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Evaluation of Mental Foramen Position and Morphology on Panoramic Radiographs

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Background: The mental foramen (MF) is a key anatomical landmark in oral and maxillofacial surgery; its accurate localization is critical for preventing neurovascular complications. This study aimed to radiologically evaluate MF position, morphology, symmetry, and interforaminal distance using panoramic radiographs, with particular emphasis on clinical relevance in surgical planning.

Material/Methods: This retrospective study included panoramic radiographs of 500 patients from the Department of Oral and Maxillofacial Surgery, Eskişehir Osmangazi University. MF position was classified into 6 categories based on relationship to adjacent teeth. Shape, symmetry, and interforaminal distance were also assessed. Statistical analyses were performed using SPSS software.

Results: The most common MF position was at the level of the second premolar (position 4, 50.9%), followed by the area between the first and second premolars (position 3, 38.9%). A round shape was the most frequently observed morphology (40%), followed by irregular (34%) and oval (26%) forms. The MF was asymmetrically located in most cases (80.2%). The mean interforaminal distance was 51.95±7.08 mm. No statistically significant differences were observed among age groups ($P=0.308$); men exhibited significantly greater interforaminal distances than women ($P<0.001$).

Conclusions: Panoramic radiography is susceptible to positioning errors, magnification, and superposition artifacts; careful image acquisition and interpretation are thus essential for accurate evaluation of the MF. Although panoramic radiography can provide useful preliminary information, advanced imaging modalities may be required in complex cases. These findings may assist clinicians in improving surgical safety and reducing mental nerve injury risk during dental procedures.

Keywords: Mental Foramen • Radiography • Anatomic Variation

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Introduction

The mental foramen (MF) is a critical anatomical landmark with substantial relevance in various oral surgical interventions. Before clinicians perform such procedures, it is essential to evaluate the position, shape, and possible anatomical variations of the MF to minimize mental nerve injury risk. Due to its consistent location and identifiable morphology, the MF is frequently used as a reference in diagnostic evaluations and clinical practice. A thorough understanding of its anatomical characteristics—including location, shape, and size—is vital for ensuring safety and precision during surgical procedures such as dental implant placement, endodontic treatment, and osteotomies [1]. Injury to neurovascular structures traversing the MF during oral surgical interventions can result in a serious postoperative complication known as paresthesia. This condition occurs when delicate neurovascular bundles are damaged, underscoring the importance of careful surgical planning and anatomical awareness to prevent sensory disturbances in the affected region [2]. Additionally, the mental nerve may follow various anatomical courses as it approaches and enters the MF [3]. The anterior loop of the mental nerve represents another clinically important anatomical variation in the MF region, particularly during implant placement and other surgical procedures in the premolar area; failure to recognize its presence can increase the risk of neurosensory injury [1].

Various methods have been used to evaluate the MF [4]. Anatomical approaches, such as cadaveric dissections, have historically provided fundamental information regarding its morphology and position [5]. In contrast, radiological imaging techniques are widely used in clinical practice for in vivo assessment. These include panoramic radiography, periapical radiography, computed tomography, cone-beam computed tomography (CBCT), magnetic resonance imaging, and ultrasonography [3,6,7]. Additionally, ultrasonography has been proposed as a noninvasive, radiation-free alternative for evaluating the MF region [7]. Among these imaging modalities, CBCT is considered particularly important because of its ability to provide 3-dimensional visualization, high spatial resolution, and more accurate assessment of anatomical structures, making it a highly reliable method for preoperative localization of the MF [4].

Although CBCT is more precise in determining the location and morphology of the MF, it is not routinely used as a standard diagnostic method in oral surgical practice. In contrast, panoramic radiography is widely used due to its accessibility and practicality. However, its diagnostic value for precise anatomical localization is limited by the inherent constraints of 2-dimensional imaging (eg, distortion, magnification, and superimposition). Thus, panoramic radiography may be considered a useful tool for the preliminary assessment of MF location, shape, continuity, and symmetry [3,8,9].

Given the anatomical variability of the MF and its importance in oral surgical procedures, accurate preoperative assessment is essential for safe surgical planning. Whereas many previous studies primarily relied on CBCT, the present study encompassed a large-scale evaluation based on panoramic radiographs, reflecting routine clinical practice conditions. The aim of this study was to radiographically evaluate MF position, shape, symmetry, and interforaminal distance on panoramic radiographs and to expand anatomical knowledge relevant to preoperative planning in oral surgical practice.

Material and Methods

Study Design

This study was conducted at the Faculty of Dentistry, Eskişehir Osmangazi University, and was approved by the Non-Interventional Clinical Research Ethics Committee (IRB 2024-55; decision date: July 23, 2024). The study adhered to the principles of the Declaration of Helsinki; informed consent had been obtained from all patients at the time of treatment. All participants were informed verbally and in writing about the purpose and methods of the study, and written informed consent was obtained from each participant.

All patients who presented to the Department of Oral and Maxillofacial Surgery, Eskişehir Osmangazi University, between January 1, 2022, and January 1, 2024, were retrospectively screened. Within this population, patients who met predefined inclusion and exclusion criteria were included in the study. The localization, shape, and symmetry of 1000 MFs in 500 patients (right and left sides) were evaluated using orthopantomograms. Patient age, sex, and side (right/left) were analyzed, along with the position, shape, and symmetry of the MF. Patients were categorized into the following 4 age groups: adolescents (< 20 years), young adults (20-34 years), middle-aged adults (35-49 years), and older adults (≥ 50 years). Information regarding residency status and nationality was not available in the archived records and thus could not be evaluated.

Inclusion and Exclusion Criteria

Patients were eligible for inclusion if they were older than 18 years; had no missing teeth between the right and left first premolars and second molars; had no radiolucent or radiopaque lesions affecting the mandibular arch on panoramic radiographs; and had no systemic disease affecting dentition. Patients were excluded if they exhibited crowding, spacing, or misalignment of the mandibular teeth; had a fracture line in the maxillary or mandibular arch; had a history of orthognathic surgery; or had panoramic radiographs in which anatomical structures (eg, MF and mandibular canal) could not be clearly identified.

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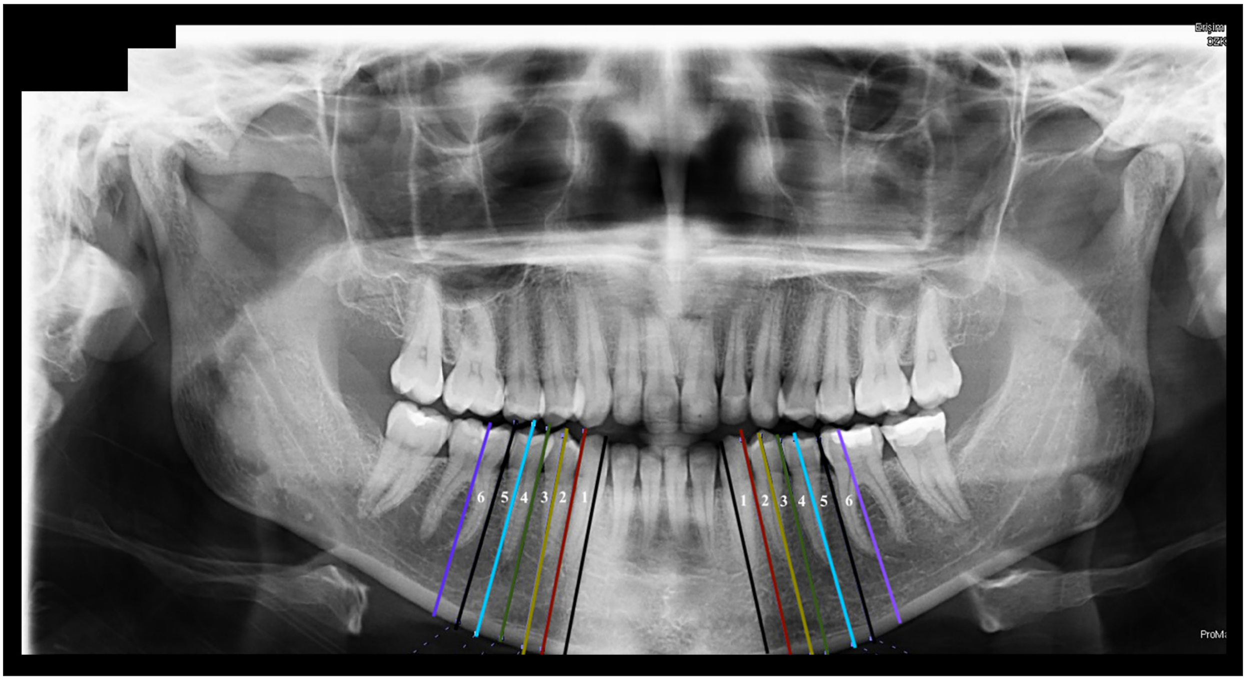

Figure 1. Classification of mental foramen positions based on relationship to adjacent teeth (Tebo and Telford classification).

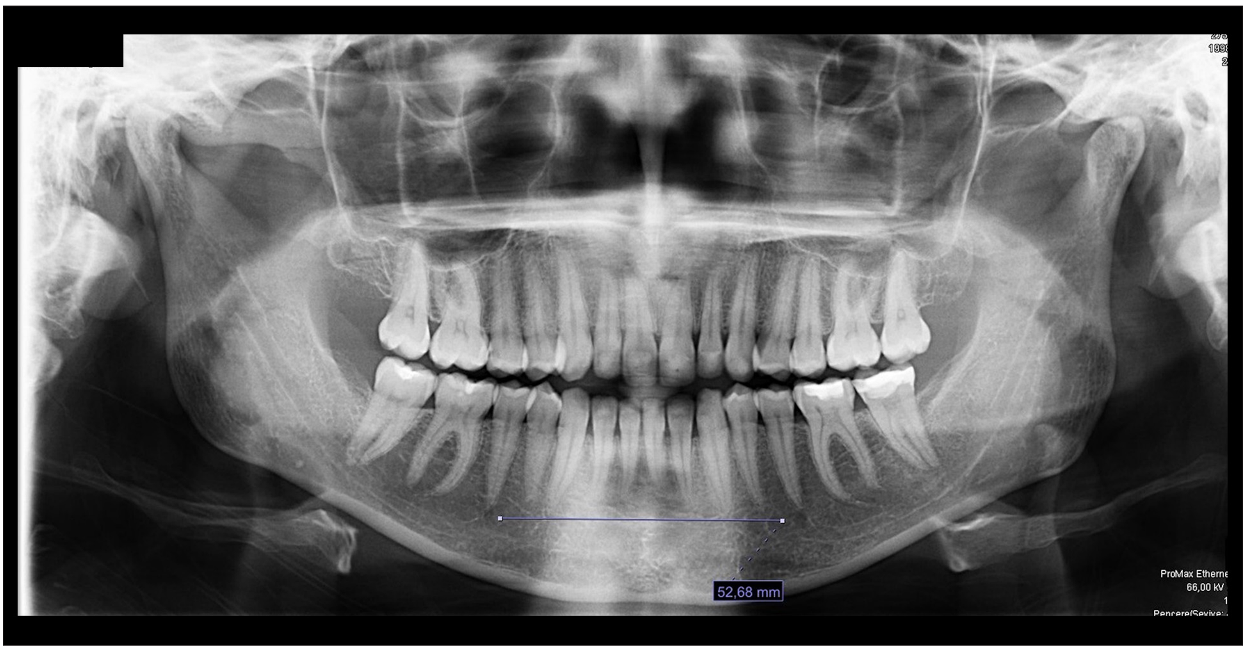

Figure 2. Panoramic radiographic evaluation of interforaminal distance measurement.

Radiologic Analysis

All panoramic radiographs were obtained using the same device (Planmeca ProMax; Planmeca, Helsinki, Finland; 65 kVp, 6 mA, 16-s exposure time) and evaluated under standardized conditions. Patient positioning was carefully standardized, with the Frankfurt horizontal plane parallel to the ground, to minimize image distortion and magnification errors inherent to panoramic imaging. The use of panoramic radiography reflects routine clinical conditions; however, it may provide less precise measurements than CBCT.

The anteroposterior position of the MF was determined in relation to adjacent teeth, according to the Tebo and Telford classification [10]. Position 1 was defined as mesial to the apex of the first premolar (between the canine and first premolar);

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position 2 corresponded to the level of the apex of the first premolar; position 3 was located between the apices of the first and second premolars; position 4 was located at the level of the apex of the second premolar; position 5 was defined as the area between the apices of the second premolar and first molar; and position 6 corresponded to the level of the apex of the first molar (**Figure 1**).

If a patient's MFs were located in the same anteroposterior position relative to adjacent teeth, they were considered symmetrical; otherwise, they were classified as asymmetrical.

MFs were morphologically classified as round, oval, or irregular. Bilateral symmetry was determined based on whether an MF was located at the same anteroposterior position relative to adjacent teeth on both sides. The center of an MF was defined as the geometric midpoint of its radiographically visible borders. Interforaminal distance comprised the linear distance between the centers of right and left MFs according to digital imaging software (**Figure 2**).

All radiographic evaluations were performed by a single examiner under standardized conditions. Although formal intraobserver and interobserver reliability analyses were not performed, all measurements were conducted using consistent criteria and imaging protocols to minimize potential variability.

Statistical Analysis

Statistical analysis was performed using SPSS version 22.0 (IBM, Armonk, NY, USA). Normality was assessed using the Shapiro-Wilk test. The Kruskal-Wallis test was used to compare interforaminal distances among age groups, and the Mann-Whitney U test was used for sex-based comparisons. The significance threshold was set at $P<0.05$. Descriptive statistics, including mean, standard deviation, and range, were calculated for all variables.

Results

In total, 500 patients were included in the study (285 women [57%] and 215 men [43%]). The distribution of MFs according to side was equal: 50% were located on the right side, and 50% were present on the left side.

Demographic Characteristics

Among the participants, 57% of MFs (n = 570) belonged to women and 43% (n = 430) belonged to men, based on the total of 1000 MFs evaluated in 500 patients. The majority of the sample consisted of young adults (65.2%), followed by middle-aged adults (24.8%), older adults (7.8%), and adolescents (2.2%).

Table 1. Mental foramen position according to adjacent teeth (frequency).

Position	n = 1000
1	4
2	34
3	389
4	509
5	61
6	3

Positions: 1, between canine and first premolar; 2, at the level of first premolar; 3, between first and second premolars; 4, at the level of second premolar; 5, between second premolar and first molar; 6, at the level of first molar.

MF Shape

The most frequently observed MF shape was round (40%), followed by irregular (34%) and oval (26%). When evaluated according to sex, a round shape remained most common in both men (42.8%) and women (37.9%). An irregular shape was slightly more frequent in women (35.3%) than in men (32.3%).

MF Position

The distribution of MFs based on position relative to adjacent teeth is presented in **Table 1**. The most common MF location was position 4 (50.9%), corresponding to the level of the second premolar. This was followed by position 3 (38.9%), located between the first and second premolars. Less frequently, the MF was observed at position 5 (6.1%), between the second premolar and first molar, and position 2 (3.4%), at the level of the first premolar. Positions 1 and 6 were rarely detected, representing only 0.4% and 0.3% of cases, respectively.

MF Symmetry

The MF was asymmetrical in most cases (80.2%); only 19.8% of cases exhibited symmetry. Sex-based evaluation showed that asymmetry was slightly more frequent in women (82.5%) than in men (77.2%). Asymmetry was predominant across all age groups, and the highest rate was observed among older adults (87.2%).

Interforaminal Distance According to Age Group

A comparison of interforaminal distance according to age group is presented in **Table 2**. The mean MF-MF distance gradually increased with age. The mean value was lowest in the adolescent group (50.16 ± 7.71 mm) and highest in the older adult group (53.04 ± 7.70 mm). Mean distances in the young adult

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Table 2. Interforaminal distance according to age group.

	Age group	N	Min (mm)	Max (mm)	Mean (mm)	Standard geviation
MF-MF distance	Adolescent	11	41.39	69.02	50.16	7.71
	Young adult	326	26.79	73.93	51.71	6.93
	Middle-aged adult	124	35.47	72.40	52.39	7.18
	Older adult	39	42.16	76.09	53.04	7.70
***P*-value**		0.308*				

* Kruskal-Wallis test. Age groups: adolescents, < 20 years; young adults, 20-34 years; middle-aged adults, 35-49 years; older adults, ≥ 50 years.

Table 3. Interforaminal distance according to sex.

Variable	Group	N	Mean ± standard deviation	Min-Max (mm)	*P*-value
Sex	Men	215	53.88 ± 7.01	37.58-76.09	< 0.001*
	Women	285	50.49 ± 6.78	26.79-69.02	
	Overall	500	51.95 ± 7.08	26.79-76.09	–

* Mann-Whitney U test.

(51.71 ± 6.93 mm) and middle-aged adult (52.39 ± 7.18 mm) groups were intermediate between these values. Although a trend toward increasing MF-MF distance with advancing age was observed, differences among age groups were not statistically significant (Kruskal-Wallis test, $P = 0.308$).

A comparison of interforaminal distance according to sex is presented in **Table 3**. The mean MF-MF distance was significantly greater in men (53.88 ± 7.01 mm) than in women (50.49 ± 6.78 mm). The overall mean interforaminal distance for the entire sample was 51.95 ± 7.08 mm; values ranged from 26.79 mm to 76.09 mm. The difference between men and women was statistically significant (Mann-Whitney U test, $P < 0.001$), indicating that sex had a substantial effect on interforaminal distance.

The distribution of mental foramen positions according to sex and age group is presented in **Tables 4 and 5**. Chi-square analysis revealed no statistically significant association between mental foramen position and sex ($\chi^2 = 4.844$, $P = 0.435$). Similarly, no statistically significant association was observed between mental foramen position and age group ($\chi^2 = 18.144$, $P = 0.255$). The second premolar region (position 4) was the most common location across all age and sex categories, followed by position 3.

Discussion

A thorough understanding of the anatomical location and morphology of the MF is essential to achieve successful mental nerve blocks and avoid neurovascular complications during surgical interventions in the labiomental region. Therefore, the present study was designed to systematically evaluate morphological variation and anatomical positions of the MF in the study population. Morphological variation is common and expected. Literature concerning the MF describes diverse structural patterns, including differences that impact its typical oval shape, the presence of accessory foramina, and, rarely, its complete absence [11,12].

According to classical human anatomy literature, the typical MF location is between the roots of the first and second premolars [5]. In the present study, the most frequent MF location was position 4, corresponding to the level of the second premolar (50.9%), followed by position 3, located between the first and second premolars (38.9%). These findings are largely consistent with a systematic review by Pelé et al [3], which identified the MF primarily between the premolars or at the level of the second premolar. Similarly, Abdullah Bahamid et al [8] noted that positions 3 and 4 were predominant in a Saudi population. Aldosimani et al [13], Mahabob et al [14], and Srivastava [15] also demonstrated that the MF is predominantly located

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Table 4. Distribution of mental foramen positions according to sex.

Position	Men, n (%)	Women, n (%)	Total, n (%)
1	3 (75.0)	1 (25.0)	4 (0.4)
2	12 (35.3)	22 (64.7)	34 (3.4)
3	169 (43.4)	220 (56.6)	389 (38.9)
4	221 (43.4)	288 (56.6)	509 (50.9)
5	27 (44.3)	34 (55.7)	61 (6.1)
6	0 (0.0)	3 (100.0)	3 (0.3)
Total	430 (43.0)	570 (57.0)	1000 (100.0)

Chi-square test: $\chi^2 = 4.844$, df = 5, $P = 0.435$. No statistically significant association was observed between mental foramen position and sex.

Table 5. Distribution of mental foramen positions according to age group.

Position	Adolescent, n (%)	Young adult, n (%)	Middle-aged adult, n (%)	Older adult, n (%)	Total, n (%)
1	0 (0.0)	3 (75.0)	1 (25.0)	0 (0.0)	4 (0.4)
2	0 (0.0)	19 (55.9)	10 (29.4)	5 (14.7)	34 (3.4)
3	9 (2.3)	259 (66.6)	96 (24.7)	25 (6.4)	389 (38.9)
4	10 (2.0)	334 (65.6)	127 (25.0)	38 (7.5)	509 (50.9)
5	3 (4.9)	34 (55.7)	13 (21.3)	11 (18.0)	61 (6.1)
6	0 (0.0)	3 (100.0)	0 (0.0)	0 (0.0)	3 (0.3)
Total	22 (2.2)	652 (65.2)	248 (24.8)	78 (7.8)	1000 (100.0)

Chi-square test: $\chi^2 = 18.144$, df = 15, $P = 0.255$. No statistically significant association was observed between mental foramen position and age group.

below or near the second premolar in distinct populations. Our results support this common anatomical pattern. It is important to note a methodological distinction when comparing these findings. Most aforementioned studies, with the exception of work by Pelé et al [3], used CBCT for their analyses; measurements in our study were obtained from orthopantomographic radiographs. Although CBCT provides superior visualization of 3-dimensional anatomical structures, panoramic radiography offers a practical alternative that is more cost-effective, easier to perform, and simpler to interpret [16]. Despite its widespread clinical use, panoramic radiography has inherent limitations that must be considered when interpreting the present findings. As a 2-dimensional imaging modality, panoramic radiography is subject to distortion, magnification errors, and superimposition of anatomical structures, which may affect linear measurement accuracy and MF localization. Standardized patient positioning and imaging protocols were used to minimize these effects, but slight deviations cannot be completely eliminated. Thus, advanced imaging techniques such as CBCT may provide more precise 3-dimensional evaluation when detailed anatomical assessment is required [6,16].

Our findings identified the second premolar level (position 4) as the most frequent location of the MF, which contrasts with some reports from various geographic regions. For instance, studies by Green [17] and by Santini and Land [18] demonstrated that the longitudinal axis between the first and second premolars (position 3) is the predominant location within Chinese, British, and European populations [19]. This discrepancy highlights the influence of ethnic and regional variation on MF position and underscores the need for population-specific anatomical assessments [20].

When evaluating interforaminal distance (MF-MF) across different age groups, we observed a gradual numerical increase with advancing age, ranging from a mean of 50.16 mm in adolescents to 53.04 mm in older adults. However, this trend was not statistically significant ($P = 0.308$). This observation aligns with the broader context of age-related anatomical changes

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reported by Babshet et al [21], who described a relative posterior repositioning of the MF in older age groups due to continuous anterior drifting of the teeth. Although their study highlighted a relative shift in relation to dentition, our results suggest that the absolute transverse distance (MF-MF) also exhibits a slight, nonsignificant increase with age.

Regarding sex differences, our analysis revealed a statistically significant difference in interforaminal distance ($P<0.001$). The mean MF-MF distance was noticeably greater in men (53.88±7.01 mm) than in women (50.49±6.78 mm). These observations are consistent with findings by Coban et al [4], who also reported a sex-based difference ($P=0.001$): men exhibited a mean distance of 53.40 mm compared with 51.08 mm in women. Such consistent findings across different populations support the tendency toward a broader mandibular structure in men. Recent imaging-based work has similarly shown age- and sex-related differences in MF position and interforaminal relationships [22].

Regarding the morphological appearance of the MF, our study indicated that a round shape was most prevalent (40%), followed by irregular (34%) and oval (26%) forms. Comparison with the literature reveals notable differences in shape distribution. According to Pelé et al [3], the general population predominantly exhibits round or oval MF shapes, often representing more than 60% of cases; irregular shapes are much less common (11.14%). Although a round shape was also the most common morphology in the present study, the substantially higher prevalence of irregular forms suggests distinctive anatomical variation within our patient cohort. Comparison with regional studies further highlights these differences. Abdullah Bahamid et al [8] similarly reported a deviation from classical anatomical patterns, identifying an irregular shape as the most prevalent morphology in their sample. In contrast, another recent study showed clear predominance of an oval shape (83.33%), with bilateral round shapes representing only 16.67% of the examined mandibles [23]. Compared with our findings, in which an oval shape was the least common morphology (26%) and irregular forms were relatively frequent, these results emphasize considerable diversity in MF morphology among populations. Collectively, such findings indicate that the structural morphology of the MF is not uniform and may substantially vary according to population characteristics.

In terms of bilateral positioning, the present study revealed a striking predominance of asymmetry. MFs were asymmetrically located in the vast majority of cases (80.2%), whereas only 19.8% exhibited true bilateral symmetry. Further demographic analysis indicated that this asymmetrical presentation was slightly more common in women (82.5%) than in men (77.2%); its prevalence was highest among older adults (87.2%). In contrast to our findings, Abdullah Bahamid et al [8] reported that MFs predominantly exhibited a symmetrical distribution in their sample. They noted that clinically significant asymmetry was primarily associated with dental crowding, rather than representing a common anatomical pattern. Similarly, Ghandourah et al [24] reported symmetrical positioning in 64.7% of participants, and only 35.3% of MFs were classified as asymmetrical. Relative to these findings, the considerably higher asymmetry rate observed in our study represents a distinct anatomical divergence. A particularly striking finding in the present study was the high prevalence of bilateral asymmetry (80.2%) in MFs. This rate is substantially higher than observations in several previous studies and may reflect population-specific anatomical variability [8,24]. Additionally, differences in imaging modalities and classification criteria may have contributed to this discrepancy [3,8].

In some radiographs, minor patient-positioning errors (eg, midline deviation) may result in unequal magnification between the right and left sides. These factors can affect the accuracy of linear measurements, particularly interforaminal distance, and may have contributed to variability observed in the present study. Furthermore, these findings should be interpreted with caution because panoramic radiography is a 2-dimensional imaging modality inherently susceptible to magnification, distortion, and positioning errors [6,16]. Such limitations can affect symmetry assessment and potentially lead to misclassification in some cases [25]. Recent CBCT-based studies have highlighted the superiority of 3-dimensional imaging for accurately assessing MF position and morphology [3]. Therefore, the high asymmetry rate observed in the present study may not fully reflect true anatomical variation. Another limitation of the present study is the absence of formal intraobserver and interobserver reliability analyses for radiographic assessments. Consequently, the reproducibility of the measurements could not be objectively verified; this limitation should be considered when interpreting the findings.

Conclusions

Standard anatomical literature presents varying descriptions of the MF, given that its characteristics considerably differ among populations. The present study used panoramic radiographs to evaluate MF position, shape, symmetry, and dimensional characteristics. Within the limitations of this study, it can be concluded that the MF exhibits substantial anatomical variability. The most common location was at the level of the second premolar (position 4). Although a round shape was the most prevalent morphology, a high rate of bilateral asymmetry (80.2%) was a key characteristic of the evaluated cases. Furthermore, although age did not substantially affect interforaminal distance, sex played a prominent role: men exhibited a greater interforaminal distance compared with women.

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Precise preoperative knowledge of these anatomical variations is essential for dental professionals. Accurate radiographic assessment is critical to avoid nerve injury and paresthesia during surgical procedures such as implant placement.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Department and Institution Where Work Was Done

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Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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