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RESEARCH ARTICLE

ANATOMICAL PATTERN COURSE OF MANDIBULAR CANAL AND ITS FORAMINA LOCATION ON SAMPLE OF YEMENI PATIENTS USING CONE BEAM COMPUTED TOMOGRAPHY

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Abstract

Background and aim: Failure of inferior dental anesthesia, increased sensorineural disturbances, and postoperative bleeding in the mandibular canal region has amplified the demand for preoperative planning and appropriate evaluation to prevent these complications. The aim of the study was to reveal the locations and anatomical course pattern of the mandibular canal, as well as the cross-sectional diameter and positions of the mandibular and mental foramina, between samples of Yemeni patients.

Material and methods: A retrospective descriptive cross sectional study was performed to evaluate 165 CBCT images taken from the archives of Diagnostic Radiology Centers in Sana'a City, using EZ3D plus software. Data were retrieved from February 2017 to January 2021. Recorded data were collected, tabulated and statistically analyzed by SPSS (version 24).

Results: The mean diameter of the mandibular foramen vertical and horizontal were measured to be 4.15±0.84 mm and 3.46±0.71 mm, respectively. The mandibular foramen was located approximately 2.87 mm above the midpoint of vertical ramus and 3.0 mm behind the midpoint horizontally. The mean diameters of the vertical and horizontal mental foramen were measured to be 3.46±0.78 mm, 3.54±1.5 mm, respectively. The mental foramen was located approximately in the middle of the mandibular body vertically. The most common anteroposterior position for the mental foramen was A (HP3) between the first and second premolars of the mandible (50.6%). The most common superior- inferior position for the mental foramen was (VP3) below the level of the root apices of the first and second mandibular premolars (62.2%). The inferio-superior position of the mandibular canal showed that the superior measurements ranged from 12.3-14.4 mm.

Conclusions: This CBCT study reveals differences in the position of the mandibular canal course and the location of the mandibular and mental foramina among Yemeni patients. Therefore, careful evaluation and planning using cone-beam CT before any surgical intervention in the mandibular canal area is highly recommended to avoid unwanted complications among Yemeni patients.

Keywords: Cone Beam Computed Tomography (CBCT), foramina location, mandibular canal, Sana'a, Yemen.

INTRODUCTION

It is accepted that prior to any mandibular surgery, the most important concern is to determine the trajectory of the mandibular canal and the location of the foramina. Because the diameter and location of the mandibular, the mental foramina, and the course of the mandibular canal vary with the age, sex, ancestry, and dental condition of individuals from different populations throughout the world. Therefore, increasing awareness among dentists about the existence of these differences, and improving knowledge of these vital anatomical structures and their variations makes it imperative for surgeons and dentists to plan carefully before any mandibular surgical procedures in terms of aiding in diagnosis, treatment planning, and preventing or minimizing complications during and after surgery[1].

In the past few decades, the trajectory of the mandibular canal and the location of the foramina have been evaluated using various imaging modalities, ranging from intraoral and extra-oral radiography to computed tomography (CT). It was found that each imaging method has advantages and disadvantages[2]. In recent times, additional practitioners are retracing the mandibular canal using CBCT images. This method, which uses only 3-5% of the radiation dose of conventional CT, may reduce iatrogenic injury to the neurovascular bundle, thus avoiding (sedation, paresthesia, hyperalgesia, hypoest-hesia, allogenic pain and dysesthesia) and bleeding in the lower lip, buccal gingiva, chin and tooth[2,3].

The inferior alveolar nerve (IAN) is located 4-11 mm inferior to the mandibular edge surface, but in 5% of cases the distance was 1-4 mm. Not only does the injury cause uncomfortable sensations, but it can affect the ability to speak and chew successfully. Injury to IAN causes impaired sensation and pain in the area innervated by nerves, for example, it may lead to constant pain in the lower face (hyperalgesia, neuralgia) and social suffering. Some patients complain of strange sensations (painful pain, dysesthesia, paresthesia) when touching the lower lip area. Additionally, injury to related blood vessels (e.g., inferior alveolar or lingual arteries) may result in excessive bleeding[4]. Injury to these essential structures also results from surgical errors and failure to locate these structures[5]. Many surgeries in the lower part of the mandible may injure the inferior alveolar nerve as may be the case near the roots of the third molar. Additionally, more than a few retrospective studies have reported an occurrence of 80% to 100% of sensory neurological disturbances as soon as after bilateral sagittal split osteotomy (BSSO)[6]. Injection of local anesthesia into the inferior alveolar nerve is also a potential factor for nerve damage and repositioning and manipulation of the inferior alveolar nerve during placement of endosseous implants in the posterior mandible is another risk of nerve injury. In recent decades, intraosseous implants have been widely used in dentistry. Although many factors influence the outcome of treatment, careful preoperative assessment of the bony support in the jaw and the precise location of vital anatomical structures are among the most important success factors for dental implants[7]. The knowledge and attitude of Yemeni dentists toward the use of CBCT is still not enough[8].

Although previous research has been conducted on dental caries, oral and facial abscesses of odontogenic origin, localized aggressive gingivitis (LAP), periodontitis, bacterial and fungal oral infections, interleukin-1 levels in human gingival sulcus, prevalence and association of the maxillary sinus septum with sex and location in the maxillary among adults, factor analysis and pattern of permanent tooth extraction, effect of removable dentures on aerobic bacterial colonization, and clinical effects of platelet-rich fibrin (prf) after surgical extraction of impacted lower third molars[9-21], there is no information regarding the locations and anatomical course pattern of the mandibular canal, as well as the cross-sectional diameter and positions of the mandibular and mental foramina, among Yemeni patients. Therefore, this study was carried out determine the locations and anatomical course pattern of the mandibular canal, as well as the cross-sectional diameter and positions of the mandibular and mental foramina, among a sample of Yemeni patients.

SUBJECTS AND METHODS

The sample of this cross-sectional study was accomplished from the CBCT scans of subjects referred to the Department of Oral and Maxillo-Facial Surgery, Faculty of Dentistry, Sana'a University Sana'a, Yemen, between February 2017 and January 2021(this time capsule was chosen due to the availability of CBCT scans in good condition with good archiving). The CBCT scans done by Al-Waleed, Al-mammon, and Mass radiology center, Sana'a city. Thousand and six hundred CBCT images were screened for eligibility. To be included in the study, CBCT images should have high diagnostic quality with proper fields of view (FOV) covering mandibular MF &MnF, MC, anterior, posterior, superior, inferior ramus borders, alveolar crest and base of mandible, on both sides.

The images illustrate any pathology in the mandibular canal or mandibular and mental foramina (MnF & MF) area were excluded. The exclusion criteria also involved images that pertained to subjects with missing mandibular permanent premolars and molars, and those who had a history of previous surgery or implant placement in the region of premolars and molars. From the pool of 1600 CBCT images evaluated, 100 scans, totaling 165 sides, met the inclusion criteria of the study. These pertained to 46 males and 54 females with a mean age of 22.6±8.04 years (age range: 15-50 years).

CBCT imaging: The images were reformatted using Ez3D plus software from Vatech comp, Korea. The Ez3D plus software allows viewing of axial, coronal, panoramic and 3D visualization of the jaw on the same screen. The Ez3D plus workstation is most notable for its three-dimensional renderings. This workstation is capable of displaying an entire volume of data from a large number of angles. It therefore allows the operator to define the picture elements that make up the osseous structures. In the 3D visualization, the jaw can be turned in space, rotated or spun 360 degrees and viewed from any angle. The vital structures such as the inferior alveolar nerve canal can be colored and displayed through the bone as if the bone were transparent. The measurements were done by one experienced oral and maxillofacial radiologist in a darkened room. The adjustment in density and contrast of the images was made if necessary for better assessment and measurement procedures.

Statistical method: Descriptive statistics were used to indicate the locations and vertical and horizontal length of the mandibular and mental foramina, the unilateral *versus* bilateral course of mandibular canal, the superior-inferior and buccolingual course direction of the mandibular canal and the location of mandibular and mental foramina. The chi-square test was employed to detect the difference in the course pattern of mandibular canal and the difference in the location of the mandibular and mental foramina between genders.

Ethical approval: Ethical approval was obtained from the Medical Ethics Committee of the Faculty of Dentistry, Sana'a University that dated January 21-2022 with official number 2022-28. All data, including patient identification and CBCT images were kept confidential.

RESULTS AND DISCUSSION

Vertical diameter of the mandibular foramen: This was measured with a mean vertical diameter (D1) of 4.2 mm (Table 2). This value was lower than that reported in another study conducted among the Turkish population, which was 8.3 mm[22]. The MnF vertical diameter of the right side and the left side of the mandible was measured and the results of the statistical test showed that no significant difference was found between the two sides at (p=0.507) (Table 3) indicating symmetry of both sides.

Horizontal diameter of the mandibular foramen: For the horizontal diameter of the the mandibular foramen in the Yemeni population. This was measured with a mean horizontal diameter (D2) of 3.5 mm (Table 2). This value was lower than those reported by other studies, 7.02 mm by Aglarci, Gungor *et al.*,[22] in Turkey and 5.8 mm by Rezaei *et al.*,[23] in Iran. The MnF horizontal diameter of the right side and the left side of the mandible were measured and the results of the statistical test showed that no significant difference was found between the two sides at (p=0.957) (Table 4) indicating symmetry of both sides.

Table 1: Descriptive statistics of the study groups (age and sex) (N=165).

Characteristic		No. of patients	No. of sample specimens (Right and left) (%)
Gender	Males	46	69 (41.8 %)
	Females	54	98 (58.2 %)
Total		100	165 (100 %)
Age (years), Mean±SD=22.6±6.8			
15–20 group		51	106 (64.2 %)
21 – 30 group		20	30 (18.2 %)
31 – 40 group		19	19 (11.5 %)
41 – 50 group		10	10 (6.1 %)
Total		100	165 (100 %)

Location of the mandibular foramen: To determine the position of the mandibular foramen relative to five referral points, namely, the anterior (D3), posterior (D4), superior (D5), inferior border (D6) and ramus borders and inferior tangent with extension of the occlusal plan (D7) from measurements of the mandibular posterior molars respectively, in Yemeni population and measured as follows: first, the mean distance from the anterior aspect of the MnF to the anterior border of the ramus (D3) was 15.72 (3.2) mm (Table 2). This value was close to a similar study in Egypt (16.9 mm)[24], but was lower according to other studies conducted in other countries (17.4 mm) in South India[25], (17.5 mm) in Brazil[26], (17.5 mm) in Pakistan[27], (17.7 mm) in Jordan[28], (20.1 mm). In Tanzania[29], (24.87 mm) in Ethiopia[30]. However, it was larger than 15.0 mm[23] in Turkey. These differences may be explained by ethnic differences, craniofacial growth patterns, anatomical variance, genetic factors, environmental factors, and the distinct methodologies used in these investigations. The mean (D3) was measured for the right and left side of the mandible and the results of the statistical test showed no significant difference between the two sides at (p=0.365) and gender at (p=0.350) (Table 4). This result is consistent with the results of a similar study in Egypt[24]. In addition, the mean distance from the posterior aspect of the MnF to the posterior border of the ramus (D4) was 13.01 mm. This value was very similar to the results for 12.3 mm by Abu Zaid and Hashim *et al.*,[24], 12.6 mm from Rosa and Fabian[29], 12.9 mm from Al-Shayyab[28], 12.6 mm from Ansari and Ahmed[27], and 12.6 mm from Aglarci, Gungor *et al.*,[22]. However, it was smaller than the values of the others' study (15.2 mm)[26] and larger than the 7.97 mm of Rezaei, Imani *et al.*,[23], and 10.4 mm by Shalini, Ravi Varman *et al.*,[25]. Also, the mean distance from the superior aspect of MnF to the superior border of the ramus (D5) was 16.3 mm (Table 2). This is consistent with the data reported in other studies (17.2 mm)[26], (17.6 mm)[22] and (17.7 mm)[23]. However, it was smaller than the values obtained from other studies (21.8 mm) [30], (19.3 mm)[28], (21.9 mm)[25], (21.5 mm)[29] and (21.2 mm)[31], and larger than the values of 15.8 mm[24]. Fourthly, the mean distance from the inferior aspect of MnF to the inferior border of the ramus (D6) was 26.7 mm (Table 2). This value was close to (26.6mm)[29], and (27.7 mm)[31]. However, it was smaller than (28.8 mm)[23], (29.4 mm)[24], and larger than (20.1 mm)[30], (22.3 mm)[25], (24.5 mm)[22] and (25.7 mm)[28].

Vertical diameter of the mental foramen: To determine the mental foramen vertical diameter in the Yemeni population and this was measured to have a vertical diameter (D8) of 3.5 mm (Table 2) which is closely to the values reported as 3.9 mm[32], 3.3 mm[22], and (3.2) mm[33]. While it was larger than the values as 2.4 mm[34], 2.4 mm[35], and 2.9 mm[36] and smaller than the 5.7 mm reported by Souaga *et al*.,[37].

Table 2: Locations and anatomical course pattern of the mandibular canal, as well as the cross-sectional diameter and positions of the mandibular and mental foramina, among a sample of Yemeni patients.

Reading	Mean (mm)	SD	N	Skewness	Kurtosis
Distance from MF and MnF to specific points and V and H diameter of MF and MnF					
D1	4.15	0.8	165	0.7	0.3
D2	3.46	0.7	165	0.4	-0.4-
D3	15.18	3.2	165	4.6	5.2
D4	13.01	2.6	165	0.5	0.8
D5	16.27	3.5	165	0.06	1.1
D6	26.39	4.1	165	1.2	5.49
D7	2.89	2.1	165	2.2	4.7
D8	3.5	0.8	165	0.510	0.846
D9	3.5	1.5	165	9.105	103.500
D10	12.9	2.5	165	0.229	-0.395
D11	12.4	1.6	165	0.833	1.739
Distance from MC to Buccal, Lingual, Inferior and Superior cortical borders of mandible respectively, at R1					
R1B	5.6	1.9	165	0.4	-0.4
R1L	4.1	1.3	165	0.4	-0.2
R1I	6.3	1.1	165	0.8	0.9
R1C	14.3	2.6	165	0.1	0.7
Distance from MC to Buccal, Lingual, Inferior and Superior cortical borders of mandible respectively, at R2					
R2B	5.56	1.9	165	0.9	1.1
R2L	4.67	1.2	165	0.2	0.2
R2I	6.13	1.4	165	0.9	1.4
R2C	15.52	2.7	165	-0.6	1.1
Distance from MC to Buccal, Lingual, Inferior and Superior cortical borders of mandible respectively, at R3					
R3B	6.7	2.0	165	0.4	-0.6
R3L	3.2	1.1	165	1.2	2.2
R3I	8.3	1.8	165	2.3	3.1
R3C	13.9	2.7	165	-1.3	2.5
Distance from MC to Buccal, Lingual, Inferior and Superior cortical borders of mandible respectively, at R4					
R4B	7.9	4.2	165	7.9	4.6
R4L	2.4	1.2	165	0.9	1.7
R4I	10.4	1.8	165	0.8	0.5
R4C	12.3	3.1	165	-0.4	2.6

MnF=Mandibular foramen, MF=Mental Foramen, H=Horizontal, V=Vertical, MC=Mandibular Canal, R1=location of the mandibular canal at the distal aspect of second molar, R2=location of the mandibular canal 10 mm away from R1 misally, R3=location of the mandibular canal 10 mm away from R2 misally, R4=location of the mandibular canal 10 mm away from R3 misally

Horizontal diameter of the mental foramen: Considering the horizontal diameter of the mental foramen in the D9 Yemeni population, it was 3.5 mm (Table 2). This value is approximately similar to 3.9 mm[38], and about 3.2 mm[32], while it was larger than that reported by Udhaya, Saraladevi *et al.*,[29] (2.9 mm), and smaller than those reported by Zhang[32] 5.1 mm.

Location of the mental foramen in relation to the superior and inferior borders of the mandible: Considering the position of the mental foramen in relation to the superior (D10) and inferior (D11) borders of the mandibular body, in the Yemeni population, they were measured to be 12.9 mm (D10) and 12.4 mm for D11 (Table 2). These obtained values were closer to those reported elsewhere, 13.4 mm[34], 13.6 mm[33], and 13.0 mm[35]. But they are smaller than 14.0 mm[22], 16.2 mm[37], and slightly larger than12.2 mm[36], and 11.8 mm[32].

Horizontal location of the MF in relation to the lower teeth: Considering, the anterior-posterior position of the MF in relation to lower teeth in the Yemeni population. The most frequent horizontal location of the MF was a (HP3=46.6 %) between the 1st and 2nd premolars of the mandible (Table 3). These values are closely to the values reported by Zmyslowska-Polakowska *et al.*,[39] using CBCT methods in the Polish population. This value agrees with a similar study using CBCT method[40] in Turkish population.

Vertical location of the mental foramen in relation to the root apices of the lower premolars: To localize the superior-inferior position of the MF in relation to the root apices of the lower premolars among Yemeni population, the most frequent vertical location of the MF was VP3=62.5%) below the root apices of the lower premolars (Table 3). The second most frequent position of the MF found in the current study patients was VP2 (26.1%) at the level of the root apices of the lower premolar teeth; followed by the VP1 (11.4%) above the root apices of the lower premolars. These results were similar to those obtained by Sekerci *et al.*,[41] using CT scan methods in the Turkish population and by Alam *et al.*,[42] using CBCT methods in the Arabic population (Saudi, Jordanian, and Egyptian).

Table 3: Comparison frequency and percentage of the horizontal (anterior-posterior) location of the MF on the right and left side.

Horizontal position	Right side N (%)	Left side N (%)	Mean difference	*p* value
HP 1	0 (0%)	0 (0%)	0-0%	0.008
HP 2	4 (4.5%)	2 (2.6%)	4.5-2.6%	
HP 3	41 (46.6%)	39 (50.6%)	46-50%	
HP 4	32 (36.4%)	24 (31.2%)	36-31%	
HP 5	10 (11.4%)	11 (14.3%)	11-14%	
HP 6	1 (1.1%)	1 (1.3%)	1.1-1.3%	
Comparison frequency and percentage of the vertical (Superior-Inferior) location of the MF on the right and left side				
VP 1	10 (11.4%)	13 (16.9%)	11-16%	
VP 2	23 (26.1%)	17 (22.1%)	26-22%	0.507
VP 3	55 (62.5%)	47 (61%)	62-61%	

Based on the obtained findings, is of importance to endodontists can more accurately estimate the position of the MF and perform safer endodontic treatments to the lower 1st and 2nd premolars, by not passing the MF, as well as, the oral and maxillofacial surgeon should modify their surgical techniques in the region of the MF to avoid nerve injuries[43].

Course of the mandibular canal: To determine the mandibular canal course at all R's (R1-R4) locations. They were measured at four aspects, which are the buccal, lingual, inferior and superior measurements respectively.

Inferio-Superior course of the mandibular canal: In the current study, the superior measurement of the position of the mandibular canal was 14.3±2.6 mm at R1, 15.2±2.7 mm at R2, 13.9±2.7 mm at R3 and 12.3±3.1 mm at R4, while the inferior measurement was 6.3±1.1 at R1, 6.1±1.4 mm at R2, 8.3±1.8 mm at R3 and 10.4±1.8 mm at R4 (Table 2). Based on these findings, it is of importance to the oral and maxillofacial surgeons to determine the average length of dental implant in these areas in Yemini patients, with taking into account the natural loss of the alveolar bone after tooth extraction.

Table 4: Comparison of length measurements for all Ds and Rs locations on the right and left sides.

Reading	Length measurements (mm)				t-statistics (df)	*p* value
	Right mean (SD)	SD	Left mean (SD)	SD		
D1	4.10	0.8	4.19	0.9	-0.7-	0.507
D2	3.46	0.7	3.45	0.7	0.1	0.957
D3	15.17	3.4	16.35	3.5	-0.9-	0.365
D4	12.90	2.4	13.13	2.9	-0.6-	0.576
D5	16.30	3.4	16.24	3.6	0.1	0.920
D6	26.83	4.4	26.59	4.1	0.3	0.776
D7	2.96	2.3	2.80	1.7	0.5	0.605
D8	3.46	0.8	3.46	0.7	-0.1-	0.939
D9	3.47	0.6	3.63	2.1	-631-	0.530
D10	13.29	2.5	12.44	2.4	2.2	0.026
D11	12.16	1.4	12.75	1.8	-.2.3-	0.020
R1						
R1B	5.65	2.0	5.56	1.9	0.3	0.770
R1L	4.21	1.3	4.04	1.3	0.9	0.390
R1I	6.3	1.2	6.33	1.0	-0.1-	0.903
R1C	14.35	2.3	14.28	2.8	0.2	0.863
R2						
R2B	5.67	2.1	5.43	1.8	0.8	0.427
R2L	4.66	1.3	4.69	1.2	-0.2-	0.849
R2I	6.16	1.6	6.09	1.0	0.3	0.767
R2C	15.5	2.8	15.6	2.6	-0.2-	0.817
R3						
R3B	6.74	2.1	6.59	1.9	0.5	0.647
R3L	3.25	1.2	3.07	1.0	1.1	0.293
R3I	8.23	1.9	8.33	1.7	-0.4-	0.723
R3C	13.95	3.0	13.98	2.3	-0.2-	0.868
R4						
R4B	7.77	2.5	8.22	5.6	-0.7-	0.517
R4L	2.46	1.2	2.38	1.2	0.4	0.685
R4I	10.4	1.7	10.5	1.9	-0.4-	0.718
R4C	12.5	2.8	12.00	3.4	0.9	0.329

Buccolingual course of mandibular canal:
This study is believed as a benchmark study in the location of buccolingual of the mandibular canal. The data acquired from this study measured the buccal and lingual bone thicknesses of the mandibular canal in 4 different locations along the course of the canal. The acquired mean for the position of the mandibular canal were 5.6±1.9 mm (buccal) and 4.1±1.3 mm (lingual), 5.6±1.9 mm (buccal) and 4.7±1.2 mm (lingual), 6.7±2.1 mm (buccal) and 3.2±1.1 mm (lingual), 7.9±4.3 mm (buccal) and 2.4±1.2 mm (lingual) at R1, R2, R3 and D4 respectively (Table 2). From the above findings, it was noted that the mandibular canal, approximately passes through the half distance between the buccal and lingual mandibular cortex at the 1st and 2nd molar regions. These obtained findings are agreed with the results of a of Levine *et al.*,[43]**.** Also, the buccal distances increased significantly from the distal aspect of the 2nd premolar (R3) to the distal aspect of the 1st premolar (R4), while, decreased gradually from the distal aspect of the 2nd molar (R1) to become touched the lingual cortex at distal aspect of the 1st premolar (R4). It is interesting among the Yemeni population to mention that the greatest distance measurements from the MC to the buccal cortex existed at the distal aspect of the first premolar region (R4B), followed by a distal aspect of the second premolar (R3B).

Limitation of the study
In this study, only CBCT images were chosen for reasons of image quality, field-of-view size and accuracy for obtaining measurements. Hence, they were selected from the archives of Sana'a x-ray centers (Al-Walid, Al-Ma'moun, and Mass) and had been previously obtained for diagnostic purposes. Most of the archived CBCT scan images were ordered in field of view sizes of 5*5, 8*5, and 8.5*8.5 cm. The field of view size required for this study was 12*8 and 12*10 cm. For the above reasons, due to the many measurements that were ordered, the sample size of CBCT images was limited to one hundred patients (bilateral measurements - 165).

CONCLUSION

This CBCT study reveals differences in the position of the mandibular canal course and the location of the mandibular and mental foramina among Yemeni patients. Therefore, careful evaluation and planning using cone-beam CT before any surgical intervention in the lower canal area is highly recommended to avoid unwanted complications among Yemeni patients.

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AUTHOR'S CONTRIBUTION

Alkohlani FHAAS: writing original draft, methodology. **Alhadi YAA:** investigation, formal analysis, conceptualization. **Alasbahi AA:** editing, methodology. **Al-Shamahy HA:** formal analysis, supervision. All the authors approved the finished version of the manuscript.

DATA AVAILABILITY

Data will be made available on reasonable request.

CONFLICT OF INTEREST

None to declare.

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