longitudinal axes of mandibular second and third molars, in Winter's classification [34]. We have used the Winter's classification like several authors, in this report. The angulation of impacted third molar was documented based on Winter's classification with reference to the angle formed between the intersected longitudinal axes of the second and third molars: the vertical impaction (10° to –10°), mesioangular impaction (11° to 79°), horizontal impaction (80° to 100°), distoangular impaction (–11° to –79°), others (111° to –80°) and buccolingual impaction (any tooth oriented in a buccolingual direction with crown overlapping the roots). In an adult Turkish population with mandibular third molars, the present investigation was made to determine location of the mandibular foramen in relation to the mandibular ramal landmarks (fi, fr, fm, fd, and fo) using CBCT. Differences of the parameters were also evaluated according to gender, side, impaction status and position of impacted third molar groups.

There was no statistical difference between the right and left side position of MF in this present report. The finding is in harmony with the studies of

Mbajiorgu [14] and Hayward et al. [7]. Seo et al. [27] compared the distance between MF and anterior border of the mandibular ramus in patient with normal occlusion and prognathism using panoramic radiography. This distance was found 24.48 mm on average in normal occlusion and 24.53 mm in prognathism. Park and Lee [19] compared this distance in normal, class II and class III patient using CBCT and its average values were found it to be 19.41 mm, 19.01 mm and 19.85 mm, respectively. In our study CBCT was used and this distance was 18.64 mm in female, 17.95 mm in male, 18.41 mm in impacted, 18.04 mm in erupted group, 17.9 mm in vertical, 18.8 mm in mesioangular, 18.1 mm in horizontal group, 18.3 mm in right and 18.23 mm in left side group. And there was not statistically significant difference between the groups ($p > 0.05$).

Lima et al. [11] stated that vertical position of MF served critical clinical significance for orthognathic surgery and they found that the average distance between MF and mandibular incisura was 27.70 mm. Gutierrez-Ventura and Vivanco [4] found this distance as 17.44 mm. Yu and Wong [35] reported average distance was 22.70 mm in the male and 20.50 mm in female group. Park and Lee [19] found these values 21.59 mm in the normal occlusion group, 20.49 mm in the class II malocclusion and 18.77 mm in the class III group. In this study the average distance between MF and the deepest point of the mandibular incisura was 19.53 mm in females, 17.78 mm in males, 18.68 mm in impacted, 18.43 mm in erupted group, 18.9 mm in vertical, 18 mm in mesioangular, 19.5 mm in horizontal group, 18.4 mm in right and 18.75 mm in left side group. There was statistically significant difference only between the female and male groups ($p < 0.05$). The distance was found less in the male group.

Park and Lee [19] compared the distance between MF and occlusal plane and found it was 0.10 mm below the occlusal plane in normal occlusion patient, 0.03 mm below the plane in class II and 2.79 mm above in class III group. Also they compared gender groups and found as 1.89 mm in male group and 0.04 mm in female group. In this study the average distance between MF and the occlusal plane was 5.42 mm in females, 4.96 mm in males, 5.18 mm in impacted, 5.16 mm in erupted group, 5.2 mm in vertical, 5.2 mm in mesioangular, 5.1 mm in horizontal group, 5.15 mm in right and 5.19 mm in left side group. All of the distances were found higher the occlusion plane. And there was not statistically significant difference between the groups ($p > 0.05$).

In this study some of the measured distances were found different, especially between MF and occlusal plane (fo) compared to other studies. The reason of these differences may be related to our method that used marked deep point of MF a reference point. The population and study groups may be related too. Also the distance between MF and posterior border of the mandibular ramus (fd) and between MF and the inferior border of the ramus (fr) were measured in this study. In this study, the average distance between distance MF and the posterior border of the ramus was 11.9 mm in females, 10.77 mm in males, 11.16 mm in impacted, 11.46 mm in erupted group, 9.8 mm in vertical, 11.2 mm in mesioangular, 11.7 mm in horizontal group, 11.21 mm in right and 11.35 mm in left side group. There was statistically a significant difference only between the vertical and horizontal groups ($p < 0.05$). The distance was found less in the vertical group. The average distance between MF and the inferior border of the mandibular ramus was 33.28 mm in females, 29.61 mm in males, 31.22 mm in impacted, 31.36 mm in erupted group, 29.7 mm in vertical, 31.9 mm in mesioangular, 30.9 mm in horizontal group, 31.30 mm in right and 31.25 mm in left side group. There was a statistically significant difference only between the female and male groups ($p < 0.05$). The distance was found less in the male group.

CONCLUSIONS

In this study, CBCT was chosen as the best method for analysing the positional relationship of the MF and mandibular third molars. According to the results reported here, in the presence of vertically impacted third molars, distance between MF and the posterior border of mandibular ramus (fd, in mm) was found less than the horizontal impaction and the other groups. Furthermore in the male group with third molars, distance between MF and the posterior border of ramus (fd), between MF and the deepest point of the mandibular notch (fi) and distance between MF and the inferior border of the ramus (fr) was found less than the female group. This study provided new information about localisation of MF in patients with third molars according to gender, side, impaction status (erupted, impacted) and subgroups of impaction. Because surgical applications of impacted and erupted third molar are common in dentistry, this information is clinically important. The conclusion however should be confirmed on a larger sample size considering sex variability and different age groups. According to this study, because of the fact that mandibular foramen is less common as vertical position with male patients have third molar tooth, attention should be paid to regional anaesthesia and orthognathic surgery. However, since there is no significant difference between the other measured distances, there is no significant change in needle-tip optimisation.

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