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Anatomy of the Mental Foramen: Relationship among Different Metrical Parameters for Accurate Localization

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Featured Application: The anatomical position of the mental foramen, as visualized on CBCT scans, has several potential applications in various fields. Its precise location can be useful for Dental Implant Placement, as implants need to be positioned carefully to avoid damaging important structures like nerves and blood vessels. Anatomical details of the mental foramen help in determining the appropriate implant length and angulation, reducing the risk of complications. The mental foramen is the exit point of the mental nerve. By identifying the mental foramen's position, dental professionals can avoid damaging the nerve during certain procedures, such as extractions or surgical interventions. Other applications include local anesthesia, endodontic and orthodontic treatments and maxillofacial surgeries involving the anterior mandible.

Abstract: Purpose: The mental foramen (MF) is important in dental surgery procedures for preventing possible iatrogenic lesions and for anesthetic procedures. This paper aims at expanding knowledge on the metrical characteristics that are useful for the correct anatomical assessment of the MF. Materials and Methods: On 100 CBCT scans (50 males and 50 females), height, width, depth, linear distance from the inferior and superior mandibular edge and position according to teeth and dental apices were analyzed. Differences according to sex and the side for each metrical measurement and for teeth and dental apices were assessed through a two-way ANOVA test and Chi-square test, respectively. Pearson's test and a one-way ANOVA test were used to test correlations among the chosen parameters ($p < 0.01$). Results: The depth and distance from the inferior and superior mandibular edges showed sexual dimorphism ($p < 0.01$). Height and width were positively related, as well as depth and distance from the inferior mandibular edge in females ($p < 0.01$). Conclusions: Novel data about the anatomical position of the mental foramen are described, which are useful for the management of surgical procedures.

Keywords: mental foramen; anatomy; CBCT; anesthesia

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1. Introduction

The mandibular canal (MC) is located within the mandible and hosts the inferior alveolar nerve and artery: it opens posteriorly through the mandibular foramen and anteriorly through the mental foramen (MF) [1]. The inferior alveolar nerve divides into its two branches—respectively, the incisive nerve and the mental nerve: the latter one passes through the MF together with the mental artery [2–4]. The MF represents a crucial anatomical point, as the mental nerve can be injured in several dental procedures, including endodontic procedures, overfilling, teeth extractions and implantology [1], with consequent sensory alterations of the inferior facial third medially to the MF [5].

The MF position is highly variable among subjects of the same ethnicity and age, and even the same person can have very different MF positions on either side. This foramen can be single, double, multiple and, in rare instances, even absent. In cases of multiple foramina, the smaller ones are considered minor foramina [4].

For many years, 2D imaging methods including conventional radiography have been the mainstay of dental diagnostic and treatment management. However, because the two-dimensional representation has limited visualization of the anatomy, there are serious problems with diagnosis and treatment planning.

Variants of the mental foramen have already been widely analyzed on dry mandibles or cadavers [4,5]; however, the introduction of Cone Beam Computed Tomography (CBCT) widened the chances of exploring this important anatomical structure.

Cone Beam Computed Tomography (CBCT) is a relatively recent imaging technique used in dentistry to obtain 3D images of the oral and maxillofacial regions. Compared to traditional two-dimensional dental X-rays, CBCT offers several advantages, as CBCT provides high-resolution 3D images that allow dentists to view the teeth, bone structures, nerves and soft tissues from various angles and is not limited by image distortion related to overlapping structures. This level of accuracy helps in better understanding the anatomy and identifying potential issues.

The identification of the mental foramen on CBCT images is significant in dental and maxillofacial imaging and surgical procedures [6–9]. CBCT imaging allows clinicians to visualize the exact position and size of the mental foramen. This information is crucial for precise treatment planning in dental implantology, orthodontics and various mandibular surgical procedures. Knowing the exact location of the mental foramen helps avoid damage to vital structures, such as the mental nerve and vessels, during surgical interventions. In dental implant procedures, the accurate identification of the mental foramen helps determine the optimal implant placement. Placing implants too close to the mental foramen may lead to nerve injury, resulting in numbness, tingling or pain in the lower lip and chin. CBCT enables implantologists to choose implant sites that provide sufficient bone support while avoiding interference with the mental foramen.

The mental nerve exits through the mental foramen, and its precise identification aids in the administration of local anesthesia [6]. Dentists can deliver anesthesia more effectively and with greater patient comfort by avoiding direct contact with the mental nerve.

In endodontic treatments, anatomical details about the position of the mental foramen are beneficial for successful root canal therapy. They help dentists accurately locate the mental nerve's canal and thoroughly clean and fill the root canals in the affected teeth [8].

In orthodontics, the position of the mental foramen can guide the orthodontist in planning the movement of teeth and aligners, especially in cases of lower anterior tooth retraction. Being aware of the proximity of the mental foramen allows the orthodontist to design treatment plans that do not interfere with the neurovascular bundle.

The identification of the mental foramen on CBCT can aid in diagnosing pathologies or abnormalities related to the mandible and surrounding structures. It can help detect cysts, tumors, fractures, or any other conditions that may affect the mental foramen area.

Therefore, the identification of the mental foramen on CBCT images is an invaluable tool in dental and maxillofacial practices.

In the literature, several metrical and morphological parameters were analyzed to correctly assess the anatomical characteristics of the MF, including the maximum height [7] and width [9], the distance from the upper and lower mandibular border [1,6,10,11], the shape [1,7,12], the opening angle at the external surface of the mandible [1,7] and the position according to the teeth [7]. Moreover, some anatomical variants such as the possible anterior loop of the mental nerve [7,10,12], its distance from the MF [1,8,10] and the accessory MF [8,12] have been analyzed. However, although most of the literature has so far analyzed different metrical parameters separately for epidemiological purposes, very few articles in the literature have evaluated possible correlations among different metrical measurements commonly used in the surgical localization of the MF.

The present article aims at assessing seven different parameters that are useful for MF localization and verifying possible correlations among different measurements and parameters: the results will be useful in improving our knowledge about this important anatomical structure.

2. Materials and Methods

2.1. Materials

One hundred CBCT scans taken from the patients for diagnostic dental purposes from 2021 to 2022 (CBCTs were performed for different clinical purposes, including bone volume evaluation for dental implant planning, the planning of endodontic treatments prior to non-surgical and surgical therapies and preoperative evaluations for orthognathic surgery) were randomly extracted from a hospital database, including 50 males (mean age: 54 ± 16 years) and 50 females (mean age: 51 ± 19 years).

The inclusion criteria were patients aged >18 years, white ancestry, CBCT including the complete mandibular arch, evidence of mandibular premolars and first molars on both the right and left sides and totally erupted mandibular premolars.

Subjects affected by pathologies involving the mandible were excluded, as well as edentulous patients. The study follows international laws and guidelines (Helsinki Declaration) and was approved by the local ethical committee (7331/2019).

All examinations were acquired on the same CBCT equipment, Orthophos XG 3D (Sirona Dental System, Charlotte, NC, USA), with the following acquisition parameters: kVp 85, mA 5, mAs 71.5, field of view 80×80 cm^2, voxel size $0.16 \times 0.16 \times 0.16$ mm^3, acquisition-exposure time 28/14 s, effective exposure time 2–6 s.

2.2. Methods

A panoramic image was reconstructed along the inferior alveolar canal. Both the right and left MF of each patient were analyzed, for a total of two hundred MFs. From each CBCT scan, the following measurements were taken (Figure 1):

1. Width of the MF in the transverse axial section;
2. Height of the MF in the coronal section;
3. Depth of the MF in the coronal section (distance between the center and the deepest point of the MF);
4. Distance of the center of the MF from the inferior mandibular edge in the coronal section;
5. Distance of the center of the MF from the superior mandibular edge in the coronal section.

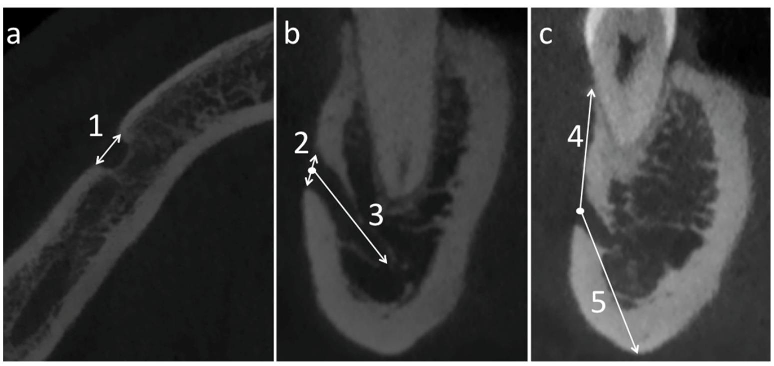

Figure 1. Details of metrical parameters assessed for assessing the localization of the MF: (**a**) transversal section: 1: width of the MF; (**b**) coronal section: 2: height of the MF; 3: depth of the MF; (**c**) coronal section: 4: distance of the center of the MF from the upper mandibular edge; 5: distance of the center of the MF from the lower mandibular edge.

Moreover, the position of the MF according to the following anatomical landmarks was assessed:

- Position according to teeth, classified in five degrees as follows [7]:

I: between the canine and first premolar;
II: at the level of the first premolar;
III: between the first and second premolars;
IV: at the level of the second premolar;
V: between the second premolar and the first molar;
VI: at the level of the first molar.

- Position according to dental apices, classified in three degrees as follows [7]:

1: above the level of the dental apices;
2: at the level of the dental apices;
3: below the level of the dental apices.

For ten individuals (20 MFs), metrical measurements were repeated by the same and another observer (dental radiologists with, respectively, 10 and 15 years of experience in the field, both experienced in the metrical and morphological assessment of radiological analyses) to assess the repeatability of the procedure. For the position of the MF according to teeth and dental apices, the assessment was jointly performed by the two observers.

2.3. Statistical Analyses

Differences in age according to sex were evaluated through Student's *t*-test: rTEM (relative technical of measurement) for each metrical measurement was calculated in order to quantify intra- and inter-observer errors [13].

Differences according to sex and side were assessed through a two-way ANOVA test; for the position of the MF according to teeth and dental apices, the same analysis was performed through a Chi-square test ($p < 0.01$).

Pearson's test was used to test possible correlations between metrical measurements: differences in each measurement according to the position of the MF according to dental apices and teeth were assessed through a one-way ANOVA test ($p < 0.01$).

3. Results

The ages of the chosen male and female subjects were not significantly different ($p > 0.01$).

All metrical measurements were found to be repeatable (Table 1), with both intra- and inter-observer errors classified as "very good" or "good" for each parameter [14].

Table 1. rTEM (relative technical error of measurement) recorded for the intra- and inter-observer assessment of different metrical measurements.

	Intra-Observer Error (%)	Inter-Observer Error (%)
Width	3.3	4.4
Height	2.6	5.4
Depth	3.4	5.5
Distance from inferior mandibular edge	3.2	5.2
Distance from superior mandibular edge	2.0	4.1

The results from the assessment of the metrical measurements are exposed in Table 2: the width ranged between 1.4 mm and 6.8 mm, the height ranged between 1.2 mm and 5.4 mm, the depth ranged between 3.0 mm and 13.2 mm, the distance from the lower mandibular edge ranged between 11.4 mm and 21.0 mm and the distance from the upper mandibular edge ranged between 4.6 mm and 20.6 mm.

Table 2. Average values reported for each metrical parameter divided according to sex and side (R: right side; L: left side): among round brackets, standard deviation (SD).

		Width	Height	Depth	Distance from Inferior Mandibular Edge	Distance from Superior Mandibular Edge
Males	R	3.3 (0.7)	3.2 (0.9)	7.3 (1.7)	15.8 (1.8)	13.2 (2.8)
	L	3.2 (0.9)	3.1 (0.9)	7.2 (1.8)	16.1 (1.9)	13.0 (2.7)
Females	R	3.0 (0.9)	2.7 (0.6)	6.1 (1.7)	14.5 (1.7)	12.6 (2.8)
	L	3.1 (0.7)	2.7 (0.7)	5.8 (1.4)	14.7 (1.6)	12.5 (2.9)
Total	R	3.2 (0.8)	2.9 (0.8)	6.7 (1.8)	15.2 (1.9)	12.9 (2.8)
	L	3.2 (0.8)	2.9 (0.8)	6.5 (1.8)	15.4 (1.9)	12.7 (2.8)

For what concerns the position of the MF according to teeth, most of the subjects showed a degree of three or four (between the first and second premolar or at the level of the second premolar); in most of the cases, the MF was located below the dental apices (Table 3).

Table 3. Distribution of different degrees of the position of MF according to teeth and dental apices divided according to sex and side (R: right; L: left).

Type		Position According to Teeth (%)						Position According to Dental Apices (%)		
		1	2	3	4	5	6	1	2	3
Males	R	6	10	38	34	12	0	6	24	70
	L	6	4	42	36	12	0	6	24	70
Females	R	6	6	36	32	18	2	14	28	58
	L	6	6	44	26	16	2	14	24	62
Total	R	6	8	37	33	15	1	10	26	64
	L	6	5	43	31	14	1	10	24	66

Among metrical measurements, the depth and distance from the inferior and superior mandibular edges were higher in males than in females ($p < 0.01$), with an eta squared classified as medium (between 0.06 and 0.14) [15]. No difference according to side or interaction between sex and side was found for any measurement ($p > 0.01$). Instead, the position according to teeth and dental apices did not show differences according to sex or side (Table 4).

Table 4. Differences according to sex and side for width, height, distance from inferior and superior mandibular edge (two-way ANOVA test) and position of the MF according to teeth and dental apices (Chi-square test). *: $p < 0.01$.

Two-Way ANOVA Test	Sex			Side			Sex × Side		
	F	p	η^2	F	p	η^2	F	p	η^2
Width	3.492	0.063	0.018	0.032	0.859	0.000	0.670	0.414	0.003
Height	1.770	0.185	0.009	0.215	0.643	0.001	0.033	0.856	0.000
Depth	31.611 *	<0.001	0.139 *	0.811	0.369	0.004	0.139	0.709	0.001
Distance from inferior mandibular edge	28.615 *	<0.001	0.126 *	0.824	0.365	0.004	0.224	0.637	0.001
Distance from superior mandibular edge	17.720 *	<0.001	0.083 *	0.423	0.516	0.002	0.204	0.652	0.001
Chi-square test	Chi-square		p	Chi-square		p			
Position according to teeth	3.501		0.623	4.049		0.132			
Position according to dental apices	0.374		0.996	0.111		0.946			

Pearson's test found a significant positive correlation between height and width, both in males and in females, independently from the side, with a correlation index ranging between 0.39 and 0.52 ($p < 0.01$); moreover, in females, a significant positive correlation was found between the depth and distance from the inferior mandibular edge, with a correlation index of 0.44 and 0.40, respectively, on the right and left sides ($p < 0.01$, Tables 5 and 6).

Table 5. Pearson's correlation indices among different metrical parameters in males: the *p* value is reported among round brackets. *: statistically significant values ($p < 0.01$).

Males	Width	Height	Depth	Distance from Inferior Mandibular Edge	Distance from Superior Mandibular Edge
Width	-	0.524 (<0.001) *	−0.027 (0.850)	0.003 (0.983)	0.246 (0.086)
Height	0.386 (0.006) *	-	−0.052 (0.720)	0.201 (0.161)	0.181 (0.208)
Depth	0.002 (0.988)	0.153 (0.288)	-	0.077 (0.596)	−0.059 (0.686)
Distance from inferior mandibular edge	0.027 (0.853)	0.173 (0.229)	0.301 (0.033)	-	0.149 (0.302)
Distance from superior mandibular edge	0.070 (0.630)	0.035 (0.808)	−0.065 (0.653)	−0.016 (0.912)	-

Table 6. Pearson's correlation indices among different metrical parameters in females: the *p* value is reported among round brackets. *: statistically significant values ($p < 0.01$).

Females	Width	Height	Depth	Distance from Inferior Mandibular Edge	Distance from Superior Mandibular Edge
Width	-	0.403 (0.004) *	−0.272 (0.056)	−0.045 (0.757)	0.131 (0.365)
Height	0.388 (0.005) *	-	−0.220 (0.125)	0.185 (0.198)	0.133 (0.359)
Depth	−0.186 (0.196)	0.061 (0.673)	-	0.440 (0.001) *	0.084 (0.560)
Distance from inferior mandibular edge	−0.151 (0.296)	0.020 (0.892)	0.397 (0.004) *	-	0.241 (0.092)
Distance from superior mandibular edge	0.117 (0.418)	0.088 (0.546)	0.192 (0.182)	0.145 (0.314)	-

Finally, no significant correlation was found between the metrical parameters and the position of the MF according to the teeth and dental apices, independently of sex and side ($p > 0.01$, Table 7).

Table 7. Relationship between different metrical measurements and the position of the MF according to the teeth and dental apices (one-way ANOVA test: $p < 0.01$).

One-Way ANOVA Test		Right Side						Left Side					
		Position According to Teeth			Position According to Dental Apices			Position According to Teeth			Position According to Dental Apices		
		F	*p*	η^2	F	*p*	η^2	F	*p*	η^2	F	*p*	η^2
Males	Width	0.758	0.558	0.063	0.821	0.446	0.034	1.605	0.190	0.125	1.314	0.279	0.053
	Height	2.439	0.061	0.178	4.763	0.013	0.168	3.592	0.013	0.242	0.421	0.659	0.018
	Depth	1.591	0.193	0.124	0.732	0.487	0.030	0.573	0.683	0.049	0.135	0.874	0.006

Table 7. *Cont.*

One-Way ANOVA Test		Right Side						Left Side					
		Position According to Teeth			Position According to Dental Apices			Position According to Teeth			Position According to Dental Apices		
		F	*p*	η^2	F	*p*	η^2	F	*p*	η^2	F	*p*	η^2
	Distance from inferior mandibular edge	0.165	0.955	0.014	1.630	0.207	0.065	0.641	0.636	0.054	0.920	0.406	0.038
	Distance from superior mandibular edge	0.208	0.933	0.018	1.699	0.194	0.067	1.339	0.270	0.106	0.606	0.550	0.025
Females	Width	1.055	0.398	0.107	0.671	0.516	0.028	1.076	0.387	0.109	0.046	0.955	0.002
	Height	2.007	0.096	0.186	0.007	0.993	0.000	1.918	0.111	0.179	0.314	0.732	0.013
	Depth	1.008	0.424	0.103	1.460	0.243	0.058	3.349	0.012	0.276	0.398	0.674	0.017
	Distance from inferior mandibular edge	0.639	0.671	0.068	1.609	0.211	0.064	0.591	0.707	0.063	1.425	0.251	0.057
	Distance from superior mandibular edge	1.359	0.258	0.134	0.108	0.898	0.005	0.637	0.673	0.068	0.144	0.867	0.006

4. Discussion

The study investigated the anatomical position of the mental foramen through a comprehensive analysis of CBCT images. The mental foramen is a crucial landmark in dental and maxillofacial surgeries, and its accurate localization is essential for successful procedures. The literature has widely described the anatomical characteristics of the mental foramen [16]. The study aimed to determine the relationship between various metrical parameters to enhance the precision of MF localization.

The results indicate that there were no significant age differences between males and females concerning the position of the mental foramen, suggesting that age may not play a significant role in determining the localization of the mental foramen in the population studied. The lack of age-related differences may be beneficial in clinical practice, as it implies that age might not be a critical factor to consider when planning dental and surgical procedures involving the mental foramen.

Lim et al., in fact, observed that the MF position may change during primary dentition, remaining stable during the eruption of the primary and mixed dentitions [17]. As our samples include only subjects aged >18 years of age, we therefore found no significant differences according to age, and this agrees with the results of Sheikhi et al., who observed that the distance from the mental foramen to the midline and inferior border of the mandible was similar between different ages [6].

The study found that all metrical measurements were repeatable, demonstrating the reliability and consistency of the CBCT analysis in determining the dimensions and positions of the mental foramen. The repeatable measurements indicate that the CBCT method is a valid and robust tool for accurately assessing the mental foramen's anatomical position.

The analysis revealed differences in certain metrical parameters between males and females. Specifically, the depth of the mental foramen and the distances from the inferior and superior mandibular edges were significantly higher in males compared to females. These findings may have important implications for treatment planning and surgical procedures in different genders. Surgeons should be mindful of these gender-based variations to achieve better outcomes and minimize potential complications related to the mental foramen's position.

The study identified significant positive correlations between specific metrical parameters.

First, in both males and females, a positive correlation was found between the height and width of the mental foramen, independent of the side. This relationship suggests that, as the height increases, the width also tends to increase proportionally. This finding can be valuable in predicting the mental foramen's dimensions based on one of the other parameters when the first is unknown.

Second, in females, a significant positive correlation was found between the depth of the mental foramen and the distance from the inferior mandibular edge. This correlation indicates that as the depth of the mental foramen increases, the distance from the inferior mandibular edge also increases. This knowledge is beneficial for predicting the mental foramen's position along the inferior mandibular edge in female patients.

The MF is an important reference point, as it hosts the mental nerve that can be injured in several surgical and dental procedures [1]; consequent sensory impairment has a strong effect on the patient's life. Moreover, finding the MF is crucial for mental nerve block anesthesia [6]. Therefore, the literature has widely explored its size through the assessment of the height, width and depth and its position according to surrounding structures, namely, dental elements and mandibular edges, usually through the analysis of CBCT. CBCT is a low-dose scanning system [18] and is specifically developed for the visualization of teeth and jaws [19]: therefore, it represents the gold standard for the assessment of the anatomical characteristics of the MF [1].

In the literature, several articles have analyzed the different metrical parameters that are useful for the anatomical assessment of the MF [1,7–12], especially for what concerns the MF size (height and width). For example, Pelè et al. and Ahmed et al. already reported that both MF diameters are higher in males compared to females [1,9], and similar results were found by Alsolehiat et al., this last case only concerning the height of the MF [20]. Moreover, Ahmed et al. found that the distance of the MF from both the upper and lower edges of the mandible is higher in males than in females [9].

For what concerns the position of the MF according to teeth, our study showed that the most common position is between the first and second premolar (position III), followed by the position at the level of the second premolar (position IV). These data are similar to those reported by other colleagues concerning different populations such as Hong Kong Chinese, British, Asian Indian and East African people (position III more prevalent than position IV) but different from Zimbabweans, Malawians and South Indians (position IV more prevalent than positions V and III) and from Nigerians and Kenyans (most common positions are II and III) [21]. Overall, these results show that there are significant differences among populations with different geographic origins (Table 4). Overall, our results confirm the conclusions of a recent meta-analysis by Pelé et al., according to which the most prevalent location for the mental foramen among the global population is mostly between the two premolars (between 50.4% and 61.95%) or apical to the second premolar (from 50.3% to 57.9%) [1].

Table 8. Location (%) of the mental foramen in different populations (adapted from Udhaya et al. [20]). The colors help to visualize the most frequent positions (green > yellow > orange > red > grey). Populations with similar distributions are placed next to each other.

Position	I	II	III	IV	V
Italians (present study)	6.0	6.5	40.0	14.5	1.0
East Africans	0.3	7.6	57.9	31.5	0.0
British people	0.0	9.1	59.1	31.8	0.0
Asian Indians	0.0	6.2	75.4	19.2	0.0
Hong Kong Chinese	0.0	21.0	51.0	24.0	4.0
Chinese	0.0	21.0	59.0	19.0	1.0
Nigerians	1.8	27.0	55.6	12.3	3.3
Kenyans	0.0	31.9	56.1	12.1	0.0
Turks	0.0	0.0	44.1	55.9	0.0
North Indians	0.0	2.1	18.1	69.8	11.5
North Americans	0.0	3.5	23.0	49.4	24.1

Table 8. *Cont.*

Position	I	II	III	IV	V
Zimbabweans	0.0	0.0	12.4	56.3	31.3
Malawians	0.0	2.8	10.0	62.9	24.3
South Indians	0.0	4.4	16.7	55.2	27.8

So far, most authors have considered only data such as the position of the MF and the presence of accessory mental foramina; however, only a few have evaluated the existence of correlations between metrical and morphological characteristics of the MF [7–12,20–23]. Therefore, it is not easy to provide a unitary framework of the anatomical characteristics of the mental foramen [1]. For example, some authors took into consideration position and size without finding any significant correlation [9]. Also, our results did not find any correlation between metrical measurements and the position of the MF according to teeth and dental apices, thus suggesting that the above-mentioned parameters are independent of each other.

Furthermore, a qualitative comparison of the metric data reported by different authors shows some variability regarding the dimensional parameters and the localization of the MF with respect to the mandibular edges—for example, within Indians (Table 9). In the future, these data could be subject to further analysis considering not only the inter-ethnic variability but also factors related to the different study techniques (dry jaws vs. CBCT) and the methods used for the measurements.

Table 9. Comparison of metrical data regarding anatomical characteristics of the mental foramen in selected populations.

Population	Distance from the Inferior Mandibular Edge		Distance from the Superior Mandibular Edge		Height		Width	
	R	L	R	L	R	L	R	L
Italians (present article)	15.2 (1.9)	15.4 (1.9)	12.9 (2.8)	12.7 (2.8)	2.9 (0.8)	2.9 (0.8)	3.2 (0.8)	3.2 (0.8)
Turks [7]					2.25 (0.52) * 1.98 (0.47) §	2.22 (0.54) * 1.96 (0.51) §		
Jordanians [19]	12.7 (1.6)	12.8 (1.7)	12.0 (2.5)	12.2 (2.6)	2.9 (0.8)	2.5 (0.9)	2.3 (0.7)	3.0 (0.7)
Indians [24]	10.67	0.21	10.71	0.18	3.58 (0.17)	3.55 (0.18)		
Indians [25]	12.16 (3.04)	12.11 (3.11)	14.05 (3.05)	13.82 (3.06)				
Indians [26]	17.3	1.37	17.0	18.6	2.79	2.57		
Turks [27]	14.61	14.29	13.62	14.62	2.38	2.64	2.93	3.14
Bosnians [28]	12.67 (2.00)	12.72 (1.66)	14.37 (4.37)	14.37 (4.22)	1.71 (1.02)	1.69 (0.64)	2.56 (1.05)	2.41 (0.94)
Polish people [29]					3.55 (1.08) * 3.02 (0.83) §	4.06 (1.25) * 3.03 (0.86) §	4.24 (1.1) * 3.89 (1.12) §	4.06 (1.25) * 3.92 (1.18) §

* male; § female.

On the other side, the present study found a significant correlation between the two diameters of the MF (height and width), both in males and in females: in addition, in females, depth shows a positive correlation with its distance from the inferior mandibular edge. The latter finding has particular importance in surgical practice, as it may help in predicting the depth of the MF in cases where anesthesia of the mental nerve is requested.

In conclusion, the present study analyzed the correlation among different parameters useful for the localization of the MF: the results partially confirmed the existing literature; moreover, correlations between metrical measurements were found.

The results of this study have important clinical implications for dental and maxillofacial surgery. First, our study confirms the existence of differences in the predominant localization of the mental foramen among different populations. Second, clinicians should consider gender-specific differences like the depth and the distances from the mandibular edges when planning procedures involving the mental foramen. Tailored treatment approaches based on gender and ethnicity can lead to a more accurate localization of the nerve pathway and better surgical outcomes.

The observed repeatability of metrical measurements with CBCT underscores the reliability of this imaging modality for assessing the mental foramen's position. CBCT should be considered as a preferred method for precise localization in dental and maxillofacial procedures.

The identified correlations between metrical parameters enable clinicians to predict one measurement based on another, providing additional insights into the MF dimensions without the need for additional imaging.

It is essential to acknowledge some limitations of the study. The research was conducted on a specific population, and its generalizability to other ethnicities or regions might be limited. Future studies with larger and more diverse sample sizes could provide a more comprehensive understanding of the relationship between metrical parameters and the mental foramen's position. Additionally, exploring other factors that may influence mental foramen localization, such as genetic variations or anatomical anomalies, could further enhance the precision of surgical planning.

In conclusion, the paper presents significant findings regarding the anatomical position of the mental foramen based on a meticulous analysis of CBCT images. The results highlight the absence of significant age differences between genders, the repeatability of metrical measurements and gender-specific differences in certain metrical parameters. The correlations between metrical measurements provide valuable insights for predicting the mental foramen's dimensions. These findings contribute to improved treatment planning, enhanced surgical accuracy and reduced potential complications in dental and maxillofacial surgeries. Clinicians should consider these results when planning procedures involving the mental foramen, and further research may explore the applicability of these findings to diverse populations.

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References

1. Pelé, A.; Berry, P.A.; Evanno, C.; Jordana, F. Evaluation of Mental Foramen with Cone Beam Computed Tomography: A Systematic Review of Literature. *Radiol. Res. Pract.* **2021**, *2021*, 8897275. [CrossRef] [PubMed]
2. Kawai, T.; Sato, I.; Asaumi, R.; Yosue, T. Cone-beam computed tomography and anatomical observations of normal variants in the mandible: Variant dentists should recognize. *Oral. Radiol.* **2018**, *34*, 189–198. [CrossRef] [PubMed]
3. Solar, P.; Ulm, C.; Frey, G.; Matejka, M. A classification of the intraosseous paths of the mental nerve. *Int. J. Oral. Maxillofac. Surg.* **1994**, *9*, 339–344.
4. Robinson, C.; Yoakum, C.B. Variation in accessory mental foramen frequency and number in extant hominoids. *Anat. Rec.* **2020**, *303*, 3000–3013. [CrossRef]
5. Apinhasmit, W.; Methathrathip, D.; Chompoopong, S.; Sangvichien, S. Mental foramen in Thais: An anatomical variation related to gender and side. *Surg. Radiol. Anat.* **2006**, *28*, 529–533. [CrossRef]

6. Sheikhi, M.; Kheir, M.K. CBCT Assessment of Mental Foramen Position Relative to Anatomical Landmarks. *Int. J. Dent.* **2016**, *2016*, 5821048. [CrossRef]
7. Goyushov, S.; Tözüm, M.D.; Tözüm, T.F. Assessment of morphological and anatomical characteristics of mental foramen using cone beam computed tomography. *Surg. Radiol. Anat.* **2018**, *40*, 1133–1139. [CrossRef]
8. Gupta, A.; Pubreja, L.; Malik, R.; Gupta, N. Evaluation of the Dimensions of Anterior Loop of Mental Nerve in CBCT: A Radiographic Analysis. *J. Maxillofac. Oral. Surg.* **2020**, *19*, 168–172. [CrossRef]
9. Ahmed, A.A.; Ahmed, R.M.; Jamleh, A.; Spagnuolo, G. Morphometric Analysis of the Mandibular Canal, Anterior Loop, and Mental Foramen: A Cone-Beam Computed Tomography Evaluation. *Int. J. Environ. Res. Public Health* **2021**, *18*, 3365. [CrossRef] [PubMed]
10. Chen, J.C.; Lin, L.M.; Geist, J.R.; Chen, J.Y.; Chen, C.H.; Chen, Y.K. A retrospective comparison of the location and diameter of the inferior alveolar canal at the mental foramen and length of the anterior loop between American and Taiwanese cohorts using CBCT. *Surg. Radiol. Anat.* **2013**, *35*, 11–18. [CrossRef]
11. Gungor, E.; Aglarci, O.S.; Unal, M.; Dogan, M.S.; Guven, S. Evaluation of mental foramen location in the 10-70 years age range using cone-beam computed tomography. *Niger. J. Clin. Pract.* **2017**, *20*, 88–92. [CrossRef]
12. Krishnan, U.; Monsour, P.; Thaha, K.; Lalloo, R.; Moule, A. A Limited Field Cone-beam Computed Tomography-based Evaluation of the Mental Foramen, Accessory Mental Foramina, Anterior Loop, Lateral Lingual Foramen, and Lateral Lingual Canal. *J. Endod.* **2018**, *44*, 946–951. [CrossRef] [PubMed]
13. Adao Perini, T.; Lameira de Oliveira, G.; dos Santos Ornellas, J.; Palha de Oliveira, F. Technical error of measurement in anthropometry. *Rev. Bras. Med. Esporte* **2015**, *11*, 86–90.
14. Camison, L.; Bykowski, M.; Lee, W.W.; Carlson, J.C.; Roosenboom, J.; Goldstein, J.A.; Losee, J.E.; Weinberg, S.M. Validation of the Vectra H1 portable three-dimensional photogrammetry system for facial imaging. *Int. J. Oral. Maxillofac. Surg.* **2018**, *47*, 403–410. [CrossRef] [PubMed]
15. Cohen, J. *Statistical Power Analysis for the Behavioural Sciences*; Erlbaum: Hillsdale, MI, USA, 1988.
16. Hauser, G.; De Stefano, G.F. *Epigenetic Variants of the Human Skull*; Schweizerbart: Stuttgart, Germany, 1989.
17. Lim, M.Y.; Lim, W.W.; Rajan, S.; Nambiar, P.; Ngeow, W.C. Age-related changes in the location of the mandibular and mental foramen in children with Mongoloid skeletal pattern. *Eur. Arch. Paediatr. Dent.* **2015**, *16*, 397–407. [CrossRef]
18. Dawood, A.; Patel, S.; Brown, J. Cone beam CT in dental practice. *Br. Dent. J.* **2009**, *207*, 23–28. [CrossRef]
19. Al-Khateeb, T.; Al-Hadi Hamasha, A.; Ababneh, K.T. Position of the mental foramen in a northern regional Jordanian population. *Surg. Radiol. Anat.* **2007**, *29*, 231–237. [CrossRef]
20. Alsoleihat, F.; Al-Omari, F.A.; Al-Sayyed, A.R.; Al-Asmar, A.A.; Khraisat, A. The mental foramen: A cone beam CT study of the horizontal location, size and sexual dimorphism amongst living Jordanians. *Homo* **2018**, *69*, 335–339. [CrossRef]
21. Udhaya, K.; Saraladevi, K.V.; Sridhar, J. The morphometric analysis of the mental foramen in adult dry human mandibles: A study on the South Indian population. *J. Clin. Diagn. Res.* **2013**, *7*, 1547–1551.
22. Haktanir, A.; Ilgaz, K.; Turhan-Haktanir, N. Evaluation of mental foramina in adult living crania with MDCT. *Surg. Radiol. Anat.* **2010**, *32*, 351–356. [CrossRef]
23. Laher, A.E.; Wells, M.; Motara, F.; Kramer, E.; Moolla, M.; Mahomed, Z. Finding the mental foramen. *Surg. Radiol. Anat.* **2016**, *38*, 469–476. [CrossRef] [PubMed]
24. Rastogi, R.; Budhiraja, V.; Sathpathi, D.K.; Singh, S.; Gour, K.K.; Nair, S. Morphology and morphometry of the mental foramen in dry adult human mandibles from central India and their clinical correlation. *Eur. J. Anat.* **2012**, *16*, 22–26.
25. Agarwal, D.R.; Gupta, S.B. Morphometric analysis of mental foramen in human mandibles of South Gujarat. *People's J. Sci. Res.* **2011**, *4*, 15–18.
26. Singh, R.; Srivastava, A.K. Study of position, shape, size and incidence of mental foramen and accessory mental foramen in Indian adult human skulls. *Int. J. Morphol.* **2010**, *28*, 1141–1146. [CrossRef]
27. Oguz, O.; Bozkir, M.G. Evaluation of location of mandibular and mental foramina in dry, young, adult human male, dentulous mandibles. *West. Indian Med. J.* **2002**, *51*, 14–16.
28. Voljevica, A.; Talović, E.; Hasanović, A. Morphological and morphometric analysis of the shape, position, number and size of mental foramen on human mandibles. *Acta Med. Acad.* **2015**, *44*, 31–38. [CrossRef]
29. Zmyslowska-Polakowska, E.; Radwanski, M.; Ledzion, S.; Leski, M.; Zmyslowska, A.; Lukomska-Szymanska, M. Evaluation of Size and Location of a Mental Foramen in the Polish Population Using Cone-Beam Computed Tomography. *Biomed Res. Int.* **2019**, *2019*, 1659476. [CrossRef]