

Original Article

Morphometric and Epidemiologic Evaluation of the Main and Accessory Mental Foramina Using CBCT

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ABSTRACT

Background: Mental foramen (MF) is a sensitive anatomy that should be avoided in surgeries like dental implantation. Therefore, epidemiological studies evaluating anatomic variations of the main MFs and accessory foramina are of significant clinical importance.

Purpose: Due to controversies over MF characteristics, this study was conducted to examine comprehensively the anatomical properties of main and accessory mental foramina in a rather large sample of Iranians by employing cone-beam computerized tomography (CBCT).

Materials and Method: In this epidemiological cross-sectional study, 452 hemi-mandibles of 234 patients (age: 50.1±13.3 years, 113 males, 121 females) were examined. The presence of MF and accessory MF (AMF), horizontal and vertical diameters, surface areas, shapes, position, and distance of AMF to MF, and the closest tooth to the MF were recorded. Data were analyzed using Fisher, chi-square, McNemar, independent-samples *t*-test, and paired *t*-test.

Results: Prevalences of MF and AMF were 99.9% and 5.5%. Oval, round, irregular, linear, and tear-drop shapes were respectively seen in 43.8%, 33.6%, 18.6%, 3.1%, and 0.4% of cases. The closest tooth to the MF was the second premolar (96.4%) followed by the first premolar (2.7%). MF's width and height were 3.31±0.82 and 3.17±0.75 mm. The AMF was seen mostly mesial-superior (33.3%) and distal-superior (25.0%) to the MF. The AMF's width and height were 1.91±0.82 and 2.00±0.81 mm. The MF-AMF distance was 6.60±3.14 mm. Only MF height and surface area were greater in males than females (*t*-test *p* Value<0.001).

Conclusion: MF can be found around the second premolar and usually in oval and round shapes. Its height might be larger in men. Accessory foramina were rare and unilateral.

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Introduction

The mandible has been a fascinating subject of study and extensive research in the realms of dentistry and human anatomy because of its intricate structure and remarkable variation [1]. One important mandibular anatomical component with clinical significance is the

mental foramen (MF) [1]. The neurovascular structures that innervate the lower front portion of the face rely on the MF as a vital conduit. This makes it an important area of study for maxillofacial surgeons, dental implantologists, anthropologists, and dentists [1].

In the mandible trunk almost between the roots of

the premolars, the inferior alveolar nerve furcates in two branches including the incisive nerve that innervates the anterior mandible, and the other branch which exits the bone through the MF innervating the lower lip and chin area [2-12]. Therefore, there are many nerve fibers around the MF, making it a sensitive area for performing surgeries like apicocurretage, retrograde amalgam filling, periodontal surgery, surgical orthodontics, and dental implantation [3-13]. Also, the MF serves as a target for effective nerve blocks [8]. Hence, the knowledge of the position and anatomic variations of the main MF and an accessory mental foramen (AMF) is of significant value. When performing surgery, the existence of an AMF is a crucial factor. These extra foramina contain blood vessels and nerves that might cause problems like bleeding or numbness in the lower lip if they are injured during surgery [14]. Therefore, planning and carrying out safe and successful surgical procedures requires an awareness of the location and content of MFs and AMFs [1,14].

Since most of this information is not obtainable accurately by panoramic radiography, 3D studies on ethnicities regarding these anatomic features are important. The MF might vary among populations in terms of position and shape [15], its absence [16], or prevalence of accessory foramens [8]. Most previous cone-beam computed tomography (CBCT) studies were controversial, and had rather small sizes and/or limited methods [3-4, 6, 10-12, 17-18].

Because of the importance of this matter as well as controversial reports on different populations and a lack of adequate expansive CBCT studies, we aimed to examine comprehensively the anatomical properties of main and accessory mental foramina in a rather large sample of Iranians. The study questions were the prevalence of MFs and AMFs, their position, shape, size, and prevalence, as well as their potential associations with gender and age. The null hypotheses were the absence of sex dimorphism and any role of age.

Materials and Method

In this epidemiological cross-sectional study, all available CBCT scans taken previously for clinical-only indications (e.g., assessment of pathologies, impacted teeth, implant planning, etc.) were originally screened against the inclusion and exclusion criteria. The ethics of study

protocol were approved as a part of the whole thesis, by the research committee of the Islamic Azad University, Dental Branch of Tehran, in accordance with the *Hel-sinki declaration* (Thesis registration number: 22023, thesis identity code: 22710201882094). Since the CBCTs were all obtained retrospectively for other reasons rather than the study itself, the need for informed consent was waived by the research committee.

All evaluated CBCTs (more than 700) had been taken with the same CBCT unit (NewTom VGi, Verona, Italy) at a private radiology center. The radiation parameters were 110 kV, 2.94 mA, and 3.6 seconds. The voxel size was 0.027mm^3 , and a slice thickness of 0.27 mm.

The exclusion criteria were any local defects or pathologies, or any systemic or local pathologies (determined from patients' records and histories) influencing the pathway and position of the mandibular canal and MF. The inclusion criteria were CBCT volumes and images of proper quality, existence of complete patient files and records, patients having all anterior teeth, being ≥ 18 years old, and the coverage of at least 2 cm distal to the MF in the CBCT as well as coverage of the bone around the MF down to the lower cortical border of the mandible [5,7]. The standardized method for assessment of AMFs was to search in all cross-section of each hemimandible in an area around the main MF; this region extended distally to 20 mm distal to the main MF, and mesially to the lingual nerve foramen; it extended to the lower border of the mandible.

The study included 452 CBCT quadrants in 234 participants. There were 113 male patients and 121 female patients out of the 234 total. With a range of 18 to 84 years, their average age was 50.1 ± 13.3 years. A total of 217 of these patients had bilateral anterior mandibular CBCT volumes, while seventeen had unilateral mandibular CBCT volumes. Age and gender were used to categorize the instances [5,7].

Measurements

All the measurements were performed using the CBCT unit's calibrated software (NNT, version 4.5, NewTom) by a dentist experienced in using the software and device. After reconstructing the sagittal, frontal, and axial slices and 3D volumes, the MF was identified on each side of each hemi-mandible. The anatomical variables which have been recorded (only once by the same observer) were the presence of MF and AMF, horizontal

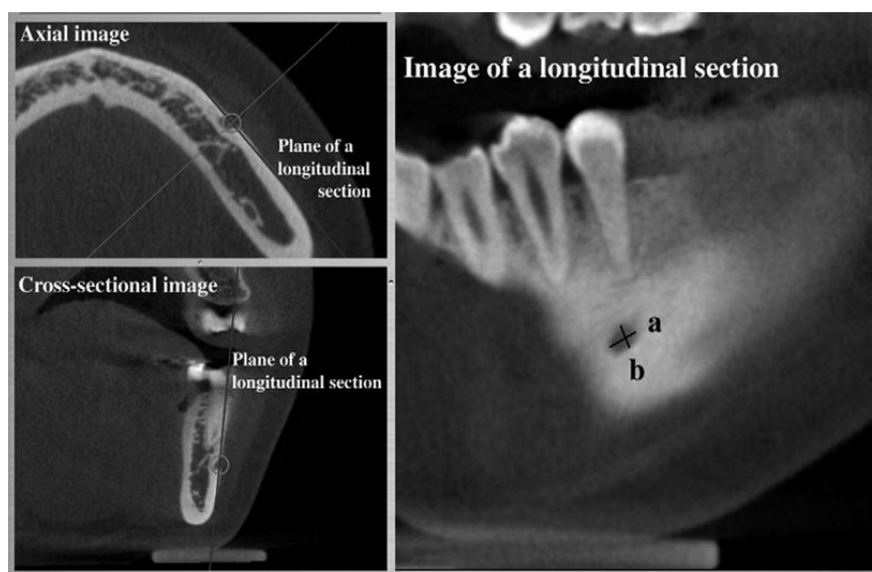


Figure 1: Calculating the height and width of a mental foramen. a=width; b=height

diameter of the main and accessory foramens (width), their vertical diameter (height), width/height ratios of MF, surface areas of MF and AMF, shape of MF and AMF (round, ovoid, irregular, linear, tear-drop), position of AMF related to the main foramen (distal, mesial, inferior, superior, or combinations of them [e.g., disto-superior, mesioinferior, etc.]), and the distance between MF and AMF. Also, the closest tooth to the MF was determined and recorded. The surface areas were calculated using the following formula: surface area = $\frac{\pi \cdot \text{width}}{2} \times \frac{\text{height}}{2}$ (Figure 1). This formula is for calculating the surface area of elliptical shapes, which also applies to round shapes. Since most of MFs are round or oval [9,15,17,19-21], we assumed that the foramens would be round or elliptical, and used this formula. The distance between the centers of main and accessory

mental foramina was calculated using the formula for Euclidean distance between the center of main and AMFs. The Euclidean distance formula is used for calculating the length of a line between two points, given their X and Y coordinates. It is calculated as $\text{Distance} = \sqrt{(X1 - X2)^2 + (Y1 - Y2)^2}$ where X1 and Y1 are coordinates of the center of the main MF and X2 and Y2 are coordinates of the AMF (Figure 2).

Statistical analysis

Descriptive statistics and 95% confidence intervals (CI) were calculated for hemi-mandibles and patients. The role of associated factors was evaluated using partial correlation coefficient controlling for sex, Fisher exact, chi-square, McNemar, independent-samples *t*-test, and paired *t*-test of SPSS (IBM, Armonk, NY, USA). In all independent-samples analyses, the unit of analysis was

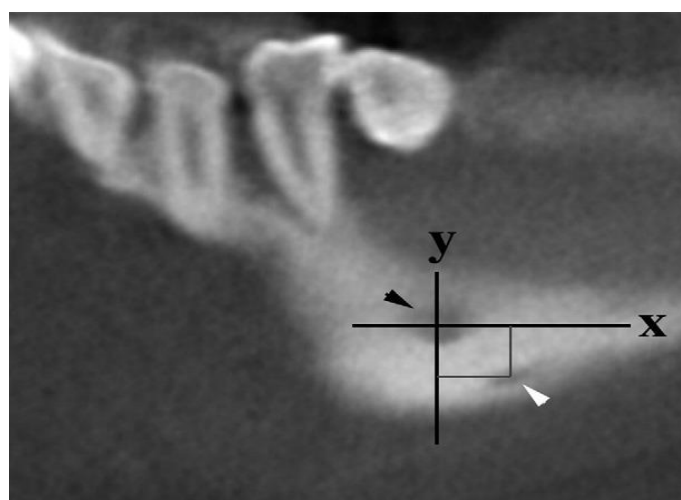


Figure 2: Method of calculating the distance between the main and accessory mental foramina using the Euclidean distance formula.

the patient. In the paired t-test analysis, the unit of analysis was left and right hemimandibles. The level of significance was set at 0.05.

Results

The MF was observed in 450 quadrants (i.e., 99.9% of 451 evaluated quadrants) and in all the 234 patients. Of the 450 MFs, 198 (44.0%), 152 (33.7%), 84 (18.7%), 14 (3.1%), and 2 (0.4%) had oval, round, irregular, linear, and tear-drop shapes, respectively. Of these, 99, 76, 39, 8, and 2 were on the right side; according to the McNemar test, there was no significant difference between the frequency of MF shapes in the left or right sides (p Value > 0.9). There was no difference between the prevalence of mental foramina in men and women (chi-square, $p = 1.0$). The frequencies of shapes did not differ between the sexes on the right or left sides (both chi-square $p > 0.500$, Table 1). The nearest tooth to the MF was the second premolar (in 433 of cases [96.2%]) followed by the first premolar (12 cases, 2.7%) and the first molar (4 cases, 0.9%).

All AMFs were unilateral. AMFs were seen in 25 quadrants of 25 patients (5.5% of 451 evaluated quadrants, Table 1). The difference between prevalences of AMF in males and females was not significant ($p = 0.223$) according to the Fisher test. Of the 25 AMFs, 8 (33.3%), 8 (33.3%), 8 (33.3%), 1 (4.2%), and 0 were oval, round, linear, irregular, and tear-drop-like, respectively. The

difference between prevalences of AMF shapes in males and females was not significant ($p = 0.377$) according to the Fisher test (Table 1). Of the AMFs, 2 (8.0%), 4 (16.0%), 6 (24.0%), 3 (12.0%), 8 (32.0%), and 2 (8.0%) were located distal, distal-inferior, distal-superior, mesial-inferior, mesial-superior, and mesial to the main MF.

Table 2 shows descriptive statistics and 95% CIs for continuous variables in the evaluated quadrants. According to the independent-samples t -test, the height and surface area of MF were greater in males compared to females in either of the sides, and also in both sides averaged (Table 3). The width-to-height ratio was larger in women, only in the averages of both sides (Table 3). The partial correlation coefficient, controlling for sex, showed no significant correlation between age with any of the MF parameters on the left or right sides (width, height, and surface area of MFs, all $p > 0.200$). It also did not show any significant correlation between age with any of the AMF parameters (width, height, and surface area of AMFs, and distance between MF and AMF, all $p > 0.160$).

Paired t -test was used to compare the measurements of main MFs on the right and left sides. It showed significant differences between the left and right sides in terms of height of MF, but not its width or surface area (Table 4).

Discussion

Although this study is an epidemiological morphometric study, it also has clinical implications. The knowledge of common positions of main and AMFs in Iranians can help Iranian clinicians or other clinicians practicing on a patient of Iranian descent avoid serious iatrogenic damages during surgical practices such as dental implantation. Locations of MF might depend on the ethnicity and diet which can influence mandibular development [8, 22]. In this Iranian population, the MF was closer to the second premolar root followed by the first premolar (and the first molar in very few cases). This was consistent with results of most other studies finding it usually in the proximity of the second premolar roots in populations from Brazil [18], Saudi Arabia [10], India [8, 20], Turkey [22], Malawia [23], or Iran [11-12, 17]. The average width and height of MF in this study were 3.3mm and 3.2mm, respectively. The height measurement in this study was somehow larger than measurement

Table 1: Frequency of different shapes of MFs and AMFs in males and females. Note that all accessory foramens were unilateral, therefore, their statistics are also for patients

Side		Sex		Total
		Female	Male	
MF, Left side	Irregular	20	25	45
	Oval	51	48	99
	Round	44	32	76
	Slit like	3	3	6
	Total	118	108	226
MF, Right side	Irregular	22	17	39
	Oval	50	49	99
	Round	41	35	76
	Slit like	3	5	8
	Tear like	1	1	2
	Total	117	107	224
AMF, both Left and Right sides	Irregular	1	0	1
	Oval	2	6	8
	Round	5	3	8
	Slit like	2	6	8
	Total	10	15	25

MF: Mental foramen; AMF: Accessory mental foramen

Table 2: Main and AMF measurements in 450 quadrants with mental foramina in men, women, and the sample. Note that since all accessory foramina were unilateral, their statistics are both per patient and per quadrant

Parameter	Sex	N	Mean	SD	SE	Min	Max
Width of MF	Female	235	3.261	0.771	0.050	1.5	6.0
	Male	215	3.359	0.862	0.059	1.5	6.8
	Total	450	3.308	0.816	0.038	1.5	6.8
Height of MF	Female	235	3.028	0.720	0.047	1.2	5.6
	Male	215	3.324	0.763	0.052	1.2	5.4
	Total	450	3.169	0.755	0.036	1.2	5.6
Surface Area of MF	Female	235	7.870	2.963	0.193	2.14	18.09
	Male	215	8.910	3.388	0.231	2.26	20.82
	Total	450	8.367	3.212	0.151	2.14	20.82
Surface Area of AMF	Female	10	2.776	1.000	0.316	1.13	4.32
	Male	15	3.207	2.120	0.547	0.47	7.30
	Total	25	3.034	1.745	0.349	0.47	7.30
AMF:MF (%)	Female	10	47.653	28.197	8.917	17.3	91.8
	Male	15	47.912	30.872	7.971	8.3	91.2
	Total	25	47.809	29.225	5.845	8.3	91.8
Width of AMF	Female	10	1.910	0.649	0.205	1.20	3.40
	Male	15	1.913	0.939	0.242	0.50	3.60
	Total	25	1.912	0.820	0.164	0.50	3.60
Height of AMF	Female	10	1.900	0.589	0.186	1.20	2.70
	Male	15	2.060	0.942	0.243	0.70	3.30
	Total	25	1.996	0.809	0.162	0.70	3.30
Distance between MF and AMF	Female	10	5.960	1.783	0.564	3.90	8.60
	Male	15	7.027	3.797	0.980	4.00	18.90
	Total	25	6.600	3.144	0.629	3.90	18.90
Width to Height Ratio of MF	Female	235	1.127	0.332	0.022	0.42	2.25
	Male	215	1.053	0.335	0.023	0.42	3.00
	Total	450	1.092	0.335	0.016	0.42	3.00

N, number; SD, standard deviation; SE, standard error; CI, confidence interval; Min, minimum; Max, maximum; F, female; M, male; MF, mental foramen; AMF, accessory mental foramen

ents reported in some other studies (around 2.5 mm) [8, 23-24] but close to some others; about 3.2mm [3] and 3.7mm [4]. The width measurement obtained in the present study was smaller than what was reported by some studies; around 4.2mm [4] and 5.2mm [8, 23] and was close to some others; around 3.1mm [24] or 3.6mm [17], while being larger than certain ones; around 2.6mm [17, 21]. These differences can be attributed to ethnical and methodological variations including measuring the foramina on skull photographs, various skull marks used for measurements, or using dry bone specimens versus radiographic images [7-9], which are limited to recent few small or limited studies [3-4, 6, 10-12, 17-18]. The average age of samples might not affect the size of foramen, the way suggested by a previous study [17]; although not all studies confirmed this [4]. Moreover, sex distributions of samples might matter, as it was found to be associated with height measurements in this and another study [4]. Ethnicity can directly affect the size of MFs (through developmental effects) and also can be associated with a different prevalence of

MF shapes. Although most studies have reported a higher prevalence of oval foramina compared to round ones [15, 17, 19-20], in some studies the prevalence of round foramina is still considerable [17, 19] or is even higher than that of oval foramina [9, 21]. In this study, round foramina were much more prevalent than oval ones. It should be noted that variations in shape, which can contribute to size controversies as well [8], are not limited to oval and round shapes, whereas many previous studies have ignored many other anatomic shapes [15, 17, 19, 21]. An important point to consider is the calculation of surface areas of MFs that were not elliptical. In such cases, the calculation of the surface areas based solely on width and height information. Therefore, findings regarding surface area should be approached with utmost caution.

When the mental nerve furcates before passing through the MF, the accessory branches will exit not from the MF but from accessory foramina. These structures are as well danger zones and should be prevented in surgeries; therefore, assessment of their prevalence

Table 3: Main MF measurements in left or right quadrants as well as the average of both sides, in men, women, and the sample

Side	Parameter	Sex	N	Mean	SD	SE	95% CI		Min	Max	p Value
Left	Width of MF	Female	118	3.238	0.766	0.071	3.098	3.378	1.5	5.3	0.3453
		Male	108	3.344	0.922	0.089	3.169	3.520	1.5	6.8	
		Total	226	3.289	0.844	0.056	3.178	3.400	1.5	6.8	
	Height of MF	Female	118	3.116	0.761	0.070	2.977	3.255	1.3	5.6	0.0052
		Male	108	3.400	0.747	0.072	3.257	3.543	1.2	5.1	
		Total	226	3.252	0.766	0.051	3.151	3.352	1.2	5.6	
	Surface Area of MF	Female	118	7.988	3.083	0.284	7.426	8.550	2.14	15.83	0.0133
		Male	108	9.071	3.439	0.331	8.415	9.727	2.26	20.82	
		Total	226	8.505	3.296	0.219	8.073	8.937	2.14	20.82	
	Width to Height Ratio	Female	118	1.088	0.316	0.029	1.031	1.146	0.42	2.25	0.1105
		Male	108	1.019	0.329	0.032	0.957	1.082	0.42	2.40	
		Total	226	1.055	0.323	0.022	1.013	1.098	0.42	2.40	
Right	Width of MF	Female	117	3.285	0.778	0.072	3.142	3.427	2.0	6.0	0.4038
		Male	107	3.373	0.801	0.077	3.219	3.526	1.5	5.7	
		Total	224	3.327	0.789	0.053	3.223	3.431	1.5	6.0	
	Height of MF	Female	117	2.938	0.667	0.062	2.816	3.061	1.2	4.8	0.0016
		Male	107	3.247	0.775	0.075	3.098	3.395	1.2	5.4	
		Total	224	3.086	0.735	0.049	2.989	3.183	1.2	5.4	
	Surface Area of MF	Female	117	7.751	2.845	0.263	7.230	8.272	2.17	18.09	0.0168
		Male	107	8.747	3.343	0.323	8.106	9.388	2.59	19.63	
		Total	224	8.227	3.126	0.209	7.815	8.638	2.17	19.63	
	Width to Height Ratio	Female	117	1.167	0.344	0.032	1.104	1.230	0.51	2.23	0.0845
		Male	107	1.088	0.339	0.033	1.023	1.153	0.42	3.00	
		Total	224	1.129	0.343	0.023	1.084	1.174	0.42	3.00	
Average of both sides	Width of MF	Female	121	3.266	0.714	0.065	3.137	3.394	1.90	5.60	0.2303
		Male	113	3.385	0.797	0.075	3.236	3.533	1.50	6.25	
		Total	234	3.323	0.756	0.049	3.226	3.420	1.50	6.25	
	Height of MF	Female	121	3.016	0.623	0.057	2.904	3.128	1.50	5.10	0.0002
		Male	113	3.325	0.627	0.059	3.208	3.442	1.65	4.60	
		Total	234	3.165	0.642	0.042	3.082	3.248	1.50	5.10	
	Surface Area of MF	Female	121	7.851	2.753	0.250	7.355	8.346	2.91	15.07	0.0033
		Male	113	8.976	3.033	0.285	8.410	9.541	3.07	18.91	
		Total	234	8.394	2.940	0.192	8.015	8.773	2.91	18.91	
	Width to Height Ratio	Female	121	1.136	0.281	0.026	1.085	1.186	0.47	2.25	0.0439
		Male	113	1.061	0.287	0.027	1.007	1.114	0.48	2.29	
		Total	234	1.099	0.286	0.019	1.063	1.136	0.47	2.29	
N, number; SD, standard deviation; SE, standard error; CI, confidence interval; Min, minimum; Max, maximum; F, female; M, male. MF, mental foramen											

N, number; SD, standard deviation; SE, standard error; CI, confidence interval; Min, minimum; Max, maximum; F, female; M, male. MF, mental foramen

and anatomic variations is of value [8]. They are rare and usually occur unilaterally [8, 20-21]. Accessory mental foramina have been observed in different prevalences such as about 13% [21], 8.9% [9], 7% [3], 6.6% [8], 5.6% [20], 5.7% [4], 5.1% [11]. Very few studies had evaluated the distance between MF and AMF; it was greater in this study (about 6.6mm) compared to what observed among Polish individuals (2.86mm) [3]. Such variations might be attributed to the ethnic back

ground and measurement accuracies.

This study had some limitations. It should be noted that the findings related to the AMFs should be interpreted cautiously because of the very small number of AMFs. Moreover, though the sample size was larger than most previous studies, it was not based on sample size calculations. It is noteworthy that previous dry skull studies were mostly small, and previous CBCT studies were limited by small samples; mostly around 100 and a

Table 4: Results of paired t-test, comparing parameters of main MFs in the right and left sides

Parameter	Difference	SD	SE	95% CI	t	p Value
Width	-0.058	0.671	0.046	-0.148 0.032	-1.278	0.203
Height	0.164	0.823	0.056	0.054 0.275	2.935	0.004
Surface Area	0.219	2.769	0.188	-0.153 0.590	1.161	0.247

SD, standard deviation; SE, standard error; CI, confidence interval. MF, mental foramen

few larger samples to a maximum of 300 [10] or 400 quadrants [6] and mostly concerned with limited research questions. Moreover, the calculation of surface areas of non-elliptical foramens based on their width and height was inaccurate. It would be better if more advanced and more accurate geometrical methods were utilized to calculate surface areas of irregular foramens. However, this might need a lot of additional measurements, which could render this already large study much more difficult. Therefore, we opted to this straightforward formula of surface areas for round and oval shapes, ignoring the small inaccuracies caused by irregularities in anatomical shape deviations from perfect circular or elliptical shapes. Another methodological limitation was the use of CBCT which is not as accurate as dry skulls. However, the use of CBCTs allows the researchers to increase their sample size considerably compared to dry skull studies. Another limitation of this epidemiological study was its sample, which was limited to retrospective CBCTs of dental patients. Both the retrospective nature of the study and dental patients can limit the study. Nevertheless, there is no other option, when it comes to working with X-ray. Hence, all X-ray studies are limited to retrospective dental cases. Moreover, similar to all other studies, the findings of this study were limited to this particular ethnicity (i.e. Persians who are Caucasians). The variations in the sizes of mandibles can also act as yet another confounder. Finally, the findings related to the AMFs should be interpreted cautiously because of the very small number of AMFs.

Conclusion

MFs might exist in 99.9% of quadrants and 100% of patients. They are usually in oval followed by round and irregular shapes. It is commonly closer to the second premolar. It might be of around 3.3 mm width and 3.2 mm height; the height might be larger in men. The AMF might be present in about 5% of cases, usually superior and mesial to the main MF.

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Verification of using AI

No AI was used in preparing any parts of this paper.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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