Evaluation of mandibular foramen variations using cone beam computed tomography in Egyptian population

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Abstract

Objectives: Mandibular foramen (MF) is an anatomical landmark for inferior alveolar nerve block and many surgical procedures like sagittal split osteotomies. Sagittal split osteotomies are done to reposition the mandible in prognathism and retroganthism**.** Variations in the position of mandibular foramen and the presence of accessory mandibular foramina are the main reasons accounting for the failure rate of this technique**.** The present study will be designed to determine variations in mandibular foramen using cone beam tomography in Egyptian population. ***Method:*** 300 cone beam computed tomography (CBCT) images were grouped according to sex, and symmetry between right and left sides into two groups. Group I: males& female and group II: right & left sides. Panoramic images were reconstructed from cone beam computed tomography scans and evaluated using Blue sky software. The exact location of mandibular foramen at the two sides of the mandible was determined in relation to anterior border &posterior border of ramus, mandibular base, and mandibular notch. The recorded data will be collected, tabulated and statistically analyzed by SPSS (Statistical Package for Social Sciences)**.** ***Results:*** This study showed bilateral asymmetry between right and left sides, no significant difference between 2 sides of the mandible. There was high significant difference in the distance from MF to mandibular base between males and females. No significant difference in other parameters relative to vertical and horizontal dimensions of mandibular ramus. ***Conclusions:*** All parameters related to the position of mandibular foramen in vertical and horizontal dimensions of mandibular ramus (MF-MB, (MF-MN), (PB-MF), and (AB-MF) were symmetrical in the right and left sides. The distance from mandibular foramen to mandibular base (MF-MB) was significantly different between males and females.

Introduction:

Various anatomical landmarks are being used as surgical marks for some surgical procedures [(1)]. These anatomical landmarks that are related with mandible are significant and can be damaged during oral and maxillofacial surgical procedures like mandibular osteotomies, orthognathic surgeries, mandibular trauma management, surgeries of benign and malignant lesions, implant surgeries, pre prosthetic surgeries and also nerve damage is possible during inferior mandibular nerve block [(2)].

The morphological knowledge of the mandibular foramen (MF) is of paramount importance during the dental procedures of the lower jaw. It is an anatomical landmark for inferior alveolar nerve block (IANB) and many surgical procedures like split sagittal osteotomies. Sagittal split osteotomies are done to reposition the mandible in prognatheism and retrogantheism [3]. Mandibular foramen transmits inferior alveolar nerve and vessels and inferior alveolar nerve block technique is commonly used in dental practice and also in reconstructive surgery [4].

Detailed knowledge of variations in mandibular foramen position in relation to relevant ramus anatomical land marks and of the relationship of the structures within the inferior alveolar neurovascular bundle enable the safe and effective delivery of IAN anesthesia. The location of the Mandibular foramen is also important when planning and conducting different mandibular ramus surgeries and other surgical treatments of dentofacial deformities, mandibular fractures and tumors [5]. The mandibular foramen is often chosen as a reference point because of its stable relation with the base of the mandible in paleo-anthropological studies of the facial skeleton in different populations and for identification of the human remains [6), (7].

Inferior alveolar nerve block is a necessary and fundamental local dental anesthetic procedure [8]. The success of the procedure mainly depends on placing the needle tip close to the mandibular foramen [9]. The inferior alveolar nerve block is one of the most used techniques of anesthesia, but in the same time one that can lead to failures caused by anatomical variations.

Variations in the position of mandibular foramen and the presence of accessory mandibular foramina (AMF) are the main reasons accounting for the failure rates of this technique [9]. During surgical procedures which involve the ramus of the mandible, it is important to be familiar with the incidence and the configuration of these foramina, since complications including unexpected bleeding, parathesia and traumatic neuroma are known to occur because of trauma to the accessory canals [10]. Also the AMF can be the site for the spread of tumor cells following radiotherapy [11]. The assessment of the mandibular foramen (MF) is a key step in the correct execution of the inferior alveolar nerve block or in oral- maxillofacial surgery planning [12].

The available imaging techniques for mandibular foramen assessment include cephalometric technique, panoramic technique, multidetector computed tomographic imaging technique (MDCT) and cone beam computed tomography (CBCT). In dental practice, panoramic radiography is one of the most requested diagnostic technique, because it provides an overview of the components of the maxillary, mandibular, dental complex at relatively low cost. CBCT provides an image produced has minimal unequal magnification and distortion and produces more reliable and accurate data with low radiation dose [13].

Cone beam computed tomography is the most recent imaging technique in the maxillofacial imaging. The introduction of CBCT imaging has made a shift from a two - dimensional to a three - dimensional volumetric approach in maxillofacial imaging [14]. The advent of 3-dimensional (3D) radiographic imaging with cone beam computed tomography (CBCT) has led to a multitude of clinical applications across all dental disciplines [15]. After an initial period of slow adoption and the emergence of other CBCT manufactures, this technology has become widely accepted [16]. In addition CBCT provides high resolution images in three dimensions with low radiation dose. Accuracy of the studies evaluates anatomic structures of the maxillofacial region progress with the development of CBCT systems [17), (18]. Hence, this study will analyze the variations of mandibular foramen and the presence of accessory mandibular foramina in Egyptian persons regarding age and gender using CBCT imaging.

Methodology

This descriptive and analytical study was conducted on 300 cone beam computed tomography (CBCT) images retrieved from the outpatient clinic of the department of oral medicine, periodontology , diagnosis and oral radiology, faculty of dental medicine, boys, Cairo, Al-zahar university oral & maxillofacial radiology, El Minia university and other private radiology centers. Cone beam computed tomography (CBCT) images were collected using convenience sampling. The sample size was calculated to be 300.

Image selection and grouping:

Inclusion criteria:

- Cone beam computed tomography (CBCT) images of adult male and female patients.

- Cone beam computed tomography (CBCT) images of patients showing mandibular ramus and mandibular foramen.

Exclusion criteria:

Childern (primary & mixed dentition).

Trauma , dysplasia, prior surgery of the mandibular ramus.

No visibility of the condyle or coronoid process of the mandible.

Ramus pathology that causes alteration in the morphology of the ramus.

Poor quality image due to motion artifacts.

Osteoporosis , bone diseases affecting mandibular ramus.

Cone beam computed tomography (CBCT) images were grouped according to sex , age and symmetry between right and left sides of mandibular rami into the following groups:

Group I: according to sex.

IA: male

IB: female

Group II: according to symmetry.

IIIA: right side.

IIIB: left side.

Radiographic evaluation:

Cone beam computed tomography (CBCT) images had been taken with Kodak 9500 cone beam 3D systems with 90 Kv and 10 mA and voxel size of 0.2 mm with medium field of view. Image analysis and panoramic reconstruction were done using Blue Sky Bio software. Each cone beam computed tomography (CBCT) image was extracted from its capturing software and imported as Dicom files to image processing software (Blue Sky Bio).

Panoramic images were reconstructed from cone beam computed tomography scans with 12 mm thickness. All images were evaluated in standardized conditions e.g. room, light, and image size. The images were viewed on 14-inch LED (light emitting diode) monitor. No image enhancement was allowed. All the mandibular foramina in the right & left sides were evaluated on reconstructed panoramic images. 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.

Posterior border – mandibular foramen (PB-MF):

Distance from the mid-point of the posterior margin of mandibular foramen to the closest point in the posterior border of mandibular ramus.

Mandibular foramen – mandibular notch (MF-MN):

Distance from the most inferior point of the mandibular notch to inferior border of mandibular foramen.

Mandibular foramen – mandibular base (MF-MB):

Distance from the inferior border of mandibular foramen to mandibular base (tangent line to inferior border of mandible).

Statistical analysis: The data were collected, tabulated and statistically analyzed.

Results:

300 CBCT images of adult patients were included in the present study, 148 (49.3%) belonged to males and 152 (50.7%) belonged to females. Cone beam computed tomography (CBCT) images were grouped according to sex and symmetry between right and left sides of mandible.

Table (1): Parameters related to the exact location of mandibular foramen between males and females

	Females		Males		
	Mean (N=152)	**Standard deviation**	**Mean (N=148)**	**Standard deviation**	**P value**
MF-MB	28.32	3.52	30.59	5.16	<0.0001***

MF-MN	16.03	2.44	15.68	3.38	0.565
PB-MF	12.04	1.85	12.66	2.37	0.01*
AB-MF	16.83	2.58	17.61	2.87	0.024*

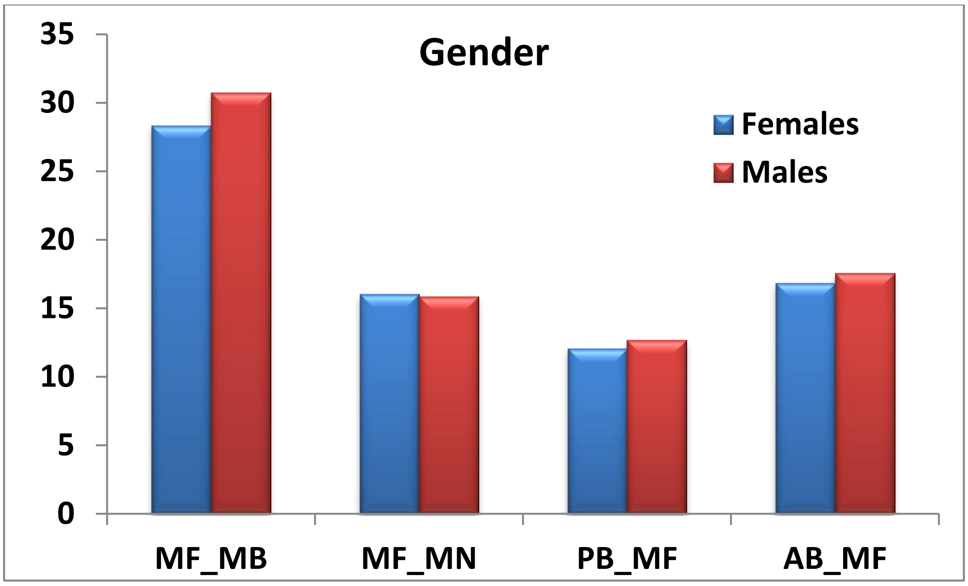

Table (1) shows parameters related to the exact location of the mandibular foramen between males and females:

Mean of (MF-MB) in females was 28.32mm±3.52 while, in males was 30.59mm±5.16.

The MF-MB shows high significant difference in females and males p value <0.0001 such that the mean value of (MF-MB) in males was greater than in females.

Mean of (MF-MN) in females was 16.03mm±2.44 while, in males was 15.76mm±3.38.

Mean of (PB-MF) in females was 12.04mm±1.85 while, in males was 12.66mm±2.37..

The PB-MF shows low significant difference in females and males as (p=0.01).

Mean of (AB-MF) in females was 16.83mm±2.58 while, in males was 17.61mm±2.87. 87.

The AB-MF shows low significant difference in females and males as (p=0.024).

Table (2): Parameters related to the exact location of mandibular foramen between right & left side

	Right side		Left side		
	Mean (N=150)	SD	Mean (N=150)	SD	P value

MF-MB	29.39	4.18	29.04	4.58	0.486
MF-MN	15.81	2.73	16.04	2.95	0.489
PB-MF	12.31	1.90	12.25	2.27	0.796

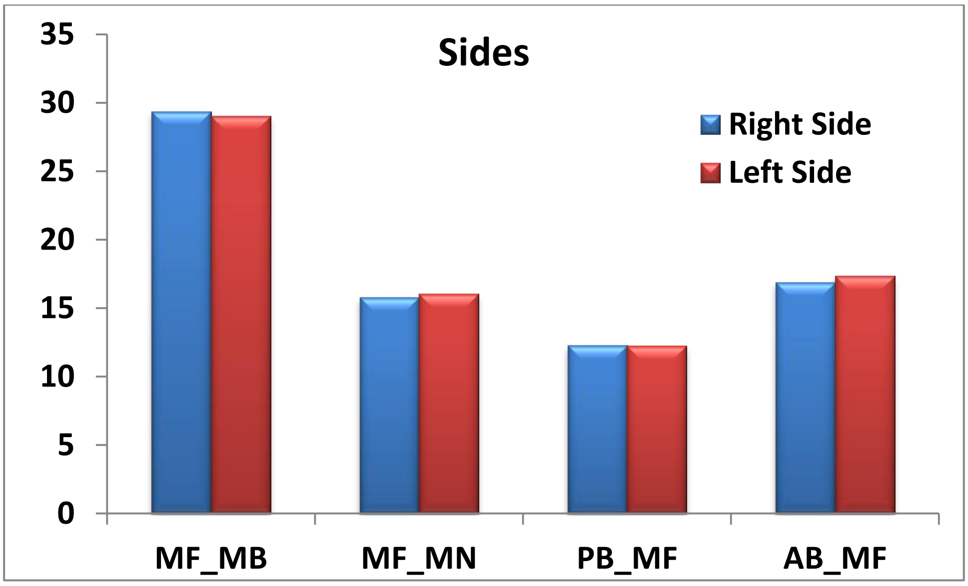

Table (2) shows parameters related to the exact location of mandibular foramen in right & left sides as follows:

Mean of (MF-MB) in right side was 29.39mm±4.18 while, in left side was 29.04mm±4.58..

Mean of (MF-MB) in right side was 15.81mm±2.73 while, in left side was 16.04mm±2.95..

Mean of (PB-MF) in right side was 12.31mm±1.90 while, in left side was 12.25mm±2.27.

Mean of (AB-MF) in right side was 16.90mm±2.53 while, in left side was 17.37mm±2.89..

All parameters show no significant difference as p value >0.05.

<u>Disscution</u>

Inferior alveolar nerve block is one of the most common nerve block technique used in dental practice. It is the most frequently used technique for local anesthesia when performing restorative and surgical procedures in the mandible. However, the approximate failure rate of this procedure has been reported to range from 20 to 25 % (19). Numerous articles describe the anatomic structures relevant to successful mandibular anesthesia, but failure still persist (20). The success of the procedure mainly depends on placing the needle tip close to the mandibular foramen. Variations in the position of the mandibular foramen and the presence of accessory mandibular foramina are the main reasons accounting for the failure rates of this technique (21).

Many authors have discussed mandibular foramen localization in relation to the success of local anesthesia in IAN desensitization. Simon et al reported that incorrect identification of the location of the Mandibular foramen due to its anatomical variations is the most common cause of failure of inferior alveolar nerve blocks . Also Thangavelu et al. reported that absence of a specific skeletal landmark and variations in height and width of mandibular ramus and position of MF are the most common causes of failure of inferior alveolar nerve block [(22)].

The location of the Mandibular foramen is essential for mandibular surgeries like sagittal split osteotomy, vertical ramus osteotomy, inverted L osteotomy and also esthetic surgeries for dentofacial deformities. Variations in the position of mandibular foramen and the presence of accessory mandibular foramina (AMF) are the main reasons accounting for the failure rates of this technique [(9)]. During surgical procedures which involve the ramus of the mandible, it is important to be familiar with the incidence and the configuration of these foramina, since complications including unexpected bleeding, parathesia and traumatic neuroma are known to occur because of trauma to the accessory canals [(10)]. Also the AMF can be the site for the spread of tumor cells following radiotherapy [(11)].

The assessment of the mandibular foramen (MF) variations is a key step in the correct execution of the inferior alveolar nerve block or in oral- maxillofacial surgery planning [(12)]. Thus, knowledge about the anatomical variations in different populations is imperative for dental clinicians. Studies on the accurate anatomical position of this landmark in different populations residing in different geographical locations are valuable. Many studies are carried out on different populations evaluating the anatomical position of mandibular foramen on CBCT images in the vertical and horizontal dimensions of ramus. ***Khan& Ansari*** (2016) evaluated MF position in Indian population [(23)]. ***Kang et al.(2013)*** analyzed the MF in Korean population[(24)]. ***Trost et al, (2010)*** published a study on France patients[(25)]. Most of studies carried out on Egyptian population focused on anatomical variations of mandibular canal and mental foramen, thus to compensate for this shortage in previous studies we aimed to assess position of mandibular foramen using CBCT in Egyptian population.

This study evaluated the position of mandibular foramen in Egyptian population using CBCT. Cone beam computed tomography is the most recent imaging technique in the maxillofacial imaging. The introduction of CBCT imaging has made a shift from a two - dimensional to a three - dimensional volumetric approach in maxillofacial imaging [(14)]. From a radiological perspective, the main advantage of CBCT is its ability to acquire 3D reconstructions of the dentomaxillofacial region with high levels of detail. When compared with multislice CT (MSCT).Cone beam computed tomography is superior than other radiographic modalities: panorama and computed tomography CT. One of significant limitations of panoramic radiography includes distortion, which is inherent in panoramic system and a relatively constant vertical magnification of approximately 10%. The horizontal magnification is approximately 20% and variable depending on the anatomical location, the position of the patient, the focus object distance, and the relative location of the rotation center of the x-ray system [(26)].

3D technology has a huge number of advantages over technologies like traditional x-ray with medical computed tomography. The main advantages of the CBCT in comparison with spiral computed tomography are the higher resolution, the significantly lower radiation burden and that artifacts, caused by metallic structures are much less disturbing. Cone beam computed tomography imaging has an incredible resolution, allowing for highly accurate imaging and measuring. This means these images can be used to pinpoint the exact location for a dental procedure [27].

CBCT machines provide isotropic voxels; equal in all three proportions as compared to voxels found in conventional CT. Although CT voxels surfaces can be as small as 0.625 mm square, their depth is usually in the order of 1-2 mm whereas, CBCT produces sub-millimeter resolution ranging from 0.4mm to as low as 0.09 mm. This sub-millimeter resolution of CBCT is precise enough for measurements in Oral & maxillofacial applications [28].

This descriptive and analytical study evaluated mandibular foramen in panoramic based on CBCT images of adult patients. Cone beam computed tomography (CBCT) images retrieved from the outpatient clinic of the department of oral medicine, periodontology , diagnosis and oral radiology, faculty of dental medicine, boys, Cairo, Al-zahar university oral & maxillofacial radiology, El Minia university and other private radiology centers in different areas in the Egypt to make a survey for all Egyptian resides. The mandibular foramina in the right and left sides were evaluated on reconstructed panoramic images. All reconstructed panoramic images were evaluated according to age, sex and symmetry of both sides of the mandible. Each cone beam computed tomography (CBCT) image was extracted from its capturing software and imported as Dicom files to image processing software (Blue Sky Bio). This processing software is one of the software programs that is capable of analyzing CBCT images imported from different CBCT machines with different softwares.

Farzad et al. (2018) evaluated CBCT images to determine the position of MF relative to the anterior and posterior borders of ramus, inferior border of the mandible and mandibular notch. ***Splendiani et. al.*** (2015) & ***Shokri et al.***(2014) also evaluated the position of mandibular foramen relative to these four references using reconstructed panorama based on CBCT images [(29), (30)].

The results of this study showed that, the mean distance from mandibular foramen to mandibular base (MF-MB) was 29.39mm in the right side and 29.04mm in the left side. These values were larger than those reported in another study by ***Sepideh Falah Kooshi et al.*** These values were 27.61mm and 27.60 mm respectively**.** In this study, the mean distance from mandibular foramen to mandibular notch (MF-MN) in the right side was 15.81mm and 16.04 mm in left side. These values were smaller than values obtained in a study done by ***Sepideh Falah Kooshi et al.*** They were 17.40mm in the right and 17.55mm in the left side. In another study carried out in indian population, this distance was 21.74mm in the right and 21.92 mm in the left side [31].

The results showed that the mean distance from posterior border of the ramus to the mandibular foramen (PB-MF) was 12.31mm in the right side and 12.25mm in the left side. These values were close to those in the Indian population (around 12mm) (231) while they were larger than values reported in a study done by ***Sepideh Falah Kooshi et al.*** in Iran population (around 7mm) and smaller than values in Zimbabwean population (around 14mm) [31].

In this study the mean distance from anterior border of the ramus to the mandibular foramen (AB-MF) was 16.90mm in the right side and 17.37 mm in the left side. Our obtained values were close to those reported in Indian population. ***Thangavelu K. et al*** found these values 17-18mm [12]. However these values these values were smaller than those measured in Zimbabwean population (around 19 mm) [32] and larger than those reported in Brazilin subpopulation. (11.8mm) [33] According to the findings in this study, no significant difference existed in the position of the mandibular foramen in the right and left sides, This finding was in agreement with the results of ***Shokri et al.,*** since they did not find any significant difference in this respect between the right and left in Hamadan city [30].

Results of this study showed that the mean distance from the mandibular foramen to mandibular base (MF-MB) was 28.32mm in females and 30.59mm in males. This means high significant difference between males and females as the distance was greater in males than in females ($p<0.0001$). These findings were similar to a study conducted in Iran population by ***Sepideh Falah Kooshi et al.*** in 2018. This study showed that the mean distance from mandibular foramen to mandibular notch (MF-MN) in females was 16.03mm and in males was 15.76 mm. This means that the distance from mandibular foramen to mandibular notch (MF-MN) was close in males to females [31]. In contrast to a study conducted on a Chilean population showed that the distance from the mandibular foramen to the mandibular notch (MF-MN) in males (24.35mm) was greater than in females (22.0mm) [34].

Obtained results showed that the mean distance from posterior border of ramus to mandibular foramen (PB-MF) in female was 12.04mm, and in males was 12.66mm. Our findings revealed low significant difference between males and females ($p=0.01$). ***Bee et al.*** indicate in their research lack of significant sexual differences of position of mandibular foramen in Brazilian population [35]. The results in this study showed that the distance from anterior border of ramus to mandibular foramen (AB-MF) was 16.83mm in females and in males was 17.61 mm. This means low significant difference between males and females. ($p=0.024$) Another study performed by ***Renato R. S. et al.*** was similar to results in our study with no significant difference between males and females [36]. While ***Sepideh Falah Kooshi et al.*** reported in a study conducted on Iran population that mean horizontal dimensions related to mandibular foramen (PB-MF) & (AB-MF) in males was significantly greater than that in females [31].

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

Conclusions

The current results showed that the position of mandibular foramen in Egyptian population was different from that in other population. All parameters related to the position of mandibular foramen in vertical and horizontal dimensions of mandibular ramus (MF-MB, (MF-MN), (PB-MF), and (AB-MF) were symmetrical in the right and left sides.

The distance from mandibular foramen to mandibular base (MF-MB) was significantly different between males and females. It was larger in males than in females. Other parameters related to position of mandibular foramen in vertical and horizontal dimensions of mandibular ramus showed low significant difference between males and females. They were nearly the same in both males and females.

Further studies are recommended to confirm the available findings of the present study and to assess changes in mandibular foramen position in children until puberty (primary, mixed, and permanent dentition). Also further studies are recommended to evaluate variations in mandibular foramen position in dentulous and edentulous mandible.

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