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Three-dimensional Position of Mandibular Foramen in a Subpopulation Residing in the West of Iran Using Panoramic Based on Cone Beam Computed Tomography

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ABSTRACT

Mandibular foramen is an important anatomical landmark for successful local anesthesia in the mandible. However, it has considerable anatomical variations. This study aimed to evaluate the three-dimensional position of mandibular foramen in a subpopulation residing in the west of Iran using cone beam computed tomography (CBCT). This descriptive and analytical study evaluated CBCT scans of 120 patients (50 males, 70 females) with a mean age of 33.78±12.85 years. Two observers measured the distance from the mandibular foramen to the anterior and posterior borders of ramus, mandibular notch, base of the mandible, apex of the retromolar triangle and third molar tooth/socket on CBCT scans. Panoramic images were reconstructed of CBCT scans with 1 mm slice thickness and the width of the mandibular foramen and the size of the gonial angle in the right and left sides were measured on the reconstructed images. Data were analyzed with SPSS version 18 using paired and independent t-test and Pearson's correlation coefficient (P<0.05). No significant difference was noted in any of the measured distances between the right and left sides (P>0.05). Vertical distances in males were significantly greater than those in females (P<0.05). The measured values had no significant correlation with age (P>0.05). Mandibular foramen was mainly located in the posterior third of the ramus in the horizontal plane in our study population.

Key words: Mandibular Foramen, Mandible, Cone-Beam Computed Tomography, Iran

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INTRODUCTION

Pain is the most common clinical experience of dental patients and local anesthesia is an important step in the successful conduction of dental procedures. Achieving adequate depth of anesthesia prior to dental procedures plays a pivotal role in patient cooperation during the procedure and subsequently increases the success rate of the procedure [1]. Risk of local anesthesia failure always exists, which is mainly related to biological differences among individuals in response to anesthetic drugs, anatomical variations in the position of landmarks and fear and anxiety of patients. Evidence shows that 90% of dental clinicians encounter a problem in successful anesthesia administration at least once a week in their clinical practice [2]. It is particularly the case for the inferior alveolar nerve block due to limited access to the nerve, considerable anatomical variations and high density of bone in this area [3].

Mandibular foramen is located slightly above the center of the internal surface of the mandibular ramus. The mandibular vessels and nerves pass through the mandibular foramen. The mandibular canal starts at the mandibular foramen and travels obliquely down the ramus [4]. Identifying the exact location of mandibular foramen is highly important for the inferior alveolar nerve block, maxillofacial surgeries, endodontic treatment and detection of pathological lesions. Incorrect identification of the location of mandibular foramen is among the most common causes of failure of inferior alveolar nerve block [5, 6]. Simon et al. [7] reported that incorrect identification of the location of mandibular foramen due to its anatomical variations was the most common cause of failure of inferior alveolar nerve blocks. Thangavelu et al. [8] reported that absence of a specific skeletal landmark and variations in height and width of mandibular ramus and position of mandibular foramen were the most common causes of failure of inferior alveolar nerve block. The failure rate of inferior alveolar nerve block has been reported to be 20-25% [9]. The position of mandibular foramen may change after the completion of growth. It may also vary among different races and even the two sides of the mandible in the same individual [10]. Kurds (western Iran) have significantly different soft tissue cephalometric norms compared to Caucasians and have more convex faces [11].

Intraoral and extraoral radiographic modalities play a pivotal role in the detection of pathological lesions and periodontal disease and anatomical assessments [12]. Periapical radiography has long been used for oral and dental assessments. Introduction of digital radiographic systems revolutionized dental imaging [13]. Cone-beam computed tomography (CBCT) is a novel imaging technique commonly used for assessment of the maxillofacial region [14]. CBCT was introduced in 1997 and quickly replaced computed tomography [15,16]. It has lower patient radiation dose than computed tomography and full-mouth periapical radiography [17]. Low cost, low patient radiation dose and high quality of images are the main reasons for the high popularity of CBCT [18]. CBCT images are the most accurate tools for assessment of the mandibular foramen and mandibular canal. Studies on the accurate anatomical position of this landmark in different populations residing in different geographical locations are valuable. Shokri et al, [19] in 2014 evaluated the anatomical position of mandibular foramen on sagittal CBCT sections to determine the position of mandibular foramen relative to the anterior and posterior borders of ramus, inferior border of the mandible and coronoid notch. However, they only evaluated the position of mandibular foramen relative to four references. To compensate for the shortcomings of previous studies, we aimed to assess position of mandibular foramen in the vertical and horizontal dimensions of ramus relative to six references namely the anterior border of ramus, posterior border of ramus, mandibular notch, Inferior border of mandible, center point or socket of mandibular third molar and retromolar triangle using CBCT.

MATERIALS AND METHODS

This descriptive and analytical study evaluated CBCT images retrieved from the oral and maxillofacial radiology clinics of Hamadan and Kermanshah cities. Images were collected using convenience sampling. The sample size was calculated to be 118according to a study by da Silva Braga et al, [20] assuming the standard deviation of the distance from the most inferior point of the mandibular notch to the posterior border of mandibular foramen in females and males to be 2.453 and 3.08, respectively, the mean values of 13.94 and 16.12, respectively, alpha=0.05 and study power of 90%. To increase the accuracy, 120 CBCT scans were evaluated.

The exclusion criteria were trauma, dysplasia, no visualization of the condyle or coronoid process of the mandible in 6 and 9-inch fields of view and poor quality of images due to motion artifact. All CBCT scans had been taken with New Tom 3G volume scanners (QR s.r.l, Verona, Italy and exposure settings of 110 kVp, 2.8 mA and 3.6 s time. Image analysis and three-dimensional reconstructions were done using NNT Viewer software. The images were observed on a 32-inch LCD monitor with 1080x1920p resolution in a semi-dark room. Panoramic images were reconstructed from CBCT scans (Figures 1). The thickness of reconstructed images was 12 mm. The mandibular foramina in the right and left sides were evaluated on reconstructed panoramic images. The exact location of mandibular foramen at the two sides of the mandible was determined by measuring the following parameters:

Anterior border-mandibular foramen (AB-MF): Distance from the mid-point of the anterior margin of mandibular foramen to the closest point in the anterior border of mandibular ramus (Figure 2)

Posterior border-mandibular foramen (PB-MF): Distance from the mid-point of the posterior margin of the mandibular foramen to the closest point in the posterior border of mandibular ramus (Figure 2)

Anterior border-posterior border (AB-PB): Ramus width from the anterior border to the posterior border (Figure 2)

Mandibular foramen-mandibular notch (MF-MN): Distance from the most inferior point of the mandibular notch to the posterior border of mandibular foramen (Figure 2)

Mandibular foramen-mandibular base (MF-MB): Distance from the inferior border of mandibular foramen to the mandibular base (Figure 2).

Mandibular foramen-mandibular third molar (MF-third molar): Distance from the center or socket of the third molar to the anterior margin of mandibular foramen (Figure 3)

Retromolar triangle-mandibular foramen (RT-MF): Distance from the apex of the retromolar triangle to the mandibular foramen and the angle of mandible (at the conjunction of inferior and posterior borders of mandibular ramus)(Figure 3)

The horizontal quadrant in which the mandibular foramen was located was determined by calculating the distance between the anterior border of mandibular ramus and mid-point of the opening of mandibular foramen. The width of mandibular foramen was calculated by subtracting the AB-PB from the sum of AB-MF and PB-MF (Figure 3).

To determine the mid-point of mandibular foramen, this distance was divided by two. To find out what percentage of ramus width (AB-PB) is occupied by the distance from the anterior border of ramus to the mid-point of mandibular foramen, the value obtained by dividing the mandibular foramen width in half was added to the AB-MF distance. The resultant value indicated the mandibular quadrant in which the mandibular foramen was located in anterior-posterior direction (Figure 3). Values from 0-25% indicated the first quadrant, 26-50% indicated the second quadrant, 51-75% indicated the third quadrant and 76-100% indicated the fourth quadrant (Figure 4).

In the horizontal plane, the quadrant in which the mandibular foramen was located was determined as the percentage ratio of MF-MN to the sum of MF-MN and MF-MB.

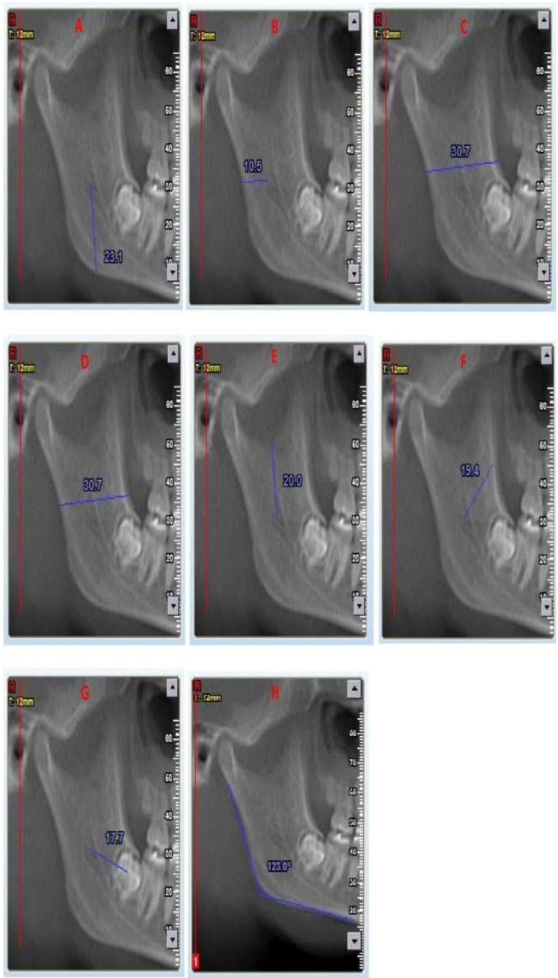

Figure 1: Reconstructed images: (A) inferior border of the mandible-mid-point of the foramen; (B) posterior border of ramus-posterior border of foramen; (C) posterior border of ramus-anterior border of ramus; (D) anterior border of ramus-anterior border of canal; (E) sigmoid notch-mid-point of the mandibular foramen; (F) mid-point of the mandibular foramen-retromolar area; (G) mid-point of the mandibular foramen-center; (H) the angle of the mandible

In this study, all CBCT images were independently observed by two observers including a maxillofacial surgeon and an oral and maxillofacial radiologist. All measurements were made again by the two observers after two weeks to ensure adequate intra-observer agreement. To assess the inter-observer and intra-observer reliability, 20 CBCT images were randomly chosen and evaluated again. The inter-class and intra-class correlation coefficients were found to be 0.959 and 0.984, respectively; which were considered excellent according to the classification by Cicchetti [21].

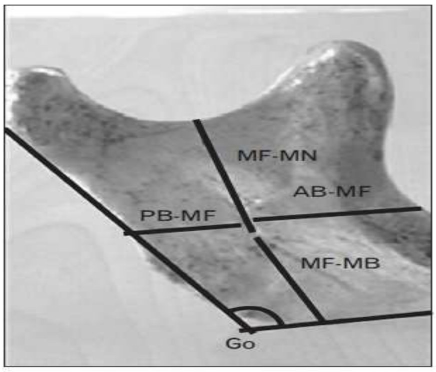

Figure 2: MF-MN (mandibular foramen-mandibular notch), AB-MF (anterior border-mandibular foramen), PB-MF (posterior border-mandibular foramen) and MF-MB (mandibular foramen-mandibular base) in the mandibular ramus

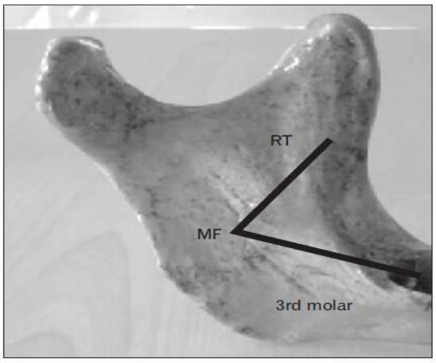

Figure 3: RT-MF (retromolar triangle-mandibular foramen) and MF-third molar (mandibular foramen-mandibular third molar) in the mandible

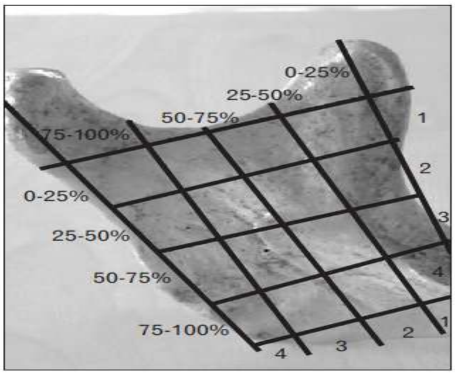

Figure 4: The first, second, third and fourth quadrants of the mandibular ramus

Data were analyzed using descriptive and analytical statistics. The mean and standard deviation of descriptive data were reported. Normal distribution of analytical data was assessed using the Kolmogorov-Smirnov test, which showed that the data were normally distributed (P>0.05). Paired t-test was used to compare the parameters of the right and left sides. Independent samples t-test was used to compare the parameters between males and females. The Pearson's correlation coefficient was used to assess the correlation between age and the parameters. Data were analyzed using SPSS version 18 (SPSS Inc., IL, USA). Level of significance was set at 0.05.

RESULTS

Of 120 CBCT scans, 50 (41.7%) belonged to males and 70 (58.3%) belonged to females. The mean age of patients was 33.78±12.85 years. Table 1 shows the parameters related to the exact location of mandibular foramen in the right and left sides. No significant difference existed in the parameters related to the location of mandibular foramen in the right and left sides (P>0.05).

Table 1: Parameters related to the location of mandibular foramen in the right and left sides

	Left		Right		P-value
	Mean	Standard Deviation	Mean	Standard Deviation	
AB-MF	15.01	2.35	14.99	2.36	.777
PB-MF	7.64	1.28	7.64	1.37	.925
AB-PB	28.07	3.46	28.08	3.42	.949
MF width	5.37	1.42	5.44	1.41	.458
H-Q	62.96	3.75	63.01	4.10	.843
MF-MN	17.55	3.13	17.40	3.16	.159
MF-MB	27.60	4.30	27.61	4.51	.968
MN-MB	45.14	6.20	45.03	6.46	.484
V-Q	38.86	4.72	38.67	4.81	.421
GO angle	126.83	6.90	126.66	7.23	.594
RT-MF	15.38	2.14	15.36	2.33	.787
Third molar-MF	26.63	4.17	26.59	4.34	.860

Table 2 shows the parameters related to the exact location of mandibular foramen in the right and left sides in males and females. The mandibular foramen width in the left side was significantly different between males and females (P=0.008) such that the mean mandibular foramen width in males was greater than that in females. The MF-MN in the left side in males was significantly greater than that in females (P=0.041). The MF-MB in the left side was also significantly different in males and females (P=0.025) such that the mean value of MF-MB in males was greater than that in females. Males and females were significantly different in terms of MN-MB in the left side (P=0.014) such that the mean value of

MN-MB in males was greater than that in females (Table 2).

Table 2: Parameters related to the exact location of mandibular foramen in the right and left sides in males and females

	Sex				
	Male		Female		P-value
	Mean	SD	Mean	SD	
AB-MF in Left Side	14.95	2.42	15.05	2.33	.824
PB-MF in Left Side	7.83	1.37	7.51	1.21	.200
AB-PB in Left Side	28.65	3.47	27.71	3.42	.160
MF width in Left Side	5.81	1.42	5.10	1.35	.008
H-Q in Left Side	62.22	4.23	63.42	3.36	.097
MF-MN in Left Side	18.30	3.57	17.07	2.74	.041
MF-MB in Left Side	28.84	5.13	26.83	3.49	.025
MN-MB in Left Side	47.12	7.46	43.90	4.92	.014
V-Q in Left Side	38.66	4.85	38.99	4.67	.717
GO angle in Left Side	126.47	7.76	127.06	6.35	.676
RT-MF in Left Side	15.54	2.17	15.28	2.14	.530
Third molar-MF in Left Side	27.54	4.10	26.05	4.15	.064

SD: standard deviation

Table 3: Parameters related to the exact location of mandibular foramen in the right side in males and females

	Sex				
	Male		Female		P-value
	Mean	SD	Mean	SD	
AB-MF in Right Side	14.89	2.39	15.05	2.36	.713
PB-MF in Right Side	7.97	1.53	7.43	1.22	.041
AB-PB in Right Side	28.74	3.34	27.66	3.43	.103
MF width in Right Side	5.85	1.48	5.18	1.31	.014
H-Q in Right Side	61.80	4.59	63.77	3.60	.012
MF-MN in Right Side	18.19	3.63	16.90	2.73	.034
MF-MB in Right Side	28.80	5.51	26.86	3.60	.042
MN-MB in Right Side	46.99	7.90	43.80	5.05	.020
V-Q in Right Side	38.68	5.32	38.66	4.49	.979
GO angle in Right Side	126.00	8.13	127.08	6.63	.461
RT-MF in Right Side	15.57	2.32	15.23	2.35	.454
3th molar-MF in Right Side	27.20	4.38	26.21	4.31	.239

SD: standard deviation

Table 3 shows the parameters related to the exact location of mandibular foramen in the right side in males and females. A significant difference was noted in PB-MF in the right side between males and females (P=0.041) such that the mean PB-MF in males was greater than that in females. The mandibular foramen width on the right side was also significantly different in males and females (P=0.014) such that the mean mandibular foramen width in males was greater than that in females. The H-Q of the right side was also significantly different between males and females (P=0.012) such that it was significantly greater in females. The mean MF-MN of the right side in males was significantly greater than that in females (P=0.034). The mean MF-MB in the right side was significantly greater in males than females (P=0.042). The mean MN-MB in the right side in males was significantly greater than that in females (P=0.020, Table 3).

Table 4 presents the correlation of parameters related to the exact location of mandibular foramen in the right and left sides with age. As shown, there was no significant correlation existed between age and the parameters related to the exact location of mandibular foramen in the right and left sides (P>0.05, Table 3).

Table 4: Correlation of parameters related to the exact location of mandibular foramen in the right and left sides with age (n=114)

		Left Side	Right Side
AB-MF	Pearson Correlation	.001	-.008
	Sig. (2-tailed)	.995	.931
PB-MF	Pearson Correlation	-.051	-.046
	Sig. (2-tailed)	.593	.625
AB-PB	Pearson Correlation	.036	-.014
	Sig. (2-tailed)	.706	.886
MF width	Pearson Correlation	.136	.023
	Sig. (2-tailed)	.148	.810
H-Q	Pearson Correlation	.017	.027
	Sig. (2-tailed)	.854	.775
MF-MN	Pearson Correlation	.029	.042
	Sig. (2-tailed)	.758	.656
MF-MB	Pearson Correlation	-.032	-.059
	Sig. (2-tailed)	.734	.536
MN-MB	Pearson Correlation	-.007	-.024
	Sig. (2-tailed)	.938	.803
V-Q	Pearson Correlation	.056	.079
	Sig. (2-tailed)	.557	.401
Gonial angle	Pearson Correlation	.048	.039
	Sig. (2-tailed)	.614	.680
RT-MF	Pearson Correlation	-.085	-.066
	Sig. (2-tailed)	.366	.487
3th molar-MF	Pearson Correlation	.009	.020
	Sig. (2-tailed)	.924	.830

DISCUSSION

The inferior alveolar nerve block is the most commonly used anesthesia technique for root canal treatment and extraction of primary and permanent mandibular teeth. Variability in the position of mandibular foramen is one reason for the failure of this technique [22]. Thus, knowledge about the anatomical variations of mandibular foramen in different populations is imperative for dental clinicians. This study evaluated the position of mandibular foramen in a subpopulation residing in the west of Iran using CBCT. The results showed that the distance from the mandibular foramen to the anterior border of ramus was 14.99 mm in the right side and 15.01

mm in the left side. These values were larger than those reported in another study on a Hamadani population (11.63 and 11.70 mm, respectively) [19]. Our obtained values were also larger than those reported in a Brazilian subpopulation (11.8 mm) [20]. However, our obtained values were smaller than those reported in a South Indian population (16 mm) [23], Indian population (17-18 mm) [8], Zimbabwean population (around 19 mm) [24] and the values measured on dry mandibles of black and white people in Chile (about 17-18 mm) [25]. These differences are mainly attributed to different populations or difference in methods of measurements.

In our study, the mean distance from the mandibular foramen to the posterior border of the mandible was 7.64 mm in the right and 7.64 mm in the left side. These values were 7.71 and 7.19 mm, respectively in the study by Shokri *et al.,* [19], which were close to the values reported in our study. However, these values in our study were smaller than the valuesin the Chilean population (11.11 mm in white females, 12.24 mm in black females, 13.1 mm in white males and 14.15 mm in black males) [25], in the South Indian population (13 mm) [23], in the Indian population (12-14 mm) [8] and in the Zimbabwean population (around 14 mm) [24].

In our study, the distance from the mandibular foramen to the posterior border of mandible was smaller than the distance from the mandibular foramen to the anterior border of mandible; in other words, the mandibular foramen was closer to the posterior border. Similarly, studies on Korean [26], Indian [8] and Chilean [25] populations showed that the mandibular foramen was closer to the posterior border. Mbajiorgu et al. [24] demonstrated that the position of mandibular foramen was 2.5 mm and 2 mm posterior to the mid-point of ramus width in the right and left sides, respectively. Kim *et al.,* [27] found that in the primary dentition period, the mandibular foramen is located at the mid-point of ramus in the anterior-posterior dimension but later it is gradually shifted towards the back. Kang *et al.,* [28] noticed an increase in the distance between the mandibular foramen and anterior border of ramus during the adolescence. According to the current findings, the mandibular foramen width was 5.44 mm in the right and 5.37 mm in the left side. Lee *et al.,* [26] in their study on a Korean population measured the horizontal and vertical diameter of mandibular foramen to be 4 mm and 2-3 mm, respectively.

Our results showed that the distance from the mandibular foramen to the mandibular notch was 17.40 mm in the right and 17.55 mm in the left side. Alves and Deana [25] measured this distance on dry mandibles of Chileans and reported larger values than ours (21-24 mm). Lavanya *et al.,* [23] reported this distance to be 20-25 mm in an Indian population. This distance was 21.74 mm in the right and 21.92 mm in the left side in another Indian population [29].

In our study, the distance from the mandibular foramen to the base of the mandible was 27.61 mm in the right and 27.60 mm in the left side. Similarly, Thangavelu *et al.,* [8] reported this value to be 27 mm in an Indian population. These values were 23.45 and 23.77 mm, respectively, in the study by Shokri *et al.,* [19].

The distance from the mandibular foramen to the mandibular notch was smaller than the distance from the mandibular foramen to the base of mandible in our study. In contrast, a study on an Indian population showed that the mandibular foramen was at the mid-point of this distance [30]. In our study, the distance from the mandibular notch to the base of mandible was 45.14 mm in the left and 45.03 mm in the right side. Park et al. [31] reported the mean vertical length of ramus to be 45.88 mm to 52.6 mm depending on gender. In our study, the gonial angle was measured in individuals with a mean age of 33.78 years and was found to be 126.66° in the right and 126.83° in the left side. Anbiaee et al. [32] measured the gonial angle on CBCT scans of an Iranian population to be 121.8° and 123.8° in the right and left sides, respectively. Leversha et al. [33] measured the size of gonial angle to be123.58° in the right and 125.21° in the left side in an Australian population with a mean age of 44.1 years. They also noticed that the size of gonial angle increased from 123.2° to 125.4° from 18 to 69 years of age. Upadhyay *et al.,* [34] showed that this angle was 145.9° in infants, 140.9° in 1 to 5-year-olds, 133.96° in 6 to 16-year-olds, 129.36° in 17 to 35-year-olds and 127.29° in 35-75-year-olds.

Our study showed that the distance from the mandibular foramen to the retromolar triangle was 15.36 mm in the right and 15.38 mm in the left side. These values were 12.27 mm and 12.13

mm, respectively in the study by Shalini *et al.,* [35] on an Indian population and 14.23 and 14.40 mm, respectively in a study by Valente *et al.,* [36] in Brazil.

In the current study, the distance from the mandibular foramen to the third molar tooth/socket was 26.59 mm in the right and 26.63 mm in the left side. In the study by Shalini *et al.,* [35] on an Indian population, smaller values were reported (22.8 mm in the right and 23.23 mm in the left side). This distance was 25 mm in the study by Kilarkaje *et al.*, [4]. Distance from the mandibular foramen to the third molar tooth/socket was 15 mm in the right and 18 mm in the left side in a study on a South Indian population [37] while these values were 22.8 mm (right) and 21.7 mm (left) in West Bengal [38].

According to our findings, no significant difference existed in the position of mandibular foramen between the right and left quadrants. This finding was in agreement with the results of Shokri *et al.,* [19] since they did not find any significant difference in this respect between the right and left sides in a subpopulation residing in Hamadan city. Similarly, Thangaveluet *et al.*, [8] in India showed bilateral symmetry in the position of mandibular foramen.

Our study revealed that in general, vertical distances (distance from the mandibular foramen to mandibular notch and to the base of mandible and also the distance from the mandibular notch to the base of mandible) in males were significantly greater than those in females. Park *et al.*, [31] reported that the mean length of vertical ramus in males was longer than that in females by about 6 mm. A study conducted on a Chilean population showed that the distance from the mandibular foramen to mandibular notch in black and white males (24.40 and 24.35 mm, respectively) was greater than those in black and white females (21.02 and 22.0 mm, respectively) [25]. Some other studies also confirmed the difference in mandibular distances between males and females and reported greater vertical distances in males compared to females [39, 40].

The present study did not show any significant difference in the size of gonial angle between males and females. This finding was in agreement with the results of Radhakrishnan *et al.,* [41] and Dutra *et al.*, [42]. In contrast to our study, Ghosh et al, [43] Bhardwaj *et al.,* [44] and Huumonen *et al.,* [45] reported that females had a larger gonial angle, which may be related to the effect of masticatory forces.

According to the current findings, the horizontal diameter of mandibular foramen in males was significantly greater than that in females; whereas, Lee *et al.,* [26] found that the mean horizontal and vertical diameters of the mandibular foramen in males were smaller than the corresponding values in females and the difference regarding the vertical diameter was statistically significant. Our study found no significant association between age and parameters related to the location of mandibular foramen in the right or left side. However, mandibular growth continues to adulthood and can change the shape of mandible [46]. But, the overall mandibular growth slows down after the growth spurt that occurs during puberty [47, 48].

In general, it seems that the controversy between our findings and those of other studies may be due to inherent differences between the populations or different methodologies of studies. The values obtained in the current study may be of use for dental clinicians practicing in Hamadan and Kermanshah cities.

CONCLUSIONS

The current results showed that the position of mandibular foramen in our study population was different from that in other populations. The majority of vertical landmarks related to the position of mandibular foramen in males were larger than those in females. The horizontal width of the mandibular foramen in males was also significantly greater than that in females. All landmarks related to the position of mandibular foramen were symmetrical in the right and left sides. The position of mandibular foramen was not correlated with age.

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Conflict of interest

The authors declare no conflict of interest.

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