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Original Research Article

Location and Anatomic Characteristics of Mental Foramen in Dry Adult Human Mandibles

Kuru Erişkin İnsan Çenelerinde Mental Foramenin Konumu ve Anatomik Özellikleri

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ABSTRACT

Aim: This study aims to investigate the mental foramen (MF) location, the presence of accessory MF, and the effect of dentition on morphometric parameters using dry mandibles.

Materials and Method: A total of 249 dry mandibles (116 dentate,133 edentate) were used. The location and number of the MF were recorded. The distance to the symphysis, posterior border of ramus, alveolar crest, and mandibular basis were measured. The symmetry of MF was examined. Student's t-tests and Kolmogorov-Smirnov were performed.

Results: The presence of dentition affected the relative superoinferior location of MF on the corpus. No statistical difference was detected in the anteroposterior position of the MF between dentate and edentate mandibles(p>0.05). The most frequent position of the MF was the alignment of the second premolar. The prevalence of accessory MF was 4.41%, while the bilateral positioning of it was 0.40%. The symmetrical location of the MF was 83.62%.

Conclusion: The lowest prevalence of bilateral positioning of the accessory MF in the Turkish population was 0.40%. The presence of dentition affected the relative location of MF on the corpus in the superoinferior aspect. The clinician should be considered different locations, and the presence of accessory foramen in the surgical and endodontic treatments.

Keywords: Anatomy; Anesthesia; Edentulous mandible; Endodontics; Mandibular bicuspid

ÖZ

Amaç: Bu çalışmanın amacı, kuru mandibulada mental foramen (MF) yerleşimini, aksesuar MF varlığını ve dişlenmenin morfometrik parametrelere etkisini araştırmaktır.

Gereç ve Yöntemler: Toplam 249 kuru mandibula (116 dişli, 133 dişsiz) kullanıldı. MF'in yeri ve numarası kaydedildi. Simfizden uzaklığına, ramusun arka sınırına, alveolar krete ve mandibular tabana olan mesafa ölçüldü. Sağ ve sol arasındaki simetri incelendi. İstatistiksel analiz için, Student t-testi ve Kolmogorov-Smirnov testleri yapıldı.

Bulgular: Dişlenmenin varlığı, MF'in korpus üzerindeki süperoinferior yerleşimini etkiledi. Dişli ve dişsiz mandibulalar arasında MF'in anteroposterior pozisyonunda istatistiksel bir fark saptanmadı (p>0.05). MF'in en sık görülen pozisyonu ikinci premoların hizasındaydı. Aksesuar MF prevalansı %4.41 iken bilateral yerleşim prevalansı %0.40 olarak bulundu. MF'in simetrik yerleşimi %83.62 olarak kaydedildi.

Sonuç: Aksesuar MF'in bilateral yerleşiminin Türk popülasyonunda en düşük prevalansı %0.40 olarak bulundu. Dişlenmenin varlığı, süperoinferior yönde korpusta MF'in yerleşimini etkiledi. Cerrahi ve endodontik tedavilerde klinisyenin MF'in yerleşim yerindeki farklılıklar ve aksesuar foramen varlığı göz önünde bulundurulmalıdır.

Anahtar Kelimeler: Anatomi; Anestezi; Dişsiz mandibula; Endodonti; Mandibular premolar

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INTRODUCTION

It is crucial to understand the anatomy of the mandible for the routine anesthesia of teeth in clinical dental practice.[1] Detailed knowledge about the relationship between the root apices and anatomic landmarks is necessary for the endodontic, periodontal, or implant surgery.[2] The dense and thick structure of the bone of the corpus mandible precludes the achievement and maintenance of local anesthesia with infiltration techniques.[1,3] Thus, the clinician must apply the block anesthesia of the inferior alveolar or mental nerve to obtain adequate numbness of posterior teeth.[4]

The inferior alveolar nerve, which is a branch of the mandibular division of the trigeminal nerve, enters the mandibular canal through the mandibular foramen, while innervating molars, and travels anteriorly through the mandibular corpus.[4,5] It is divided into two terminal branches, which are incisive and mental nerves, at the location of the mental foramen (MF).[5] The branch that leaves the MF is called the mental nerve, while the incisive nerve stays at the mandibular canal and reaches the midline. The lower lip, buccal gingiva, lower premolars, and anterior teeth are innervated via two terminal branches.[1] According to anatomy knowledge, the MF is located between the first and second premolars[6,7] Regarding structural characteristics, the MF is generally located as a single foramen, and oval or round.[8] Many variations have been reported with the studies that performed in different populations using cone-beam computed tomography (CBCT)[6,9-12] panoramic,[7,13] dry mandible,[3,14,15] or a human cadaver.[2,16] The second or even third foramen, named as accessory foramina, complicates the surgery of this region and increases the risk of postoperative complications, thus, having high clinical importance. Accessory foramina can be formed in different numbers and in different locations, termed as “foramen complex” by some authors.[9,14]

With the loss of teeth, atrophy of the alveolar bone occurs which makes reconstructive dental treatments difficult.[7] The atrophy process is affected by many factors such as hormones, nutrition, metabolism, the force of the masticatory muscles, head position, or genetics.[3] Severe atrophy of the mandible results in the inefficient residual ridge for the dental implants, or even the disturbing use of a complete denture under the masticatory function. The resorption process changes the relative location of the anatomic structures.[3,7] Since the distance between the MF and the alveolar bone peak directs the dental treatment planning, alterations in the morphometry of the mandible due to the dentition status gain clinical importance.

Because it is not possible to palpate or clinically visualize the MF, understanding the relative position of the MF to the teeth, and variations of the locations is mandatory for the proper delivery of local anesthetics, or “complication-safe” access to the surgical sites. Our study aimed to investigate the symmetry of the MF location, number, and the effect of dentition on the location of the MF using dry mandibles. Our null hypotheses were that [1] the alveolar bone upper the MF in edentate mandibles would be lower than the dentate mandibles, [2] the distance between the MF and the basis of the mandible will be similar in edentate and dentate mandibles

MATERIALS AND METHOD

Two hundred sixty-nine (269) dry adult human mandible of unknown sex were investigated for the study. The specimens were used from the anatomy department laboratory of Süleyman Demirel University Faculty of Medicine and Akdeniz University Faculty of Medicine with the obtained allowance. Mandibles with the intact posterior border of ramus, basis of the corpus, and symphysis were included in the study. Mandibles, which include mandibular teeth that will serve as a guide (the canine, first and second premolar, or first molar) for easily detecting the tooth relationship at the level of the MF, were included. Deformed, fractured, and ragged, and that have unidirectional structures mandibles were excluded from the study. In addition, mandibles with tooth sockets but no teeth were excluded from the study. For the edentate skull, only the mandibles without tooth sockets were included. Thus, 20 mandibles (13 dentate and 7 edentate) were excluded from the study. A total of two hundred forty-nine (249) specimens consisting of 116 dentate and 133 edentate mandibles were selected for this study.

For the comparison of the morphometric values of the dentate and the edentate, to calculate the minimum sample size for Student’s t-test, power analysis was performed according to the data of a previous study[7] that investigate the effect of dentition, with a power of 80%, alfa error of 0.05, effect size f value of 0.71 using the software of G*Power 3.1 (Heinrich–Heine–Universität, Düsseldorf, Germany). A total of 66 samples were included in the study as the minimum required sample size (33 samples in each group).

The distance between the MF and the symphysis menti (Ant), posterior border of the ramus (Post), alveolar crest (Upp) and mandibular basis (Lw) was measured on both sides. In addition, its position between the left and right sides, its relationship with the teeth, number and symmetry were measured. In the measurements, specimens with one or more accessory foramina were excluded to avoid distortion of the data in mm. The presence of accessory foramina was noted. As a result, 238 mandibles (110 dentate and 128 edentate) were selected for measurements. The position of the MF and the relationship between the teeth were classified; H1: canine-first premolar, H2: first premolar, H3: first-second premolar, H4: second premolar, H5: second premolar-first molar, H6: first molar.

All the measurements were made with a digital caliper (SC-6, Mitutoyo Corporation, Tokyo, Japan). Each measurement was performed twice by two different observers (an anatomist with 12 years of experience and a periodontist with 11 years of experience) and the mean value of the measurements was accepted for statistical analysis. Measurements of both observers were calibrated prior to study. To calibrate, 15% of the total samples were measured and the kappa score was calculated (0.91 to 0.93).

Statistical analysis

Statistical analysis was made using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). The mean, minimum, maximum values of the morphometric measurements were obtained with the descriptive analysis. The normality distribution of the data was analyzed by the Shapiro-Wilk. The student's t-test was performed to analyze the differences between the edentate and dentate mandibles, and two sides. The symmetry of the location of MF was analyzed with the Kolmogorov-Smirnov. Interclass correlation coefficient (ICC) was used for the reliability of observers. The level of significance was set at $p<0.05$ for Student's t-test, and Kolmogorov-Smirnov. For ICC, $p<0.001$ was considered statistically significant.

RESULTS

The morphometric measurements were demonstrated in Table 1. There was a statistical difference in the edentate and dentate mandibles in the distance between the MF and upper border of the alveolar crest ($p<0.05$). The distance of the edentate mandible was lower compared to the dentate mandible ($p<0.05$). For the distance between the MF and basis of the corpus, statistical difference was observed in the edentate and dentate mandibles ($p<0.05$). For the anterior and posterior measurements, there were no statistical differences in the edentate and dentate mandibles ($p>0.05$). For all morphometric measurements, there were no significant differences in the left and right sides ($p>0.05$).

In all of the specimens, we detected the presence of MF (100%). With regards to the accessory foramen, we detected the accessory MF (second foramina) in 11 specimens (4.41%), 6 of which were on the dentate mandibles, 5 of which were on the edentate mandibles. The prevalence of the unilateral accessory MF was 4.01%, while the bilateral ones were 0.40%. In the mandibles, 90% of the accessory foramen (n=10) were unilaterally located, 10% of it (n=1) was bilateral. The most common location of the MF was between the first and second premolar (H4) at a rate of 45.04%(n=50). In addition, H3, H2, and H5 classes were also detected at a rate of 43.24% (n=48), 8.10% (n=9), and 3.62% (n=3), respectively but no localisation of MF detected in H1 and H6 classification. There were no classes of H1(n=0) and H6(n=0) detected. The location of the MF was symmetrical on the left and right mandible (for H2; p=0.00028, H3; p=0.00041, H5; p=0.00013). The location of MF was symmetrical in 97 specimens of 116 mandibles (83.62%) (Table 2).

Table 1. Morphometric measurements (in mm) of mandibles on the left and right sides (Upp: distance between the upper margin of MF and upper margin of alveolar crest, Lw: distance between the lower margin of MF and the basis of the mandibular corpus, Ant: distance between the MF and the symphysis menti, Post: distance between the MF and posterior border of ramus).

			Upp	Lw	Ant	Post
Dentate mandibles	Left	Mean	14.26(±2.57)[a]	15.41(±1.69)[c]	27.37(±2.40)	56.17(±7.06)
		min	8.33	9.65	22.14	26.47
		max	19.40	17.07	31.1	68.65
	Right	Mean	14.29(±2.90)[b]	13.53(±1.77)[d]	27.31(±2.37)	58.09(±4.72)
		min	7.63	19.18	23.28	49.52
		max	10.14	17.45	31.28	69.33
		P value	**P=0.94**	**P=0.70**	**P=0.90**	**P=0.10**
Edentate mandibles	Left	Mean	7.35(±4.02)[a]	10.20(±2.11)[c]	26.94(±2.48)	54.98(±4.98)
		min	0.81	3.66	21.85	45.58
		max	15.22	15.50	32.23	64.74
	Right	Mean	8.26(±3.88)[b]	12.96(±1.77)[d]	26.89(±1.12)	55.86(±4.10)
		min	0	9.31	21.49	47.28
		max	16.6	16.87	31.91	64.24
		P value	**P=0.85**	**P=0.07**	**P=0.90**	**P=0.23**
		P value	**P[a]=0.001*(left)**	**P[c]=0.022*(left)**	**P=0.56 (left)**	**P=0.051 (left)**
			P[b]=0.007*(right)	**P[d]=0.028*(right)**	**P=0.42 (right)**	**P=0.43 (right)**

*Significance level p<0.05 according to the Student's t-test. Same letters mean statistical difference.

Table 2. The location of the MF according to the mandibular teeth, the symmetry of the location, and the prevalence of the accessory foramen and positioning (H1: located on a longitudinal axis between the canine and lower the first premolar, H2: located on a longitudinal axis of the lower first premolar, H3: located on a longitudinal axis between the lower first and second premolar, H4: located on a longitudinal axis of the lower second premolar, H5: located on a longitudinal axis between the lower second premolar and first molar, H6: located on a longitudinal axis of the lower first molar).

		Dentate (n=116)	Edentate (n=133)	Total (n=249)
Location of MF	H1	- (n=0)	N/A	- (n=0)
	H2	8.10% (n=9)	N/A	8.10% (n=9)
	H3	43.24% (n=48)	N/A	43.24% (n=48)
	H4	45.04% (n=50)	N/A	45.04% (n=50)
	H5	3.62% (n=3	N/A	3.62% (n=3)
	H6	- (n=0)	N/A	- (n=0)
	Symmetry		N/A	83.62 % (n=97)
Accessory MF	Total prevalence	2.40 % (n=6)	2 % (n=5)	4.41% (n=11)
	Bilateral	- (n=0)	0.40 % (n=1)	0.40% (n=1)
	Unilateral	2.40 % (n=6)	1.62 % (n=4)	4.01% (n=10)

DISCUSSION

In the present study, the most common position of MF was H4. The anatomic characteristics of the MF have been studied with different methodologies in various populations (Table 3).[1,3,8-11,13-23] A wide range of variation was reported in terms of the number from the absence to three foramina, in terms of location from the first molar to the canine.[11] There are conflicting results about the location of the MF, even in the same populations. Similar to our results, some previous studies reported the location of the MF between the first and second premolars.[13,6] Unlike our results, numerous studies from various populations reported the most common location was at the longitudinal axis of the second premolar.[3,12,15,17,18] These differences can be attributed to racial factors. On the other hand, the different MF locations did not only observe between different races but also in the same racial origins. In the previous studies that performed in the population that are the same as in our study, the frequent MF location was reported as both H3 and H4.[12,15] From a biological perspective, the position of the MF relative to a tooth is influenced by the delays in the embryological developments or the factors that affect post-embryological ontogeny.[3] A recent systematic review reported the prevalence of H3 was 43.66% as the most frequent location, and the prevalence of H4 was 43.12%.[1] In other words, at the rate of 3.33%, the MF is located posteriorly of the second premolar. According to our data, at the rate of 3.62%, the MF was located between the second premolar and first molar. However, we did not document any data at the level of the first molar or more posteriorly. The position of MF aligned at the first molar was reported.[1,3] The unexpected and rare location of the MF, like the alignment with the first molar, increases the likelihood that the clinician will interpret the MF as local pathology, especially if it is superposed with the root apex on panoramic radiography.

Table 3. Previous studies investigated the MF location and the presence of accessory MF (H2: located on a longitudinal axis of lower first premolar H3: located on a longitudinal axis between lower first and second premolar H4: located on a longitudinal axis of the lower second premolar. MF: mental foramen).

Study	Population	Sample size	Method	Location of MF	Accessory foramen
Agthong *et al.* (2005)[14]	Thais	110	Dry mandible	N/A	1.80 %
Al-Khateeb *et al.* (2007)[13]	Jordanian	860	Panoramic	H3	10 %
Aytugar *et al.* (2019)[9]	Turkish	1005	CBCT	N/A	12.23 %
Budhiraja *et al.* (2013)[22]	Indian	105	Dry mandible	H4	6.60 %
Cabanillas Padilla *et al.* (2014)[28]	Peruvian	180	CBCT	H4	55.50 %
Chrcanovic *et al.* (2011)[3]	Brazilian	80	Dry mandible	H4	5 %
Direk *et al.* (2017)[10]	Turkish	100	MDCT	H2	11 %
Goragen *et al.* (2013)[29]	Turkish	315	CBCT	N/A	6.30 %
Igbigbi & Lebona (2005)[15]	Malawian	70	Dry mandible	H4	4.30 %
Iwanaga *et al.* (2015)[33]	Japanese	63	Cadaver	N/A	14.30 %
Li et al. (2017)[8]	Chinese	784	CBCT	N/A	7.30 %
Kalender *et al.* (2012)[11]	Turkish	193	CBCT	H3	6.50 %
Mbajiorgu *et al.* (1998)[23]	Zimbabweans	32	Dry mandible	H4	N/A
Moiseiwitsch *et al.* (1998)[18]	American	105	Cadaver	H3	N/A
Oğuz & Bozkır (2002)[16]	Turkish	34	Dry Mandible	H4	6.50 %
Paraskevas *et al.* (2015)[2]	Greek	96	Dry Mandible	N/A	4.17 %
Sawyer *et al.* (1998)[32]	American	255	Dry mandible	N/A	1.40 %
Sekerci *et al.* (2013)[12]	Turkish	550	CBCT	H3	2 %
von Arx *et al.* (2013)[4]	Swiss	142	CBCT	H3	N/A
Velasco-Torres *et al.* (2017)[6]	Spanish	348	CBCT	H3	N/A
The present study	**Turkish**	**249**	**Dry mandible**	**H4**	**5.50 %**

The results of this study show that 98.28% of the MF is located in the second premolar and slightly anterior alignment without reaching the first molar. According to this result, when the trajectory of the needle is adjusted to the root of the second premolar, the successful anesthesia can be guaranteed with a rate of 98.28% in terms of the location parameter. In addition, the location variations are also important to prevent traumatic injury of the neurovascular bundle by the needle.[19] Clinicians must be remembered that, during the anesthesia, penetrating the MF may cause irreversible damage to the neurovascular bundle.

The position of the MF relative to the teeth was found to be symmetrical. At embryological levels, the reciprocal and simultaneous development of the bone and neurovascular elements of the mandible in the left and right sides results in symmetrical morphology.[3] Previous studies reported high asymmetry, and it can be explained by the minimal improprieties in the positioning of individuals during the irradiation.[13,16]

The accessory MF is located at the vicinity of the main foramen, and it complicates the periapical or periodontal surgeries of mandibular premolars and the anesthesia of these teeth. Our study showed the prevalence of accessory foramen was 4.41%. During the embryological development, at the twelfth week, the development of MF is nearly terminated.[3] Before this stage, when the ramification of the mental nerve has occurred, an accessory foramen can exist according to the principle of the bone response to the changes in nervous tissue formation.[24] The rate of accessory MF reported 2%-55.5% in range using different methods and in various populations.[6,8,10,11,20,25] The lower prevalence of the accessory MF was reported in white Americans (1.4%) and Asians (1.5%).[23] While the higher prevalence of accessory MF was in Japanese (14.2%) and Peruvians (55.5%).[20,22] Different results are related to genetic, and racial factors. The accessory MF can contain an artery, nerve, or both.[22] Therefore, determining the location of these foramina is essential for the prevention of paralysis, hemorrhage, hematoma as a postoperative complication. It emphasizes the importance of the detailed data belonging to various populations that confirmed with numerous studies. Besides, the detection of the variations on the location of the MF affects the differential diagnosis of this anatomical formation with pathologies related to the teeth. Previous studies that investigate the presence of accessory MF in the same population as ours reported the prevalence in a range of 2%-12.23%.[3,9-11,21] The results in a wide range can be attributed to the methodology of the study or the number of mandibles investigated. Our results that showed the prevalence of accessory MF as 4.41%, were in the range of the results belonging to our population. On the contrary, this consistency was not followed in terms of positioning. According to our results, most accessory foramina were unilaterally located. Bilateral positioning of the accessory MF was reported as in the range of 0.59%-3%.[9,10,21] However, our study reported the bilateral positioning as 0.40%. This is lower than other studies. To the best of our knowledge, the lowest prevalence of the bilateral accessory foramen in the Turkish population was our study with the rate of 0.40%.

From the proportion perspective, the MF was positioned at approximately midway of the dentate mandible, 14.27 mm for the upper part, and 14.47 mm for the lower part. Several studies showed a similar proportion,[25] while others reported the location of the MF as in the second half.[18] In the edentate mandibles of our study, the location of MF was at the first half, 7.82 mm for the upper part, and 11.58 mm for the lower part. Differences can be attributed methodology, and the positions of the caliper on the MF. On measurements, the probe of the digital caliper can be located on the center of the MF, or the anterior border of the MF. This can slightly differ the results in mm. The absence of standardization in the methodology caused differences in the outcomes in similar populations.

We observed a statistical difference in bone height over the MF between edentate and dentate mandibles, as expected. Thus, we accepted the first null hypothesis that the alveolar bone upper the MF in edentate mandibles would be lower than the dentate mandibles. Researchers report that bone resorption is not only related to teeth complex but also can occur at the basal aspect of the mandible.[7,14] Consistent with these reports, we also demonstrate the difference in the distance between the MF and the basis of the mandible. Therefore, we rejected the second null hypothesis that the distance between the MF and the basis of the mandible will be similar in edentate and dentate mandibles. The distance between the MF and the basis was lower in edentate mandibles. This can be attributed to physiological bone resorption. At the first 3 months after the extraction of the teeth, approximately 35% of bone thickness is lost.[1,4,7] Our study showed that the MF is nearly located on the bone crest at the edentate mandible. According to physiological resorption, the relative MF location on the corpus is changing. In addition, the changing in the eating habits due to refined food with modern living causes a decrease in bone deposition belonging to the continuous remodeling process of bone. Depending on the approximation of MF to the bone crest, mild to severe pain can be observed with the use of a complete denture. A previous study found similar results in the distance between the MF and the lower border at the dentate and edentate conditions, however, with limited samples.[14] Our study had a larger sample size, showed the effect of dentition on this distance.

The distance to the symphysis and to the posterior border between the edentate and dentate mandibles was found similar in our study. This can be explained by the slight effect of the physiological resorption process in the anteroposterior direction. The effect of dentition on the resorption process was shown with significant differences in the superoinferior directions. In the literature, the reduced morphological distances in anteroposterior direction in edentate mandibles than dentate ones were reported and concluded that the effect of masticatory forces.[3]

Detailed knowledge about MF is determinative for the procedures of the endodontic treatment and clinical approach for the endodontic abscess of these teeth. A previous study reported the closest distance between the root apex and the MF were the second premolar (70%), the first premolar (18%), and the first molar (12%), respectively.[19] In the same study, the distance between MF and the root apices was found ≤3 mm at the rate of 4%.[19] This distance creates a peril in mechanical instrumentation or chemical irrigation when performed beyond the apex of the root during endodontic treatment in terms of irreversible paresthesia. Besides, the location of MF must be determined for the proper flap design or access to lesion during endodontic or periodontal treatment. The presence of an anterior loop is another parameter that should be considered for surgical procedures. Prior to dental treatments, meticulous examination must be performed to prevent damage due to the trajectory in the mandibular canal. Panoramic radiography has some limitations such as projection errors, magnification, or distortion, thus, CBCT can be more suitable to detect the exact location of the MF for the clinical examination.[6]

The limitations of our study are that the sex and age of the specimens could not be analyzed and the proximity of the MF to the root apex could not be determined. The strength of our study is that we were able to make direct observation of MF in our population with a large sample size.

CONCLUSION

Within the limitations of the study, it was determined that MF was located between the first and second premolars. The presence of accessory MF was seen in 4.41%. Therefore, clinicians are advised to consider the variations of MF position for appropriate anesthesia. The superoinferior position of the MF was affected by tooth structure, while the anteroinferior position was not.

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