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Evaluation of mental foramen and accessory mental foramen using cone beam computed tomography in a Turkish population

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Abstract

Background The aim is to assess mental foramen (MF) and anatomical variations using cone beam computed tomography (CBCT) images in a Turkish population.

Methods In this retrospective study, CBCT images of 301 patients (162 females, 139 males) obtained between November 2021 and February 2022 were evaluated. Patients were analyzed in 4 groups according to age (Group 1: 18–30 years, Group 2: 31–45 years, Group 3: 46–55 years, Group 4: 56 years and older). The position of the MF relative to the teeth, vertical (MFV) and horizontal (MFH) dimensions; the distances of the MF to the mandibular midline (MF-MM), ramus posterior border (MF-MP), lower border (MF-ML) and upper border (MF-MU); the presence of an accessory mental foramen (AMF); and if any, the position of the AMF relative to the MF and the distance of the AMF to the MF (MF-AMF) were recorded separately for the right and left sides. Associations with gender and age were evaluated. The independent samples t test was used to determine the relationship between the measurements and gender and the evaluation of the measurement values according to age groups. The evaluation of the location of MF according to gender and age groups was performed using the Chi-Square Test.

Results On the right and left sides, MF was most commonly seen at the apical level of the second premolars (45.4% and 52.1%, respectively). MFV, MFH, MF-MM, MF-MP and MF-ML were significantly higher in males than in females, $p<0.001$ on both sides and for each parameter. There was a significant difference between the age groups for MF-MU and MF-ML on the right side, MF-MU on the left side ($p<0.001$, $p<0.05$, $p<0.001$, respectively). A total of 42 AMFs were seen in 39 (13%) of the 301 patients. AMFs were frequently located posteroinferior to the MFs (35.5%). The mean MF-AMF was 7.83 mm.

Conclusions The findings of this study contribute to the existing literature on the anatomy and variations of MF. The results of this study show that the prevalence of AMF in the Turkish population studied is high at 13%.

Keywords Accessory, Anatomic variation, Cone-beam computed tomography, Mental foramen

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Background

The mandibular canal (MC) contains the inferior alveolar nerve (IAN), vein, and artery. Verification of the course and variations of the MC is important to prevent injury to the neurovascular bundles during surgical, endodontic, and periodontal procedures and to perform effective nerve blockades [1–3].

IAN typically bifurcates into two branches within the premolar region. These branches are identified as the incisive and mental nerves. The incisive nerve continued forward into the incisive teeth, whereas the mental nerve, along with its associated vascular structures, exits the bone through the anatomical structure known as the mental foramen (MF). The mental nerve provides sensory innervation of the skin and mucosa of the lower lip, the buccal vestibule, the gingiva mesial to the mandibular first molar, and the skin of the mental region [4–6].

MF is typically observed one on each side of the mandibular bone. Multiple foramina in the surrounding area of the MF that are smaller in diameter than the main foramen are an anatomical variation and are defined as accessory foramen. In the literature, the term "accessory mental foramen" (AMF) is used to describe an additional foramen that is anatomically connected to the mandibular canal. Conversely, those foramina lacking a direct connection to the mandibular canal are referred to as "nutritional foramina" [6–9].

AMF is as important as MF as the neural and vascular branches pass through it. Knowledge of the location, shape, and dimensions of the MF and AMF is particularly important in surgical procedures involving local anesthesia and this region, such as genioplasty, root resection of mandibular premolars, mandibular rehabilitation after trauma, apical curettage, and placement of dental implants [10, 11].

Cone-beam computed tomography (CBCT) is a useful tool that provides detailed information about the structures of the maxillofacial complex, allowing the identification and evaluation of anatomical variations [12, 13]. Additionally, three-dimensional (3D) measurements can be conducted using specialized software with CBCT images. It has been reported that 3D measurements conducted on CBCT images yield results that closely resemble measurements taken directly on the skull [14, 15].

A review of the literature reveals the existence of studies that evaluate MF and AMF using a variety of radiographic methods. This study aims to contribute to the literature by providing a comprehensive analysis of the morphometric properties and relationships of AMF and MF with 3D measurements.

Methods

Study design and sample

The Clinical Research Ethics Committee of Ordu University approved this study (IRB approval no: 2023/72). The study protocol conformed to the Declaration of Helsinki, and informed consent form was signed by all study participants.

In this retrospective study, CBCT images of the patients taken for various problems at the Oral and Maxillofacial Radiology Department of Ordu University between November 2021 and February 2022 were conducted.

Inclusion and exclusion criteria

The study included CBCT images of individuals over the age of 18, obtained with the same CBCT device (KaVo OP 3D Vision, Imaging Sciences International LLC, USA), in which the mandibular corpus and ramus were included in the imaging area. Images with craniofacial syndromes, trauma or reconstructive surgery in the mandible, pathology in the mandibular corpus and ramus, partially erupted or unerupted teeth in the mental region, absence of a mental foramen due to mandibular alveolar bone resorption, artifacts, and poor quality images were excluded from this study. CBCTs were taken at 90–120 kVp, 3–8 mA, and 8.9 s. The largest voxel size in the analyzed images was 0.3 mm and the largest FOV area was 16 × 13 cm.

Study variables and data collection

In this study, CBCT images were categorized into four groups based on the ages of the respective patients (Group 1: 18–30 years, Group 2: 31–45 years, Group 3: 46–55 years, Group 4: 56 years and older). Image evaluations were performed with OnDemand software (OnDemand3D Technology Inc., USA). The measurements were performed by a dentomaxillofacial radiology research assistant with 2 years of experience. The same researcher carried out all distance measurements twice by one month apart. The mean values of two measurements were analyzed. All evaluations were performed with the mandibular plane parallel to the ground.

The assessments on CBCT images;

1. Location of the MF.
2. The distance of the medial edge of the MF to the mandibular midline (MF-MM).
3. The distance of the lateral edge of the MF to the ramus posterior border (MF-MP).
4. The distance of the upper edge of the MF to the top of the alveolar crest (MF-MU).
5. The distance of the lower edge of the MF to the basis mandibulae (MF-ML).

6. The distance between the upper and lower edge of the MF (vertical diameter of the MF) (MFV).
7. The distance between the anterior and posterior edge of the MF (horizontal diameter of the MF) (MFH).
8. The presence of an AMF.
9. The position of the AMF relative to the MF.
10. The distance of the AMF to the MF (MF-AMF).

The position evaluation of the MF was performed on a 3D model in 3D MPR images, according to the long axis of the existing teeth in patients with first molars, first and second premolars (Fig. 1) [16]. MF-MM and MF-MP measurements were performed on 3D MPR images using a 3D ruler on a 3D model (Fig. 2) [17, 18]. MF-MU, MF-ML, MFV and MFH measurements were performed using a two-dimensional (2D) ruler in the dental module (Fig. 3) [17].

The presence of AMF was evaluated as positive (+) if present on the right and/or left, and negative (-) if absent on the right and left. If AMF was present, the position assessment of the AMF was performed on the 3D model in the 3D MPR images of the software. They were recorded as posterior, postero-superior, postero-inferior, inferior, superior, anterior, antero-inferior, or antero-superior positioned according to MF. MF-AMF was measured by measuring the closest distance of the midpoints of both foramen to each other using a 3D ruler on a 3D image (Fig. 4) [2, 8].

Statistical analyses

All statistical analyses were performed with the SPSS software (version 20, SPSS®, Inc., Chicago, IL, USA). The normality of the data was evaluated using the Shapiro-Wilk test. According to the results of this test, the data were normally distributed. The independent samples t test was used to determine the relationship between the measurements and gender and the evaluation of the measurement values according to age groups. The evaluation of the location of MF according to gender and age groups was performed using the Chi-Square Test. Qualitative data were presented as frequencies and percentages. *P* value of <0.05 was considered statistically significant.

Results

A total of 301 patients (162 females and 139 males) met the inclusion and exclusion criteria and were included in the study group. The mean age in this study was 44.72 ± 14.61 years (18 to 78 years).

The mental foramen was most commonly located on the long axis of the second premolar on both sides (Tables 1 and 2). The location of the mental foramen was not statistically significantly different between the genders for either the right or left side ($p = 0.235$ and $p = 0.756$ respectively) (Tables 1 and 2).

While there was a significant difference between the right and left sides in terms of mean MF-MM, MF-ML and MFH measurements ($P < 0.001$), there was no significant difference in terms of mean MF-MP, MF-MU and MFV measurements (p = 0.701, $p = 0.136$ and $p = 0.117$ respectively).

There was a significant difference between the genders for the mean values of MFV, MFH, MF-MM, MF-MP, and MF-ML ($P < 0.001$), but no significant difference was found for MF-MU ($p = 0.291$, $p = 0.665$ and $p = 294$ respectively) (Table 3).

There was no significant difference between the age groups regarding MFV, MFH, MF-MM, MF-MP, and MF-ML measured on both sides ($P > 0.05$). There was a significant difference between the age groups in terms of MF-MU on both sides ($P < 0.001$) (Graph 1). There was

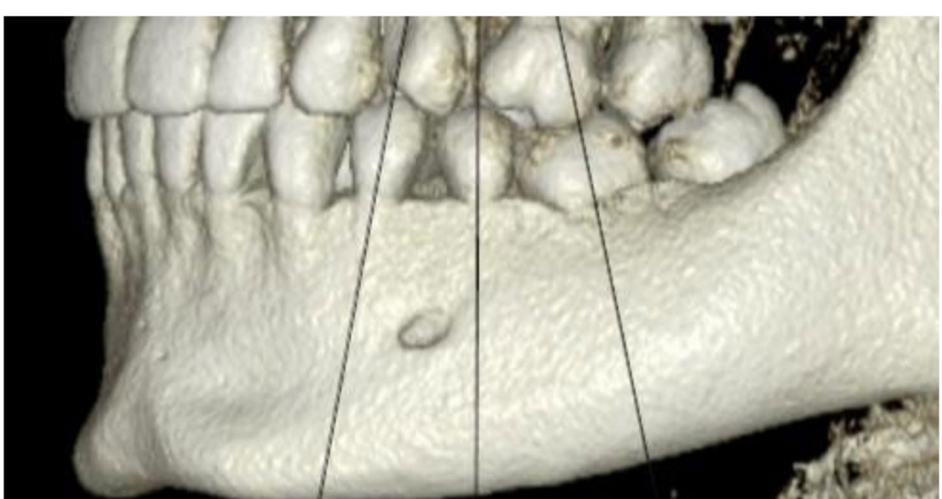


Fig. 1 The positional relationship of the mental foramen to the mandibular teeth

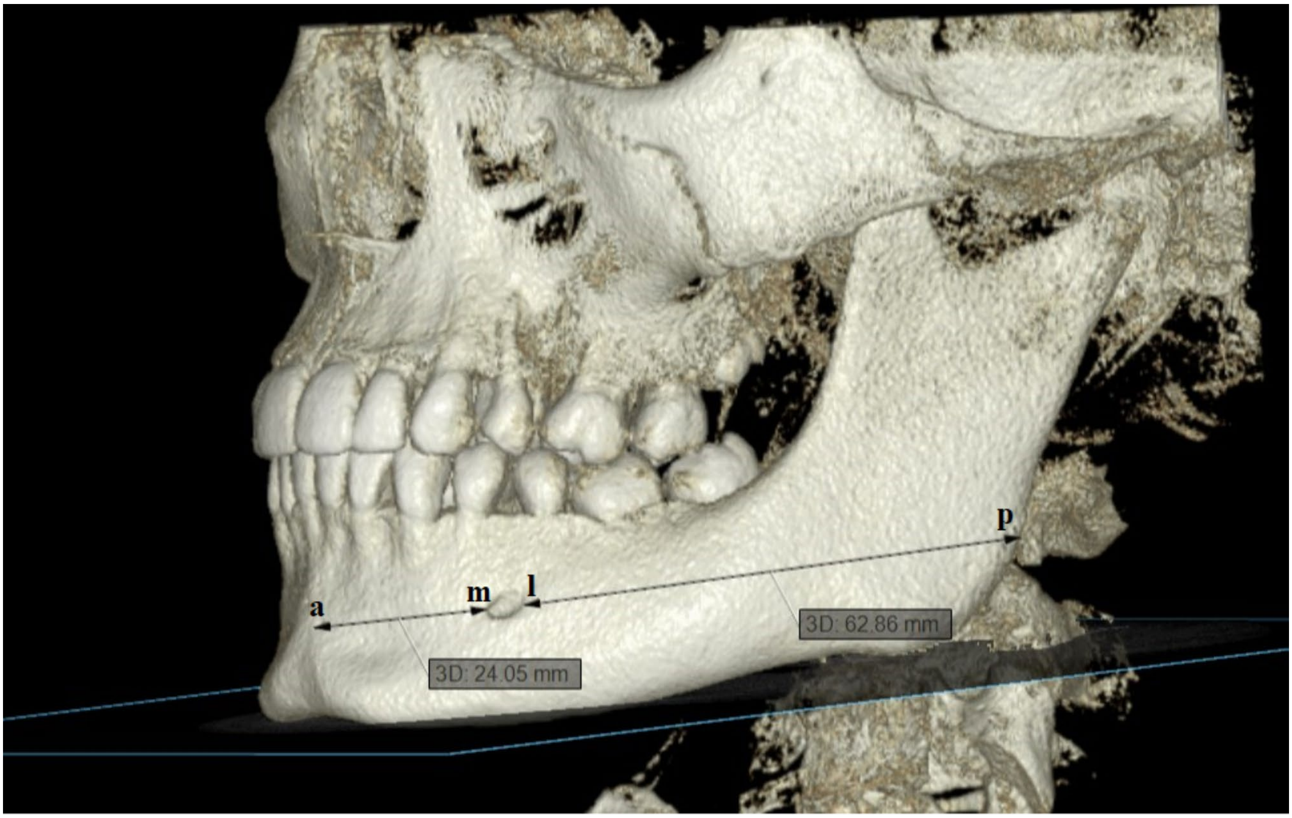


Fig. 2 The relation of the MF to the symphysis menti and the posterior border of the mandibular ramus. **m**; the point was the medial edge of the mental foramen, **a**; the point in the symphysis menti on the axis parallel to the mandibular plane and passing through the medial edge of the mentalforamen, **l**; the point was the lateral edge of the mental foramen, **p**; the point in the posterior border of the mandibular ramus on the axis parallel to the mandibular plane and passing through the lateral edge of the mental foramen, **ma**; distance between the medial edge of the MF and the symphysis menti, **pl**; distance between the lateral edge of the MF and the posterior border of the mandibular ramus

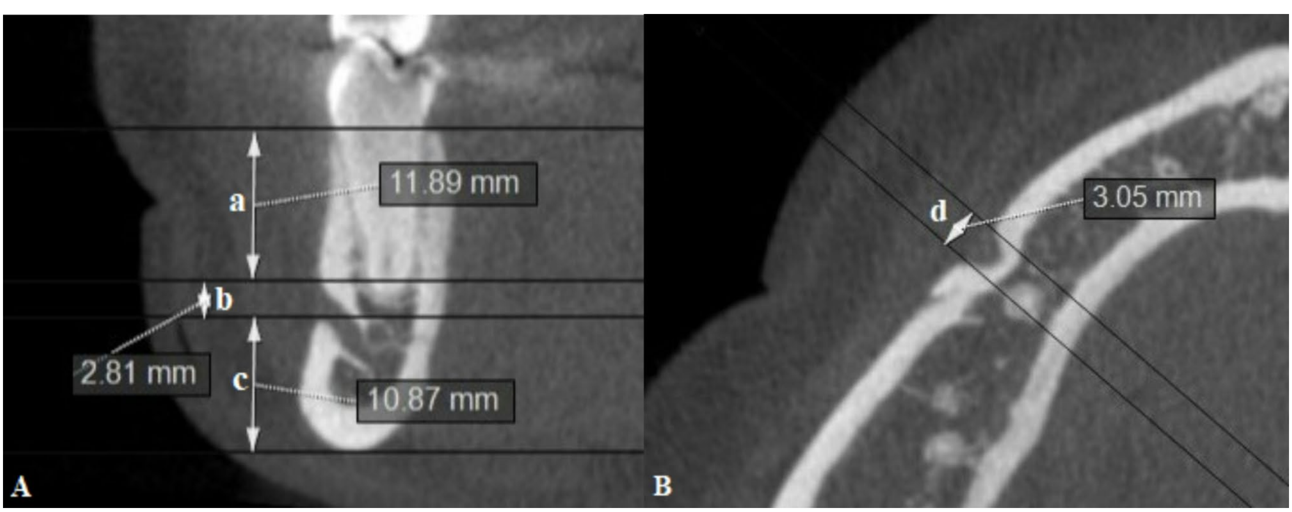


Fig. 3 **A**, cross-sectional image. **B**, axial image. **a**; distance between the upper edge of the MF and top of the alveolar crest, **b**; distance between the upper and lower edge of the MF, **c**; distance between the lower edge of the MF and the basis mandibulae, **d**; distance between the medial and lateral edge of the MF on axial plane

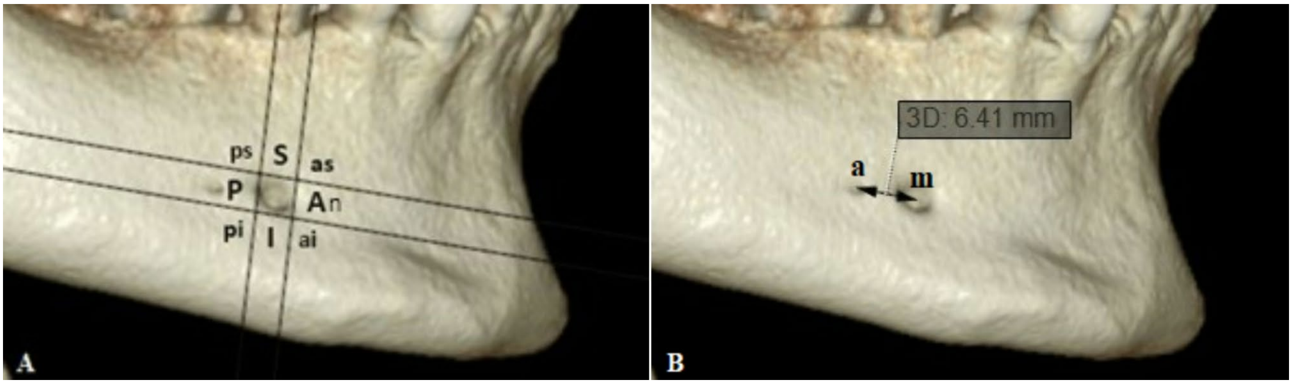


Fig. 4 Three-dimensional image of AMF and MF. **A**, The position of the AMF relative to the MF (An; anterior, as; antero-superior, ai; antero-inferior, P; posterior, ps; postero-superior, pi; postero-inferior, S; superior, and I; inferior). **B**, The distance of the AMF to the MF (a; center of the AMF, m; center of the MF)

Table 1 Gender-based analysis of the mental foramen position in relation to the teeth on the right side

	Total	Long axis of the first premolar	Between the first and second premolar	Long axis of the second premolar	Between the second premolar and first molar	*P**
	N (%)	N (%)	N (%)	N (%)	N (%)	
Female	113 (100)	5 (4.4)	54 (47.8)	47 (41.6)	7 (6.2)	0.235*
Male	92 (100)	4 (4.3)	31 (33.7)	46 (50)	11 (12)	
Total	205 (100)	9 (4.4)	85 (41.5)	93 (45.4)	18 (8.7)	

*Chi Square Test

Qualitative data were presented as frequencies and percantages

Table 2 Gender-based analysis of the mental foramen position in relation to the teeth on the left side

	Total	Long axis of the first premolar	Between the first and second premolar	Long axis of the second premolar	Between the second premolar and first molar	*P**
	N (%)	N (%)	N (%)	N (%)	N (%)	
Female	114 (100)	7 (6.1)	45 (39.5)	58 (50.9)	4 (3.5)	0.756*
Male	99 (100)	5 (5.1)	34 (34.3)	53 (53.5)	7 (7.1)	
Total	213 (100)	12 (5.6)	79 (37.1)	111 (52.1)	11 (5.2)	

*Chi Square Test

Qualitative data were presented as frequencies and percantages

a significant difference in mean MF-ML between age groups on the right side ($P<0.001$), but not on the left side ($P>0.05$) (Graph 2).

A total of 42 AMFs were observed in 39 patients, representing 13% of the total number of patients included in the study. Two patients exhibited one AMF on each side, while one patient displayed two AMFs on one side (Tables 4 and 5). The AMF was often located posterioinferior to the MF (35.5%) (Table 6). The mean MF-AMF was 7.83 ± 4.06 (3.15–19.55) mm. There was no significant difference in the presence of AMF and gender ($P>0.05$).

Discussion

In the literature, the morphology of the mental foramen and AMF has been evaluated using various imaging modalities such as periapical, panoramic, multidetector computed tomography (MDCT), CBCT or on a dry skull [4, 8, 11, 18]. Previous studies have reported that magnification and superimposition in two-dimensional images can cause difficulties in image interpretation and that panoramic radiography has a lower detection rate than CBCT in the evaluation of AMF [19, 20]. One important advantage of CBCT is that it produces 3D images, which allow for a comprehensive evaluation of the anatomy of the selected region. Additionally, 3D measurements can be made on 3D models obtained with software [14, 15]. Other advantages of CBCT include better image resolution, shorter acquisition time, relatively lower radiation dose, and lower cost, compared to MDCT [12]. This study contributed to the literature by providing a comprehensive analysis of the morphometric properties and relationships of AMF and MF with 3D measurements.

Considering the long axes of the existing teeth, in this study, MF was most common located on the long axis of the second premolar on both sides. Studies in the

Table 3 Gender-based evaluation of mean measurements

Measurement	Side	Gender		P*
		Female	Male	
MF-MM(mm)	Right	25.29	26.53	**< 0.001**
	Left	25.79	26.87	**< 0.001**
	All	25.54	26.70	**< 0.001**
MF-MP(mm)	Right	67.1	71.57	**< 0.001**
	Left	66.96	71.87	**< 0.001**
	All	67.03	71.72	**< 0.001**
MF-MU(mm)	Right	11.53	11.93	0.291
	Left	11.44	11.6	0.665
	All	11.48	11.77	0.294
MF-ML(mm)	Right	12.46	14.09	**< 0.001**
	Left	12.69	14.23	**< 0.001**
	All	12.58	14.16	**< 0.001**
MFV(mm)	Right	2.63	3.1	**< 0.001**
	Left	2.59	2.99	**< 0.001**
	All	2.61	3.04	**< 0.001**
MFH(mm)	Right	3.55	3.91	**< 0.001**
	Left	3.33	3.77	**< 0.001**
	All	3.44	3.84	**< 0.001**

* Independent Sample T Test

MF-MM: the distance of the medial edge of the MF to the mandibular midline

MF-MP: the distance of the lateral edge of the MF to the ramus posterior border

MF-MU: the distance of the upper edge of the MF to the top of the alveolar crest

MF-ML: the distance of the lower edge of the MF to the basis mandibulae

MFV: vertical diameter of the MF

MFH: horizontal diameter of the MF

literature report that the mental foramen is most commonly found in this position [11, 21–24]. In other studies in the literature, the location of the mental foramen was most commonly reported between the 1st and 2nd premolars [5, 17]. This location was the second most frequently occurring in our study. Additionally, as in previous studies, there was no significant difference between genders regarding the position of the MF relative to the teeth on both sides ($P > 0.05$) [17, 18, 21].

In this study, the mean MF-MM measurement was 25.54 mm in females and 26.7 mm in males. Apinhasmit et al. reported that the measurements on the dry skull averaged 27.94 and 29.3 mm, respectively [21]. In studies using MDCT images on the Turkish population, Direk et al. reported a mean value of 24.65 mm and 25.85 mm for MF-MM, while Haktanir et al. reported a mean value of 24.2 mm and 25.4 mm. This study found mean values similar to those found in other studies of the Turkish population [18, 25].

In this study, the mean MF-MP measurement was 67 mm and 71.72 mm in females and males, respectively. Apinhamit et al. reported this measurement of 64.95 mm and 70.92 mm, while Direk et al. reported 66.71 mm and 72 mm. These measurements were found to be consistent with those in the literature [18, 21].

In their study evaluating 142 KIBT images, Von Arx et al. reported the mean MF-MU measurement to be 12.6 mm and the MF-ML measurement to be 13.2 mm [26]. Cardenes et al. analyzed 50 KIBT images and reported measurements of 15.9 mm and 13.86 mm, respectively [27]. Lorenzo et al. evaluated 344 KIBT images and reported measurements of 11.42 mm and 13.55 mm, respectively [28]. In the present study, the mean MF-MU and MF-ML measurements were 11.62 mm and 13.32 mm, respectively.

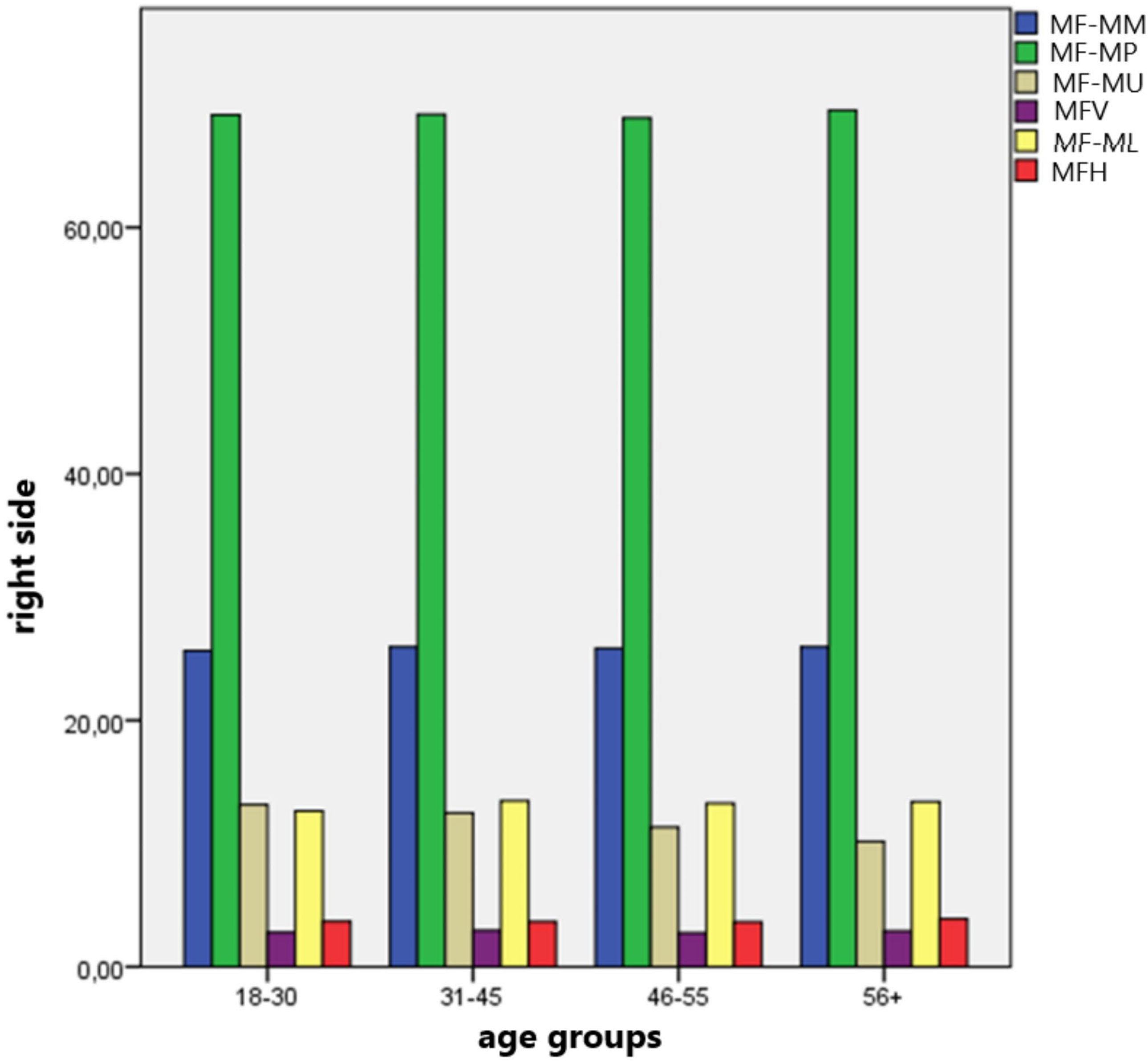
Previous studies employing CBCT imaging to assess the vertical and horizontal dimensions of the mental foramen have reported these measurements of 3.7 and 3.4 mm, respectively, by Kalender et al. and 3 and 3.2 mm, respectively, by Von Arx et al. [17, 26]. The mean measurements of MFV and MFH in the current study were 2.82 mm and 3.63 mm, respectively.

The results of our study indicate that distance measurements (MFV, MFH, MF-MM, MF-MP, and MF-ML) were significantly higher in males than in females. These findings are consistent with those reported in the existing literature [17, 21, 25, 26]. This is to be expected, given the difference in mandible size between the genders. Furthermore, the observation that the measurement outcomes are higher in males than in females indicates that these measurements can be employed as an additional radiographic method for gender determination in forensic dentistry.

Upon evaluation of the MF-MM, MF-ML, and MFH measurements obtained in this study according to the side, a significant difference was found in terms of measurement values. In the majority of studies conducted in the literature, no statistically significant difference was observed between the sides in terms of distance measurements [17, 18, 21, 25, 26]. Only Cardenes et al. reported a significant difference between the sides in terms of MF-ML measurement, which is comparable to the findings of our study [27].

The results of our study indicated a significant difference between age groups in terms of MF-MU among distance measurements ($P < 0.001$). The mean MF-MU was highest in Group 1 and lowest in Group 4 on both sides. The results of our study are consistent with the literature, and this may be explained by the increase in crest resorption with age-related tooth loss [28].

The frequency of AMF has been reported between 2% and 14.3% in the literature [2, 6–9, 17, 20, 28–30]. A review of studies conducted in the Turkish population revealed a prevalence rate of between 2% and 12.2%. In this study, the prevalence of AMF was found to be 13%, which represents the highest rate ever observed in the Turkish population [17, 20]. Bilateral AMF is a rare occurrence, with only two patients in this study exhibiting this condition. Kalender et al. evaluated CBCT

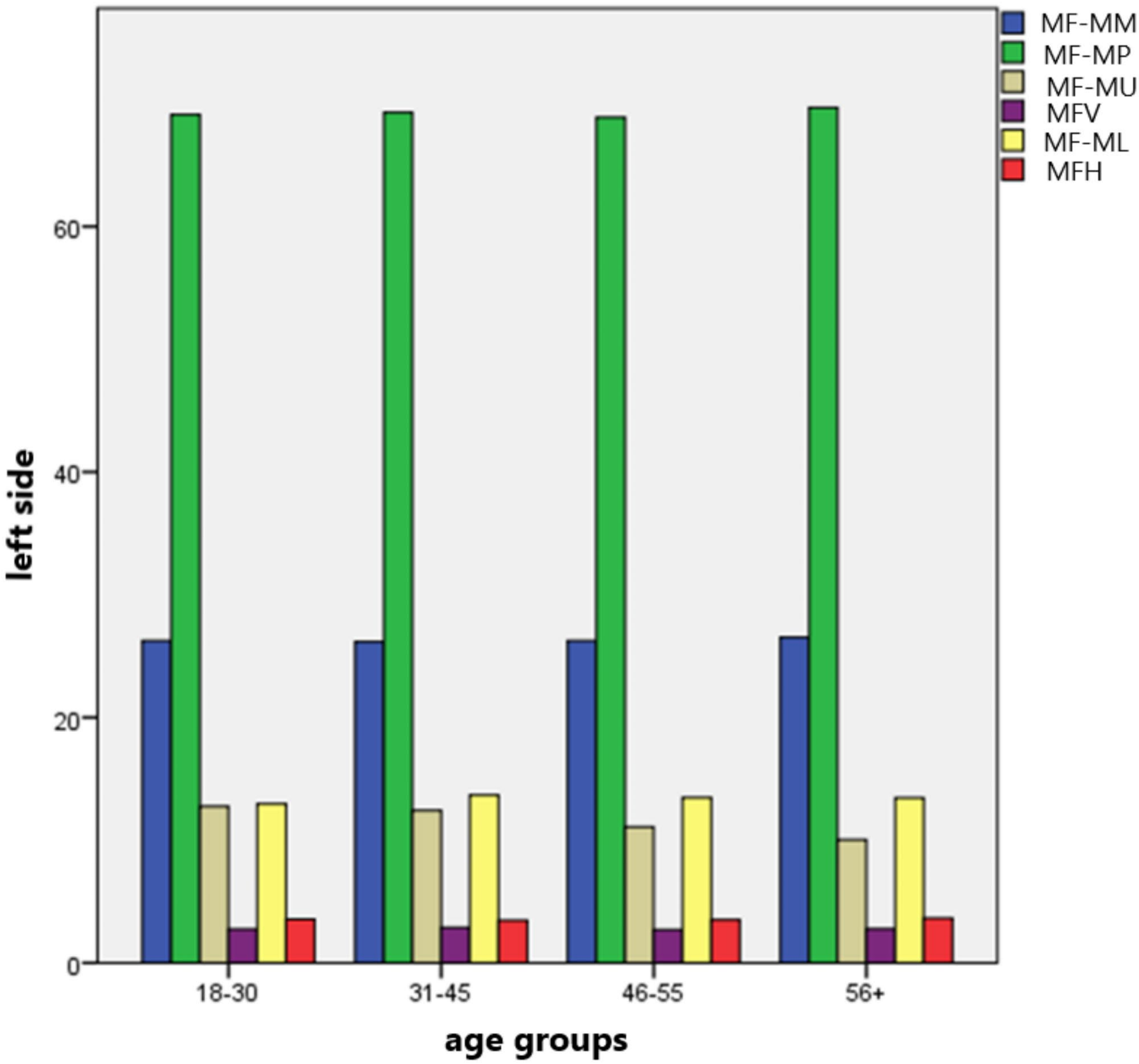


Graph 1 Evaluation of right-sided measurements according to age groups

images of 193 patients and found bilateral AMF in one case, while Direk et al. found bilateral AMF in three of 100 patients in MDCT study [17, 18]. The results of our study indicated that there was no significant difference between the presence of AMF and gender ($p > 0.05$). The most studies in the literature have indicated that there is no significant difference between the genders, a finding that is consistent with the results of our study [9, 17, 18, 20]. In a study of the Korean population, Han et al. reported that the prevalence of AMF was significantly higher in men than in women [31]. In present study, there was no significant difference between the sides in terms of the presence of AMF, as observed in the studies of Aytugar et al., Zmysłowska-Polakowska, and Kalender et al. [6, 17, 20].

In this study, AMF was most commonly positioned in a posterio-inferior position according to MF (35.5%). This position was followed by antero-inferior position (19.1%). Similarly, there are studies in the literature reporting that AMF was most commonly found in the posterio-inferior position [8, 20, 28, 29, 32].

The mean MF-AMF value in our study was 7.83 mm, with a range of 3.15 to 19.55 mm (SD: 4.06 mm). In the literature, this measurement has been reported to range from 0.64 to 15.4 mm [6–9, 17, 20, 29, 30]. In their study, Kalender and et al. observed that the distance in question exhibited a range of 1.3 to 15.4 mm, with an average



Graph 2 Evaluation of left-sided measurements according to age groups

Table 4 Incidence of accessory mental foramen by gender

	Presence (+) *N* (%)	Absence (-) *N* (%)	Total *N* (%)
Female	19 (12)	143 (88)	162 (100)
Male	20 (14)	119 (86)	139 (100)
Total	39 (13)	262 (87)	301 (100)

Qualitative data were presented as frequencies and percentages

Table 5 Distribution of the number of accessory mental foramen by side and gender

	Right *N* (%)	Left *N* (%)	Total *N* (%)
Female	12 (57)	9 (43)	21 (100)
Male	8 (38)	13 (62)	21 (100)
Total	20 (48)	22 (52)	42 (100)

Qualitative data were presented as frequencies and percentages

of 5.2 mm (SD: 4.4 mm) [17]. Naitoh et al. reported that this distance varied between 4.5 and 9.6 mm, with an average of 6.3 mm [8]. Our study found a mean MF AMF value that is higher than that reported in previous studies. The difference may be attributed to the ethnic background of the population studied, the radiographic techniques employed, and variations in measurement methodologies.

Although this study has a relatively small sample size, it provides additional data to the literature regarding the location and morphology of the MF and AMF in a

Table 6 Position of the accessory mental foramen relative to the mental foramen

Position	Right N (%)	Left N (%)	Total N (%)
Posterior	3 (15)	0	3 (7.2)
Postero-superior	2 (10)	2 (9)	4 (9.5)
Postero-inferior	**5 (25)**	**10 (45)**	**15 (35.5)**
Superior	1 (5)	2 (9)	3 (7.2)
Inferior	1 (5)	1 (4.5)	2 (4.8)
Antero-superior	2 (10)	1 (4.5)	3 (7.2)
Anterior	1 (5)	3 (14)	4 (9.5)
Antero-inferior	5 (25)	3 (14)	8 (19.1)
Total	20 (100)	22 (100)	42 (100)

Qualitative data were presented as frequencies and percentages

Turkish subpopulation. The findings of this study support the notion that anatomical measurements can be influenced by the ethnic background of the population studied, as well as by variations in radiographic techniques and measurement methodologies, when compared with previous studies in the literature.

Conclusions

In conclusion, the prevalence of AMF in the study population was found to be 13%. The most common location of AMF with respect to the MF was posteroinferior. The findings of this study contribute to the literature on the anatomy and variations of MF. This is important to prevent injury to neurovascular bundles and to perform effective nerve blockades during surgical, endodontic, and periodontal procedures.

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The study was presented as oral presentation in the Recep Tayyip Erdogan University International Dental Congress, 05–07 May 2023, in Rize, Turkey.

Author contributions
The authors confirm contribution to the paper as follows: study conception and design: DC, ZUE, ES; data collection: DC; analysis and interpretation of results: YY, ES; draft manuscript preparation: all authors. All authors reviewed the results and approved the final version of the manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The Clinical Research Ethics Committee of Ordu University approved this study (IRB approval no: 2023/72). The study protocol conformed to the Declaration of Helsinki and informed consent form was signed by all study participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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