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Morphological analysis of mental foramen; study of cone-beam computed tomography images

Merve Aydoğdu[1], Gülşah Ertaş[1], Ali Türkyılmaz[2], Şirin Rabia Adışen[3], Mehmet Zahit Adışen[1]

[1]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Kırıkkale University, Kırıkkale, Turkiye
[2]Department of Endodontics, Faculty of Dentistry, Kırıkkale University, Kırıkkale, Turkiye
[3]Department of Orthodontics, Private Bilgedent Oral and Dental Health Polyclinic, Kırıkkale, Turkiye

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Corresponding Author: Gülşah Ertaş, gulsah03ertas@gmail.com

ABSTRACT

Aims: This retrospective study investigated the location and profile of the mental foramen (MF) and its connection with neighboring structures in cone-beam computed tomography (CBCT) scans.

Methods: In this retrospective study, the sample consisted of 300 CBCT images. The height and width of the MF, its distance from the mandibular margins and midline, and its position relative to the teeth and tooth apices were also measured. Calculations were categorized by age groups (15-30, 31-45, 46-60), gender, and point.

Results: 46.2% of MF were between the two premolars, while 44.5% were at the apex of the 2nd premolar. 60.7% of MF were round. The horizontal diameter of MF was higher in the 46-60 age group (p=0.01). The horizontal/vertical diameter ratio and the distance to the upper border of the mandible were higher in the 46-60 group than in the 15-30 (p=0.03). The distance of the MF to the lower margin of the mandible was statistically lower in the 15-30 age group (p<0.001). The horizontal diameter, vertical diameter, distance to the upper border, lower border, and mandibular midline were greater in males (p<0.01).

Conclusion: Most MFs are between the two premolars and under the apex of the 2nd premolar. The data on the MF, which we evaluated with three-dimensional imaging and extensive sampling, will serve as a guide for all dental procedures in the mandible.

Keywords: Cone-beam computed tomography, mandible, mental foramen, premolar, radiology

INTRODUCTION

The mental foramen (MF) is located on the anterolateral surface of the mandible. It serves as the terminal opening of the mandibular canal, allowing the passage of mental nerves and vessels. Identifying the MF accurately holds significant importance in both diagnostic processes and clinical practices.[1,2] When an MF is damaged by iatrogenic trauma during endodontic treatments, tooth extraction, or implantology procedures, it causes transient sensory consequences similar to labiodental paresthesia. The pressure from overfilling during endodontic treatments can lead to physical damage, the neurotoxic effect of overflow paste can cause chemical damage and thermal damage can occur due to overheating of the periapical area when filling the root canals, potentially resulting in complications affecting the mental nerve.[3] While endodontic treatment regimens are the primary method of treating pulpal diseases, the success rate is not always 100%. Therefore, some patients require periapical endodontic surgery. The close relationship between the root apices of mandibular premolars and the MF may cause damage to this neurovascular bundle during endodontic surgical procedures. The dentist should consider the location, morphology, and anatomical variations of the foramen to avoid these situations.[4]

Periapical and panoramic radiographs, which are commonly used in dental radiology, provide two-dimensional imaging. However, they are not good at showing anatomical variations in the MF area.[5] Cone-beam computed tomography (CBCT) is becoming more and more popular in dentistry because it offers benefits like a low radiation dose, rapid scanning, and high resolution. CBCT allows dentists to evaluate anatomical structures and pathologies in the oral and maxillofacial region in three dimensions.[6] Research shows that CBCT is more better at detecting and measuring the MF than conventional radiography.[7] This study focused on CBCT images to radiographically assess the form, localization, dimensions, and remoteness of the MF from adjacent teeth and mandibular borders.

METHODS

The study was approved by Kırıkkale University Non-interventional Researches Ethics Committee (Date: 13.12.2023, Decision No: 2023.12.09). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. A retrospective analysis was conducted on patients who had undergone CBCT in the department of oral and maxillofacial radiology for various indications in the between April 2022 and November 2023. The sample consisted of the images of 300 patients (158 female and 142 male) between the ages of 15 and 60. Artifact-free images with fully visible mandible and MF were recruited. The exclusion criteria were (1) the presence of cysts, tumours, fractures, or bone pathology in the lower jaw, (2) having had surgery in the region for various reasons, and (3) having metabolic and syndromic diseases that may cause anatomical variations.

All CBCT images were acquired on ICAT (Imaging Sciences International, Hatfield, PA, USA) at 120 kVp, 8 mA, and 0.3 mm voxel size. Images were subsequently analyzed using InVivo Dental software. The location of the MF was checked in different planes (axial, sagittal, coronal, cross-sectional) and was categorized into four groups: at the level of the 1st premolar (1), between the 1st premolar and the 2nd premolar (2), at the level of the 2nd premolar (3), and between the 2nd premolar and the 1st molar (4) (**Figure 1**). The horizontal and vertical sizes of each MF were specified, and the ratio between these dimensions (H:V) was determined. The classification applied to describe the shape of the foramens is as follows: Type I oval horizontal form (H:V>1.24); Type II oval vertical form (H:V<0.76); type III round form (0.76≤H:V≤1.24) (**Figure 2**).[4,8] The distance between MF and the mandibular midline and its distance to the lower and upper borders of the mandible were calculated in the coronal section where the foramen is most clearly observed. The distance of the foramen to the roots of the 1st and 2nd premolars was measured obliquely from the apex of the root to the apex MF in the coronal (**Figure 3**). An oral, dental, and maxillofacial radiologist used a 22-inch LCD monitor to perform all measurements in a dimly lit and secluded room.

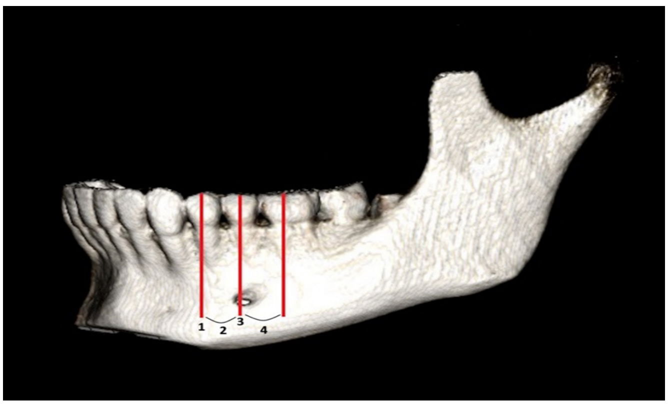

Figure 1. Classification of the location of the mental foramen: 1st premolar level (1), between 1st premolar and 2nd premolar (2), 2nd premolar level (3) and between 2nd premolar and 1st molar (4)

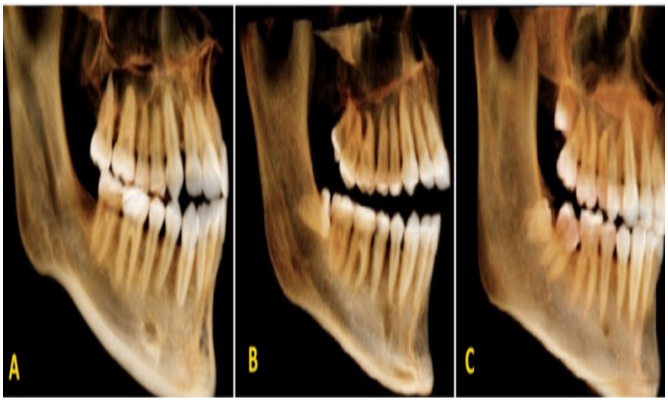

Figure 2. Type I oval horizontal form (A), type II oval vertical form (B), type III round form (C)

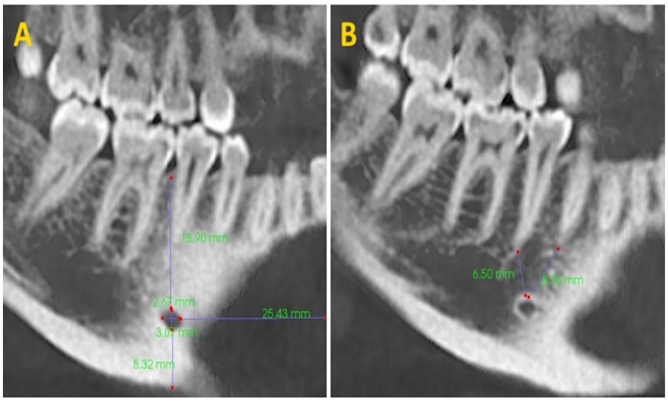

Figure 3. Measurements of the mental foramen on cone-beam computed tomography : the distance of the mental foramen to the midline and the upper-lower border of the mandible (A), the distance of the mental foramen from the roots of the 1st and 2nd premolars (B)

Statistical Analysis

All measurements were transferred to a Microsoft Excel spreadsheet. Before conducting the actual analysis, the data underwent preliminary analysis to assess whether they met parametric assumptions (normality and homogeneity). ANOVA was used for multiple comparisons (normal distribution). Tukey test was used for pairwise comparisons. The data analysis was performed using the Kruskal-Wallis test when the data were non-homogenously distributed. Pairwise comparisons for between-group differences were conducted using the Mann-Whitney U test with Bonferroni correction. The data were processed using the Statistical Package for Social Sciences (IBM SPSS, version 25.0) with a significance level set at 0.05.

RESULTS

Table 1 shows the distribution by age and gender. Participants had an average age of 30.58 years, ranging from 15 to 60. Six hundred CBCT images were assessed for MFs located on the right and left side. **Table 2** shows the distribution of MFs by the position and form of the teeth relative to their apex. Most MFs were positioned between the first and second premolars (n=277; 46.2%). 44.5% of MF were at the 2nd premolar level (n=267). Thirty-nine MF were between the 2nd premolar and the 1st molars (6.5%). Seventeen MF were at the 1st premolar level (2.8%). More than half of MF were of type III round form (60.7%). Almost a quarter of MF were of type II oval vertical form (23%). Less than a quarter of MF were of type

I oval horizontal form (16.3%). The most common form was type III round.

Table 1. The distribution by age and gender

Age groups	Gender		Total
	Female (n/%)	Male (n/%)	
15-30	117 (60.30%)	77 (39.70%)	194 (64.67%)
31-45	23 (39.00%)	36 (61.00%)	59 (19.67%)
46-60	18 (38.30%)	29 (61.70%)	47 (15.66%)
Total	158 (52.67%)	142 (47.33%)	300 (100%)

The distribution of millimetric measurements of the scope, form, and location of the MFs by age was evaluated across three groups (15-30, 31-45, and 46-60) (**Table 3**). The horizontal diameter of the MFs, the horizontal/vertical diameter ratio, and the distance to the upper and lower borders of the mandible differed significantly across age groups. The MF aged 46-60 years had a significantly higher mean horizontal diameter (mean 3.71±0.11 mm) than the other two age groups (p=0.01). The MF aged 46-60 years had a significantly higher average distance to the superior border of the mandible (15.07±0.27 mm) than those aged 15-30 years (p=0.03). The MF aged 15-30 years had a significantly lower mean distance to the lower border of the mandible (9.75±0.10 mm) than the other age groups (p<0.001). The distance between the MF and the 1st and 2nd premolar teeth showed no variation with age (p>0.05).

The horizontal and vertical diameters of the MF and its distance from the upper border of the mandible, the lower border, and the mandibular midline was higher in males than in females (p<0.01). When the position of the MF in relation to the mandibular premolars was evaluated across genders, the mean distance to the 1st premolar tooth was 5.62±0.13 and 6.14±0.15 mm in females and males, respectively. This difference was statistically significant (p<0.001). The mean distance of the MF from the 2nd premolar tooth was 3.89±0.10 mm in females and 4.20±0.13 mm in males. The difference was statistically insignificant (**Table 4**).

The distances of the MF to the mandibular upper border, mandibular midline, and 2nd premolar tooth were greater on the right side compared to the left side (p<0.05). The distance of the MF to the 1st premolar tooth was greater on the left side compared to the right side. (p<0.001) (**Table 5**).

Table 2. Distribution of the form of the mental foramen and its position relative to the apices of the teeth according to gender, mean age and sides

		Gender		Age groups			Side		Total
		Female (n/%)	Male (n/%)	15-30	31-45	46-60	Right	Left	
MF position	1	7 (41.20%)	10 (58.8%)	13 (76.50%)	3 (17.60%)	1 (5.9%)	7 (41.20%)	10 (58.80%)	17 (2.8%)
	2	151 (54.50%)	126 (45.50%)	182 (65.70%)	55 (19.90%)	40 (14.40%)	122 (44.00%)	155 (56.00%)	277 (46.2%)
	3	140 (52.40%)	127 (47.60%)	168 (62.90%)	51 (19.10%)	48 (18.00%)	148 (55.4%)	119 (44.60%)	267 (44.5%)
	4	18 (46.20%)	21 (53.80%)	25 (64.10%)	9 (23.10%)	5 (12.80%)	23 (59.00%)	16 (41.00%)	39 (6.5%)
MF form	Type 1	63 (64.30%)	35 (35.70%)	54 (55.10%)	21 (21.40%)	23 (23.50%)	49 (50.00%)	49 (50.00%)	98 (16.3%)
	Type 2	77 (55.80%)	61 (44.20%)	95 (68.80%)	23 (16.70%)	20 (14.50%)	65 (47.10%)	73 (52.90%)	138 (23%)
	Type 3	176 (48.40%)	188 (51.60%)	239 (65.70%)	74 (20.30%)	51 (14.00%)	186 (51.10%)	178 (48.90%)	364 (60.7%)

MF: Mental foramen

Table 3. Analysis of the size, shape and position of the mental foramen according to age group

		Age groups									
		15-30			31-45			46-60			
		Mean±SD	Median	Mean rank	Mean±SD	Median	Mean rank	Mean±SD	Median	Mean rank	p
MF size diameter (mm)	Horizontal	3.35±0.05	3.30	292.29[b]	3.32±0.08	3.25	288.92[b]	3.71±0.11	3.45	348.91[a]	0.01
	Vertical	3.64±0.05	3.50	307.18	3.44±0.08	3.40	268.60	3.69±0.10	3.60	312.97	0.08
	Horizontal/vertical	0.95±0.01	0.94	287.62[b]	0.99±0.03	0.99	313.58[ab]	1.05±0.03	1.01	337.26[a]	0.03
Position according to bone structures (mm)	Mandibular upper border	14.02±0.11	13.90	280.44[b]	14.55±0.25	14.60	321.78[ab]	15.07±0.27	14.95	356.57[a]	<0.001
	Mandibular lower border*	9.75±0.10[b]	9.70		10.61±0.18[a]	10.50		10.55±0.20[a]	10.50		<0.001
	Mandibular midline	26.20±0.16	26.00	298.11	26.49±0.31	26.25	306.18	26.41±0.39	26.25	303.22	0.89
Mandibular position relative to premolar teeth (mm)	1. premolar	5.77±0.13	5.55	292.54	6.00±0.22	5.70	308.60	6.09±0.23	6.20	323.21	0.26
	2. premolar	4.00±0.11	3.75	293.85	4.07±0.17	3.80	307.57	4.15±0.18	4.30	319.05	0.40

a,b: The difference between the averages with different letters in the same row or between the averages of the ranks is statistically significant (p<0.05). Mean±SD: Arithmetic mean±standard error, Ort.rank: Mean rank. *:Analysis of variance (ANOVA) was performed to compare the age groups since parametric test assumptions were met. MF: Mental foramen

Table 4. Analysis of the size, shape and position of the mental foramen according to gender group

		Gender						
		Female			Male			
		Mean±SD	Median	Mean rank	Mean±SD	Median	Mean rank	p
MF size diameter (mm)	Horizontal	3.20±0.05	3.00	263.04	3.62±0.05	3.50	342.04	<0.001
	Vertical	3.40±0.05	3.30	261.50	3.83±0.06	3.70	343.89	<0.001
	Horizontal/vertical	0.98±0.02	3.96	299.69	0.97±0.02	0.95	301.40	0.90
Position according to bone structures (mm)	Mandibular upper border	13.57±0.12	13.50	251.69	15.08±0.15	14.90	354.82	<0.001
	Mandibular lower border	9.09±0.09	9.10	215.63	11.11±0.11	11.00	394.93	<0.001
	Mandibular midline	25.74±0.16	25.75	273.85	26.89±0.22	26.85	330.15	<0.001
Mandibular position relative to premolar teeth (mm)	1. premolar	5.62±0.13	5.50	284.00	6.14±0.15	5.90	318.86	0.01
	2. premolar	3.89±0.10	3.70	289.62	4.20±0.13	3.90	312.61	0.11

Mean±SD: Arithmetic mean±standard error; Ort.rank: Mean rank. MF: Mental foramen

Table 5. Analyses of the size, shape and position of the mental foramen according to the sides

		Side						
		Right			Left			
		Mean±SD	Median	Mean rank	Mean±SD	Median	Mean rank	p
MF size diameter (mm)	Horizontal	3.37±0.06	3.30	299.11	3.43±0.06	3.30	301.89	0.84
	Vertical	3.56±0.05	3.50	293.19	3.65±0.06	3.50	307.82	0.30
	Horizontal/vertical	0.97±0.01	0.96	304.15	0.98±0.02	0.94	296.86	0.61
Position according to bone structures (mm)	Mandibular upper border	14.50±0.14	14.45	314.69	14.07±0.14	14.00	286.31	0.05
	Mandibular lower border	9.93±0.12	9.90		10.15±0.11	10.00		0.18
	Mandibular middle	26.55±0.19	26.50	316.60	26.02±0.19	25.85	284.40	0.02
Mandibular position relative to premolar teeth (mm)	1. premolar	4.94±0.12	4.80	234.81	6.79±0.14	6.50	366.19	<0.001
	2. premolar	4.25±0.12	4.15	319.66	3.83±0.011	3.50	281.35	0.01

Mean±SD: Arithmetic mean±standard error; Ort.rank: Mean rank, MF: Mental foramen, *: Since parametric test assumptions were met, independent two-group t test was used to compare symmetry groups

DISCUSSION

The MF is a critical anatomical part of the mandible. It houses the mental nerve, the terminal branch of the inferior alveolar nerve, and associated blood vessels. Most researchers have investigated the location, shape, and dimensions of the MF to ensure adequate local anesthesia during dental treatment regimens and to determine a safe working area during surgery. Experts have also been interested in the MF because it is one of the anatomical landmarks in forensic deontology.[9] The position of the MF can be influenced by ethnicity, gender, age, tooth loss, and subsequent crest resorption.[10] The anatomical structure of the MF may differ in the same individual, even in different quadrants. Some individuals have single/double or multiple MFs. In rare cases, it does not form at all.[11,12]

Conventional radiography allows us to visualize a 3D structure represented on a 2D plane. However, magnification and distortion during this transformation can lead to misinterpretation of images and anatomical landmarks.[13] CBCT addresses the limitations of traditional radiography by offering detailed three-dimensional imaging.[1] These volumetric images can be reformatted through reconstruction and offer a lower radiation dose than multidetector computed tomography (MDCT). Researchers have identified some differences between two- and three-dimensional imaging of the MF. The midline and interforaminal mean distances of the MF and mandible are lower in panoramic radiographs than in CBCT measurements.[3] Those researchers suggest the use of CBCT before surgery to prevent nerve damage in the MF region because it is better at detecting anatomical features.[9] We believe that this study, which analyzed 600 MF images three-dimensionally using CBCT in the Turkish population, will contribute to the literature.

Various studies investigating the location of MF with panoramic radiographs often show that the MF is situated either between the 1st and 2nd premolars or Aligned with the 2nd premolar.[14] Direk et al.[15] used MDCT to calculate the position and size of the MF in 100 Turkish patients. They observed the MF at the 1st premolar tooth alignment. Sekerci et al.[16] evaluated MDCT images of 550 patients. They discovered that most MF was located at the level of the 2nd premolar tooth (43.5%) or between the two premolars (42.5%). They added that the MF was round in shape. Kalender et al.[14] performed a retrospective three-dimensional analysis of CBCT images of Turkish patients. Similar to previous studies, most MF was between the 1st and 2nd premolars. The location did not differ across genders and sides. Our results also showed that most of the MF were located between the 1st and 2nd premolars (46.2%). The proportion at the 2nd premolar level was (44.5%).

Alsoleihat et al.[18] focused on CBCT images of Jordanian patients (n=139) to evaluate the location and size of MFs. They found that most MFs were between the two premolars. They also reported that the mean long diameter of the

MF was 3.08 mm in males and 2.46 mm in females. They concluded that the scope of the MF tends to decrease with age in males, but increases with age in females, which may be related to sex hormones.[18] Sheikhi et al.[19] evaluated the position and size of MFs on the CBCT images of Iranian patients (n=180). They measured the average diameter of the as 3.59 mm. Zmyslowska et al.[8] focused on the CBCT images of Polish patients. They found that the mean MF horizontal diameter was 4.24±1.1 mm in males and 3.89±1.12 mm in females, while the vertical diameter was 3.55±1.08 mm in males and 3.02±0.83 mm in females. Doğan et al.[20] analyzed the CBCT images of 148 patients. They observed that the oval shape was identified as the most prevalent type. MF was frequently between the 1st and 2nd molars, followed by the 2nd molar. They stated that the vertical dimension of the MF was 2.23 mm in males and 1.89 mm in females, while the horizontal dimension was 3.7 mm in males and 3.32 mm in females. They concluded that males had significantly higher MF dimensions than females.[20] Our findings showed that the horizontal dimension was 3.6 mm and the vertical dimension was 3.8 mm in males, while the horizontal diameter was 3.2 and the vertical diameter was 3.4 mm in females. The dimensions of the MF showed significant differences between genders.

In their meta-analysis, Pele et al.[3] concluded that the average distance from the MF to the mandibular midline ranged from 23 to 26 mm, the distance to the inferior border was 10-15 mm, the distance to the upper border was 11.2-14.3 mm, and the inter foraminal distance was 46.5-51.4 mm. Research shows that most MFs are between the two premolars, secondarily apical to the 2nd premolar. The results show that gender and side do not affect the location of the MF in relation to the teeth. In the general population, the MF are mostly round or oval.[3] Researchers report that variations in the shape, location, and position of the MF in different populations may be caused genetic variations or delayed prenatal growth.[1] Sheikhi et al.[19] reported that the distance from the MF to the lower margin of the mandible was greater in males, while the distance from the MF to the midline did not show a statistically significant difference between genders. Caglayan et al.[21] focused on the CBCT scans of 192 Turkish patients. They noted that the MF had an oval shape on both sides. The distance of the MF to the mandibular alveolar crest was 11.86 mm on the right and 12.08 mm on the left. The distance from the MF to the base of the mandible was measured as 12.86 mm on the right and 13.13 mm on the left. The distances were statistically higher in males compared to females particularly aged 20-40 years, which may be associated with the longer duration of bone development in males.[21] Direk et al.[15] also found that all MF distances but that to the posterior border of the mandible was found to be higher on both sides in males compared to females. Our results showed that the mean distances of the MF to the mandibular midline, lower border, and upper border were 26.31±0.19 mm, 10.1±0.1 mm, and 14.32±0.13'mm, respectively. Our results also indicated that the distances of the MF to bony structures were statistically greater in males than in females.

Oliveria et al.[22] focused on 104 CBCT images. According to their findings, the mean distance between the MF and the alveolar crest was 11.21 mm, the average distance between the MF and the lower margin of the mandible was 12.31 mm, and the average distance between the MF and the 1st premolar was 4.92 mm. They reported that only the distance between the MF and the lower margin of the mandible was statistically higher in males than in females. However, they reported no difference in MF size between four age groups (18-25, 26-40, 42-55, and ≥56). Lorenzo et al.[23] reported that the distance of the MF to the superior border of the mandible decreased with age, which may be attributed to bone resorption associated with lost teeth in their CBCT evaluations in different age groups. However, researchers making comparisons between different age groups did not report statistical differences between the distances of the MF to the mandibular margins.[4,19,24] Our results showed that the horizontal dimension of the MF was greater in the 46-60 age group compared to the other two age groups. Our results also showed that the horizontal/vertical diameter ratio of the MF and its distance to the superior border of the mandible were higher in the 46-60 age group than in the 15-30 age group. The length from the MF to the inferior border of the mandible was significantly shorter in the 15-30 age group compared to the other two age groups. Age-related variations in the size, position, and distance of the MF from the mandibular margins suggest that age might be a less significant factor to prioritize when planning dental or surgical procedures involving this structure. However, the fact that a fixed age range was not used when forming age groups and the small number of samples may also explain this difference in the literature.

The gap between the roots of the teeth adjacent to the MF is an important topographic point that should be evaluated to prevent nerve damage during endodontic periapical surgery. Research shows that the mean distance of the MF to the closest tooth root is 5 mm and that 47% of the MF is more than 5 mm from the nearest tooth root.[24] Kalender et al.[14] found that the length from the MF to the closest tooth was between 2.1 and 12.5 mm (average: 4.2 mm). It is important to include these measurements in similar studies. Our results showed that the average length of the MF to the closest tooth root was 5.8 mm (0.5-15.4 mm). The average distance of the MF to the 1st premolar tooth was 6.14 mm in males and 5.62 mm in females. There was a statistical difference between the sexes. The length between the left side MF and the 1st premolar root was higher than the right side. The length between the MF and tooth roots tended to increase with increasing age, but this result was not statistically significantly. The distance between the MF and the 2nd premolar did not differ according to age, sex and side.

Limitations

In this study, the positional and dimensional analysis of the MF was reported based on data obtained in a specific population. It is possible that the results may be affected by different racial and genetic variations in larger populations. Additionally; in recent years, there has been an increasing use of artificial intelligence (AI) algorithms in dentistry, with the aim of analysing medical images, detecting diseases and precisely determining anatomical regions. Image segmentation is the first step in AI technologies developed to determine the location of the MF. It is anticipated that tasks that are currently the domain of experts will be performed automatically by machines, as a result of the development of these AI technologies.[25] The MF studies conducted in various imaging methods and different populations have the potential to illuminate new studies by training and testing machines in this direction.

CONCLUSION

The structure of the mandible and the localization, size, and possible variations in the course of the neurovascular structures it contains are very important during surgical intervention. The CBCT is an important radiographic device for three-dimensional evaluation of MF. According to our results, 46.2% of MFs are between the two premolars and 44.5% are in the 2nd premolar position. The results also show that most MFs are round. Healthcare professionals should be aware that the size of the MF and its distance to the mandibular midline, lower, and upper margin are higher in males than in females. Local anesthesia should be administered accordingly during surgery. Additionally, a safe working range should be established to prevent possible neurosensory complications during implant procedures.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was approved by Kırıkkale University Non-interventional Researches Ethics Committee (Date: 13.12.2023, Decision No: 2023.12.09).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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