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ORIGINAL ARTICLE

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Evaluation of the location of mandibular foramen as an anatomic landmark using CBCT images: a pioneering study in an iranian population

Avaliação da localização do forame mandibular como referência anatômica, por meio de imagens CBCT: um estudo pioneiro na população iraniana

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ABSTRACT

Objective: Mandibular foramen (MF) is located on the internal surface of the ramus through which blood vessels and nerves pass. Determination of the anatomic position of the MF is very important in inferior alveolar nerve block anesthesia (IANBA), ramus osteotomy and surgical procedures of the posterior angle of mandibular ramus. The aim of this study was to determine anatomic position of the MF using anatomic landmarks on the three dimensional CBCT images. **Material and Methods:** A total of 103 CBCT images was evaluated. The NNT Viewer software program was used to measure the distances between the lines tangent on the MF periphery and the anterior border of the ramus, the posterior border of the ramus, the inferior border of the mandible, and the coronoid notch in mm by to age and gender. **Results:** The results showed a slight difference in anatomic dimensions between the right and left sides, with no significant differences. The anatomic dimensions of the MF on both sides were a little bigger in males than in females. There were no significant differences in the anatomic dimensions of superior-inferior and anterior-posterior dimensions of the left and right sides in different age groups. **Conclusion:** No significant changes occur in the position of the MF with age. The anatomic differences between males and females should be taken into account during IANBA procedures. Males have bigger jaws than females; therefore, there is a longer distance between the MF and the anatomic landmarks evaluated.

KEYWORDS

Mandibular Foramen; Anatomic Landmarks; Cone-Beam Computed Tomography.

RESUMO

Objetivo: O forame mandibular (FM) localiza-se na superfície interna do ramo mandíbula, onde passam vasos sanguíneos e nervos. A determinação da posição anatômica do FM é muito importante para anestesia por bloqueio do nervo alveolar inferior (ABNAI), durante osteotomiano ramo da mandíbula e para procedimentos cirúrgicos do ângulo posterior do ramo mandibular. O objetivo deste estudo foi determinar a posição anatômica do FM utilizando referências anatômicas em imagens tridimensionais de CBCT. **Material e Métodos:** Um total de 103 imagens de CBCTforam avaliadas. O programa de software NNT Viewer foi utilizado para medir as distâncias em milímetros entre as linhas tangentes na periferia do FM e borda anterior do ramo, borda posterior do ramo, borda inferior da mandíbula e processo coronóide, em relação à idade e o gênero. **Resultados:** Os resultados mostraram uma ligeira diferença de dimensões anatômicas entre os lados direito e esquerdo, sem diferenças significativas. As dimensões anatômicas do FM em ambos os lados foram um pouco maior no sexo masculino do que no feminino. Não houve diferenças significativas nas dimensões anatômicas superior-inferior e ântero-posterior, tanto do lado direito quanto esquerdo,em diferentes faixas etárias. **Conclusão:** Mudanças significativas na posição do FM não são observadas em função da faixa etária. As diferenças anatômicas entre homens e mulheres devem ser levadas em consideração durante procedimento ABNAI. Mandíbulas maiores são encontradas no gênero masculino, portanto, há uma maior distância entre o FM e as referências anatômicas avaliadas.

PALAVRAS-CHAVE

Forame Mandibular; Pontos de referência anatômicos; Tomografia computadorizada de feixe cônico.

INTRODUCTION

Inferior alveolar nerve block anesthesia (IANBA) is the main procedure for the local anesthesia of teeth. Various problems have been reported during IANBA procedures, including fracture of the needle, rupture of blood vessels, skin necrosis, diplopia and nerve injuries [1-5]. Failure in achieving anesthesia of the inferior alveolar nerve is attributed to various factors, including a wrong anesthesia technique and anatomic variations [6]. Various techniques have been reported for the anesthesia of the inferior alveolar nerve [3,7]; however, a more accurate injection for the IANBA does not necessarily increase the success rate [8,9].

Determination of the anatomic position of the mandibular foramen (MF) is important in the IANBA, ramus osteotomy and surgery of the posterior angle of the mandibular ramus [10]. The MF is located in the internal surface of the ramus and nerves and blood vessels pass through it. The position of the MF is related to the anatomic structure of the oral cavity, which can be used as reference points that are accessible easily with the least error. The height, angle and length of these anatomic structures of the oral cavity, used as reference points, are useful to help locate the MF in the IANBA technique.

In this study, three dimensional (3D) CBCT images and computer software programs were used to locate the MF [11] and some relevant standards were defined to determine the correct position of the MF, in terms of the anatomic structures of the oral cavity used in the IANBA technique. In addition, panoramic radiographs can be used to evaluate the position of the MF but their accuracy is less than that of the CBCT images because panoramic radiographs provide a two-dimensional image of a three-dimensional structure. In addition, loss of some data in the buccolingual direction and magnification in both vertical and horizontal dimensions are two drawbacks of the panoramic technique [11,12]. In this study, we aimed to determine the location of the MF on 3D CBCT images in an Iranian population.

MATERIAL AND METHOD

This study was carried out for 6months from 26 December 2012 to 26 May 2013 using the CBCT image archives of the Department of Radiology, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, the west of Iran. No sampling was carried out but all the CBCT images in the archives were evaluated and the eligible ones were enrolled in the study. The CBCT images of patients with a history of trauma, dysplasia, and cystic dysplastic lesions were excluded from the study. In addition, images with field of view (FOV) equal to six and some with FOV equal to nine were excluded from the study because the field did not cover the condyle and the coronoid area. Furthermore, images with motion artifact were excluded because they had low image quality. Finally, 103 out of 225 CBCT images were used for analysis. The CBCT x-ray machine, which was used to take the images, was NewTom 3G (Verona, Italy) at kVp = 110, mA = 2.8 and s = 3.6. All the images were evaluated with NNT Viewer (Verona, Italy) software program and 3D CBCT images were used to locate the MF.

The software program was used to draw four lines tangent to the superior, inferior, anterior and posterior borders of MF relative to the anatomic landmarks including the anterior border of the ramus, the posterior border of the ramus, the coronoid notch, and the inferior border of the mandible. Then, from each of these anatomic landmarks, a line was drawnperpendicular to the tangent lines and the distance between the two points were recorded. A checklist was used to record the four distances of the mandibular ramus by age and gender separately for each patient. The CBCT images were evaluated separately by two experienced radiologists who had already evaluated at least 1000 CBCT images. All images were displayed on a 17-inch Samsung monitor (SyncMaster 740 N, Korea) with the screen resolution set

at 1280×1024 pixels and color set to 32 bit depth. The t-test was used to compare the mean differences. All the statistical analyses were carried out at a 0.05 significance level using Stata11 statistical software program.

RESULTS

The anatomical position of the mandibular foramen by side and the observer is shown in Table 1. The results show no significant difference in the anatomic dimensions measured using the CBCT technique by the two observers. In addition, there wasa little but not statistically significant difference in the anatomic dimensions of the right and left sides.

The anatomical position of the mandibular foramen by side and gender is indicated in Table 2. An important consideration in the table is the fact that on both the left and right sides, the anatomic dimensions of the MF were a little bigger in men compared to women. Except for the distance between the MF and the posterior border of the ramus, there were significant differences between the right, left and total dimensions in both genders.

The anatomical position of the mandibular foramen by side and age groups is shown in Table 3. The data in the table show that the MF position did not change with age.

Table 1 - Anatomical position of the mandibular foramen by side and the observer using CBCT imaging technique

Mandibular foramen anatomical position	Observer 1 (n = 103)		Observer 2 (n = 103)		Difference		t-test
	Mean	SD	Mean	SD	Mean	SE	P value
Left side							
Distance to coronoid notch (mm)	10.74	3.33	10.34	3.26	0.40	0.46	0.391
Distance to inferior border (mm)	23.79	3.87	23.76	3.43	0.02	0.51	0.964
Distance to anterior border (mm)	12.04	2.92	11.34	3.01	0.70	0.41	0.094
Distance to posterior border (mm)	7.10	2.21	7.28	2.22	0.18	0.31	0.553
Right side							
Distance to coronoid notch (mm)	10.07	3.24	9.48	3.42	0.60	0.46	0.199
Distance to inferior border (mm)	23.43	4.08	23.48	4.10	0.06	0.57	0.920
Distance to anterior border (mm)	11.88	2.66	11.38	3.20	0.49	0.41	0.232
Distance to posterior border (mm)	7.89	2.83	7.53	1.88	0.35	0.33	0.295

Table 2 - Anatomical position of the mandibular foramen by side and gender using CBCT imaging technique

Mandibular foramen anatomical position	Female (n = 66)		Male (n = 37)		Both sexes (n = 103)		t-test
	Mean	SD	Mean	SD	Mean	SD	P value
Left side							
Coronoid notch	10.02	2.97	11.48	3.39	10.54	3.19	0.025
Inferior border	23.25	3.31	24.70	3.80	23.77	3.55	0.045
Anterior border	10.88	2.31	13.15	3.12	11.70	2.84	0.001
Posterior border	06.97	1.99	07.59	2.15	7.19	2.06	0.144
Right side							
Coronoid notch	09.09	2.89	10.98	3.57	9.77	3.26	0.004
Inferior border	22.78	3.07	24.66	4.87	23.45	3.90	0.018
Anterior border	11.25	2.82	12.31	2.73	11.63	2.82	0.066
Posterior border	07.52	2.20	07.99	1.56	7.71	2.00	0.286
Both sides							
Coronoid notch	9.56	2.55	11.23	3.04	10.16	2.84	0.004
Inferior border	23.01	2.68	24.68	4.03	23.61	3.31	0.013
Anterior border	11.06	2.29	12.73	2.61	11.66	2.53	0.001
Posterior border	7.26	1.72	7.79	1.58	7.45	1.68	0.125

Table 3 - Anatomical position of the mandibular foramen by side and age groups using CBCT imaging technique

Mandibular foramen anatomical position	10–19 years (n = 35)		20–39 years (n = 56)		40–65 years (n = 12)		t-test
	Mean	SD	Mean	SD	Mean	SD	P value
Left side							
Distance to coronoid notch	10.68	3.19	10.36	3.28	10.98	3.00	0.796
Distance to inferior border	24.05	3.65	23.41	3.53	24.70	3.38	0.448
Distance to anterior border	11.72	3.28	11.87	2.54	10.82	2.86	0.509
Distance to posterior border	6.83	1.44	7.42	2.12	7.18	3.13	0.418
Right side							
Distance to coronoid notch	9.43	2.29	10.24	3.73	8.63	3.19	0.227
Distance to inferior border	23.58	3.59	23.03	4.01	25.05	4.11	0.262
Distance to anterior border	11.82	2.77	11.75	2.97	10.50	2.13	0.337
Distance to posterior border	7.18	1.50	8.19	2.26	7.04	1.47	0.028

DISCUSSION

The MF is one of the most important anatomic landmarks of the mandible. Knowledge about the position of the MF is very important in various dental procedures. Knowledge about the exact location of the MF increases the success of anesthetic procedures [13]. Pain control is critical for dentists. The porous nature of the maxilla makes it possible to use the infiltration technique, but the external cortical bone of the mandible is thick and non-porous. The standard anesthetic technique for the mandible is Hasted block or the INBA, which is mainly used in the molar area of the mandible. The success rate of this technique has been reported to be 80% to 85%. The reasons for the failure of anesthetic techniques of the mandible include technical errors such as incorrect localization of the anatomic landmark of the MF or an incorrect angulation of the needle by the dentist, tissue inflammation, patient's phobia, and intravascular injection of the anesthetic agent. Due to technological advances in the methods and techniques, the INBA is associated with less problems than the past [11,14,15]. There are multiple studies reporting the necrosis of the skin of the chin subsequent to the vascular spasm of the terminal branches of the inferior alveolar nerve [4]. In addition, injuries to the vasoconstricting nerves, maxillary and middle meningeal arteries followed by blindness and ophthalmoplegia [6] and, with a lower incidence, injuries to the lingual nerve [5] might occur after inappropriate injection of the anesthetic agent.

Different techniques have been reported for the anesthesia of the inferior alveolar nerve. The most important factor in the success of the

procedure has been reported to be access to the inferior alveolar nerve through the mandibular foramen [16]. Methodological studies to determine the position of the MF have suggested the use of panoramic radiography, 45º oblique cephalometry, CT scan and ultrasound. Due to technological advances in imaging techniques, the localization of the MF has become facilitated in the three-dimensional plane.

Previous radiologic and anatomic studies have determined the location of the MF in the central segment of the ramus. Jerolimov [17] determined the location of the MF at a distance of 15 mm from the posterior border of the ramus, 17 mm from the anterior border of the ramus, and 21 mm from the angle of the mandible in the vertical dimension, which is different from the results of the present study. Lavanya [18] reported a mean distance of 20-25 mm between the MF and the mandibular notch, 16 mm from the anterior border of the ramus and 13 mm from the posterior border of the ramus in two groups of dentate and edentulous individuals. Based on the results of the present study, on the right and left sides, the average distances of the MF from the coronoid notch, the inferior border of the mandible, the anterior border of the mandible, and the posterior border of the mandible were 9.56, 23.01, 11.06 and 7.26 mm in females and 11.23, 24.68, 12.73 and 7.79 mm in males respectively. In both genders and on the both sides, the MF had the greatest distance from the inferior border of the mandible and the least distance from the posterior border of the mandible. The distance between the MF and the inferior border of the mandible was almost 2.5 times of that between the MF and the coronoid notch. The distance between the MF and the anterior border of the ramu s was almost twice that from the posterior border of the ramus. In both genders, the distance between the MF and the coronoid notch was almost the same as its distance from the anterior border of the ramus. These results were consistent with the results of the study conducted by Hayward et al. They reported that the mean distance between the MF and the anterior border of the ramus was greater than that between the MF and the posterior border of the ramus and the MF was reported to be located in the third quadrant in the antero-posterior dimension.

Trostet et al. [19] carried out a radio-anatomical study and determined the position of the MF at the border of the posterior one-third and the anterior two-third of the ramus. Despite relative variations in the position of the MF, it is less probable to be located in the posterior and superior thirds of the ramus, known as the safety zone. Therefore, there is a minimum risk of trauma to the inferior alveolar nerve in this region during the vertical osteotomy procedures of the mandibular ramus as was the case in our study. We indicated that, in both genders on both the sides, the MF was located in the upper third of the ramus in the vertical dimension (from the coronoid notch to the inferior border of the mandible) and at the border of the posterior one-third and the middle one-third in the horizontal dimension (from the anterior border to the posterior border of the ramus). Therefore, in the Iranian population, during osteotomy procedures of the ramus, the safety zone is located in the anterior one-third of the ramus in the horizontal dimension and in the middle and lower thirds of the ramus in the vertical dimension. Thangavelu et al. [20] evaluated human dry mandibles and concluded that the MF is not located in the center in the antero-posterior and inferior-superior dimensions. They located the MF at a distance of 2.57 mm from the center of the antero-posterior width of the ramus and 3 mm above the center of the vertical dimension (between the sigmoid notch and the inferior border of the mandible). In the present study, the MF was located 0.4 and 1 mm posterior to the center of the ramus in the horizontal dimension in females and males respectively. In the vertical dimension, the MF was located 9.71 and 8.72 mm superior to the center of this dimension in females and males respectively.

Thangaveluet et al. [20] did not report any significant differences between the right and left sides in the location of the MF in each patient. Their results were consistent with the results of the present study. However, there were significant differences between the left

and right sides in males and females. Only there were no significant differences in the distance between the MF and the posterior border of the ramus on both sides between the two genders, which might be attributed to the random error.

Growth and remodeling is at its maximum rate during the initial years of life (especially during the first year) but the growth rate decrease with age. Changes in the length of the mandible show that the height of the ramus and the corpus have the greatest changes. The height of the ramus is less than the total length of the mandible. The ramus is remodeled in the vertical direction only a little more than the posterior direction [21]. The overall growth of the mandible decreases after the initial growth maturation (9-10 years of age) [22]. Based on a study by Kang, changes in the distance between the MF and the anatomic landmarks were parallel with aging and growth in the 8-16 age group [11,19]. In the present study, the subjects were divided into three age groups of 10-19, 20-39 and 40-65 years. However, the changes in the location of the MF in different age groups were not statistically significant. The reasons were as follows. The sample size in the 40-65 years age group (n = 12) was smaller than that of 10-19 (n = 35) and 20-39 (n = 56) years age groups. If the sample size of the three groups had been bigger, the relationship might have become significant. Furthermore, the majority of CBCT imaging techniques, used in this study, were taken for placement of dental implants. So that, there were only five patients under 15 and the youngest subject was 10 years of age. Therefore, the majority of subjects were beyond the growth spurt period and no significant changes are expected in the anatomic location of the MF from puberty to old age [21]. Males have greater growth compared to females. Based on the results of a study conducted by Liu, the size of the mandible in males was significantly greater than that in females ($P < 0.05$). In addition, males have greater growth rate and become more mature [21]. Apart from variations in size and the form of body, head, and neck, there are specific facial characteristics in relation to gender. Based on differences in several measurements. Agthong suggested that in addition to anatomic variations, the sex and the body side should be taken into account during anesthetic procedures of the mandible [23,24]. Based on the results of the present study, during an IANBA procedure, the anatomic differences between males and females should be taken into account. Males have bigger jaws and thus the distances between the MF and the coronoid notch, the inferior border of the mandible, the anterior border of the ramus, and the posterior border of the ramus are greater in males compared to females.

CONCLUSION

In both genders and on both the sides, the maximum and minimum distances were measured between the MF and the lower border of the mandible and the posterior border of the ramus, respectively. The distance between the MF and the inferior border of the mandible was almost 2.5 times of that from the MF to the coronoid notch. The distance of the MF from the anterior border of the ramus was twice its distance from the posterior border of the ramus. In the vertical dimension (from the coronoid notch to the inferior border of the mandible), the MF was located in the superior third of the ramus, and in the horizontal dimension (from the anterior border to the posterior border of the ramus) the MF was located at the border of the posterior third and the middle third. Therefore, in the Iranian population, during osteotomy procedures of the ramus, the safety zone is located in the anterior third of the ramus in the horizontal dimension and in the middle and lower third of the ramus in the vertical dimension. Males have bigger jaws than females and the distances between the MF and the coronoid notch, the inferior border of the mandible, the anterior border of the ramus, and the posterior border of the ramus were greater in males than in females. There was no significant difference in the anatomic landmarks between the right and left sides and different age groups.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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