GENDER DETERMINATION BY ANALYSIS OF MENTAL FORAMEN USING CBCT: A RETROSPECTIVE STUDY

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Abstract

Forensic Odontology plays an important role in human identification when the information about the individual or mass population is unavailable. The main purpose of this study was to determine sexual dimorphism by CBCT (3-D) analysis of mental foramen among the population of Ahmedabad and Gandhinagar district in Gujarat. A Retrospective study was conducted using cone beam computed tomography of 120 subjects, of which 92 were included in the study with selection criteria. The average measurements from the superior and the inferior borders of the mental foramen to the lower border of the mandible (SBIBM and IBIBM respectively) were calculated in all age and gender groups. In this article, it shows bilateral dimorphism in the distance between SBIBM and IBIBM in both the gender groups, determining it as an effective tool for gender determination in radiology and forensic anthropology in any investigation or mass disaster cases.

Keywords: Forensic Odontology, Forensic Anthropology, Cone Beam Computed Tomography, Mental Foramen, Dimorphism, Gender Determination.

Introduction

"Forensic odontology can be defined as a branch of dentistry, which deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of dental findings in the interest of the justice", as stated by V. Rathod et al. [1] Forensic anthropology is the application of the science of physical or biological anthropology to the legal system. Human skeletal remains identification is the initial step in forensic investigations and is required for further analysis.[2,3] One of the most important challenges for forensic dentistry and anthropologists is the identification and determination of sex of unknown human skeletal remains, especially in totally mutilated and putrefied skeletal remains in mass disasters or criminal cases.[4] Sex determination is a subset of forensic odontology that plays an essential role in human identification when information about the deceased individual is absent.[5]

In the adult skeleton, determining a person's gender is usually the first step in the identification procedure. After then, the processes for estimating age and size are based on gender. The integrity of the remains and the level of sexual dimorphism present in the population evaluates the accuracy of sex determination.[3,6] Because sexual dimorphism varies per population, it's crucial to use data from that particular group. For many years, forensic dentistry has relied on sexual dimorphism as a technique of human identification. This method is preferable in adults due to morphological parameters in bone formation, such as growth hormones, bone alterations, and pubertal progression.[7]

When the entire adult skeleton is available for analysis, sex can be determined with 100 percent accuracy; However, in mass disasters where disintegrated bones are widespread, a 100 percent accurate gender identification is impossible and sex determination is largely dependent on the parts of the skeleton that are available.[2,3,6] In the human body, out of various skeletal remains which can guide forensic experts toward accurate identification, the strongest bone is the mandible which persists in a well-preserved state longer than any other bone.[8] Therefore, the mandible is commonly used for the identification of morphological features by anthropologists and forensic dentists in the determination of sex.[9] There is a need for population-specific standards when the skeletal characteristics vary by population.[10,11]

In the human skull, the mental foramen is found to a stable landmark on the mandible among the various anatomical landmarks.[12] According to previous research, the relative position of the mental foramen in adults can be utilized to predict sexual dimorphism and age.[7,13] These disparities might theoretically be utilized as proposed values for human forensic identification. On cone beam computed tomography (CBCT) images, some researches have sought to evaluate the effect of age and gender on the relative position of the mental foramen. New research results involving different populations and with larger sample sizes are needed to analyze the relative position of the mental foramen to determine sex determination in a specific community.[7]

Mental foramen (MF) is a small foramen usually spherical in shape and measures about 2.57 to 2.8 mm in size.[14] The foramen is a funnel-shaped orifice on the lateral surface of the mandible, near the apices of the premolars, at the termination of the mental canal which transmits mental nerves and vessels. The opening is directed outward, upward and posteriorly.[15]

In the past, forensic anthropology had radiographs as an indispensable tool. When compared to histological and biochemical approaches for age estimation and gender determination, the radiography method is the simplest and least expensive. The quality of radiographs determines the accuracy of measurements taken on them.[16] In forensic medicine, computed tomography (CT) has been employed as an auxiliary tool in the post-mortem detection of unidentified bodies in a number of investigations. In a study of Australian people, CT was utilized to estimate the age of their bodies using the third molar tooth, the medial epiphysis of the clavicle, and the spheno-occipital synchondrosis.[17] CT imaging produces multiple high-resolution pictures that allow for three-dimensional (3D) visualization and comprehensive osseous anatomical information.[18,19]

A cone beam computed tomography (CBCT) system is a relatively new CT system that focuses on the head and neck region by moving an X-ray beam and detection system around the body portion being investigated. Endodontics, orthodontics, periodontics, maxillofacial surgery, and forensic dentistry all use CBCT as their primary technique of diagnosis.[20] When compared to systems based on multi-detector computed tomography (MDCT), CBCT is a more compact and cost-effective technology that loses none of the MDCT images' reliability and accuracy.[21,22,23]

The widespread use of CBCT has spurred interest in anatomical characteristics and anatomical variations in the human mandible in recent years.[21,24,25] CBCT offers a three-dimensional assessment of the mandible, and its measurement precision is superior to that of panoramic radiography.[26] In linear measurements in the axial and coronal image planes, as well as in other parts of the maxillofacial region, CBCT is extremely accurate and reproducible.

In general, the skeletal characteristics vary by the population (ethnic/race), and there are meagre data available on the same among the population of Ahmedabad and Gandhinagar district in Gujarat. Hence, the aim of this study was to determine the gender from the analysis of the average measurements from the superior and the inferior borders of the mental foramen to the lower border of the mandible on CBCT (3D) in the population of Ahmedabad and Gandhinagar district in Gujarat.

Materials and methods:

A Retrospective study was conducted using cone beam computed tomography of patients who were reported to private CBCT centers in Ahmedabad and Gandhinagar district of Gujarat, with the age of above 18 years and below 80 years were included in the study. Cone beam computed tomography scans of 120 subjects were collected at random. No data other than name, age and sex were collected. Care was taken to restrict the subjects to the Indian population.

A) Inclusion criteria

1. Dentate or edentulous patients
2. Healthy or medically compromised patients
3. Subjects above 18 years of age and below 80 years
4. Radiographic images free of artifacts in the site of measurements.

B) Exclusion criteria

1. Patients aged less than 18 years of age because of invisibility of mental foramen due to mixed dentition
2. Patients with history of trauma, pathology to the mandible or surgical intervention in the interforaminal region
3. Syndromic patients and patients with congenital disorders
4. The reformatted CBCT images, which appear distorted or blurred due to patients' movements.
5. Presence of artifacts
6. Presence of accessory mental foramen
7. If mental foramen is not seen

C) Image analysis

CBCT scans were performed using the high-resolution imaging system by using a Kodak CS 9300 imaging machine with the following imaging protocols- field of view: 5×10 cm, voxel size: 0.18 mm, kilo voltage: 80–90 kv and milliampere: 5–10 mA. All the reconstructions and measurements were accomplished using the Carestream Imaging software [CS 3D imaging, version 3.8.7.0 (4/12/2017)] program. DICOM (Digital Imaging and Communication in Medicine) images were obtained by means of the CBCT imaging system. Patients were positioned with the occlusal plane set parallel to the floor base using a head stabilizer and a chinrest.

The same screen was used for all of the measurements. Software tools such as a linear measurement tool and a digital magnification lens were used to make measurements to the nearest 0.1 mm.

D) Tomographic measurements

Out of 120 subjects, 92 were included in the present study according to the selection criteria. The dental arch generation mode is used for the reconstruction. Axial slices parallel to the inferior border of the mandible were reconstructed on each scan. On the axial cut slice at the level of the mental foramen, a planning line was drawn along the centerline of the mandibular jaw arch.

The software automatically generated a Panorex "panoramic reconstruction" and also reconstructed cross-sectional pictures [Figure 1- 4]. The data set was used to construct these Multiplanar reformatted pictures, and the transverse section was used for identification. Following the identification of foramina, three transverse sections of each right and left side were obtained, and the best slice among the three sections was chosen in concurrence with two observers [Figures 4], and a tangent was drawn from the superior (SBMF) and inferior (IBMF) borders of the mental foramen, respectively, using the ruler software (Cs=3D) [Figures 5 and 6]. Perpendiculars were made from these two tangents to the lowest point of the mandible (highest parabolic curve) on the inferior border of mandible (IBM), and distances were recorded on both the right and left sides [Figures 7]

Figure 1: An axial scan showing planning line on center of the arch at the level of mental foramen.

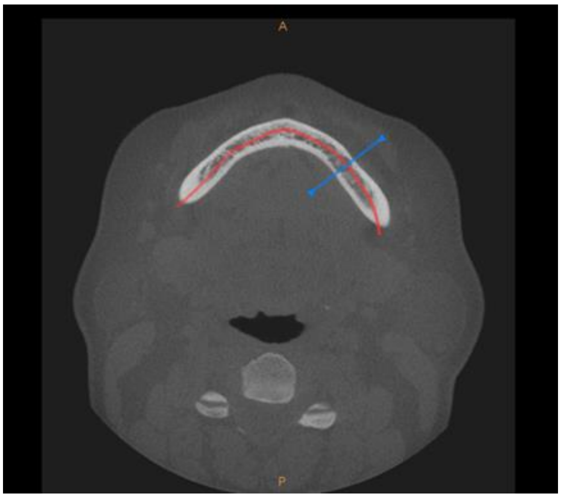


Figure 2: The reconstructed panoramic image at the level of mental foramen.

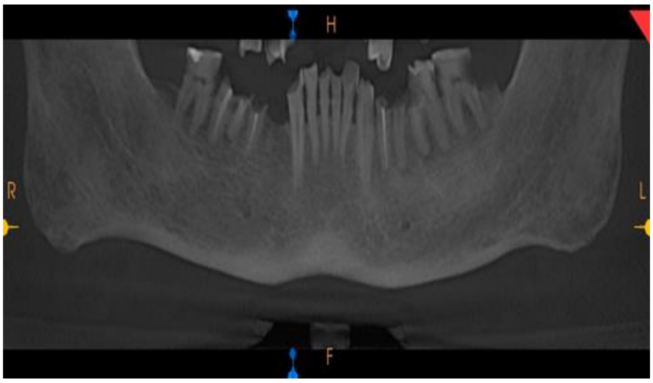


Figure 3: 3D Reconstruction of the scan.

Figure 4: Reconstructed cross-sectional image of the scan.

Figure 6: Marking the tangent on the inferior border of the mandible.

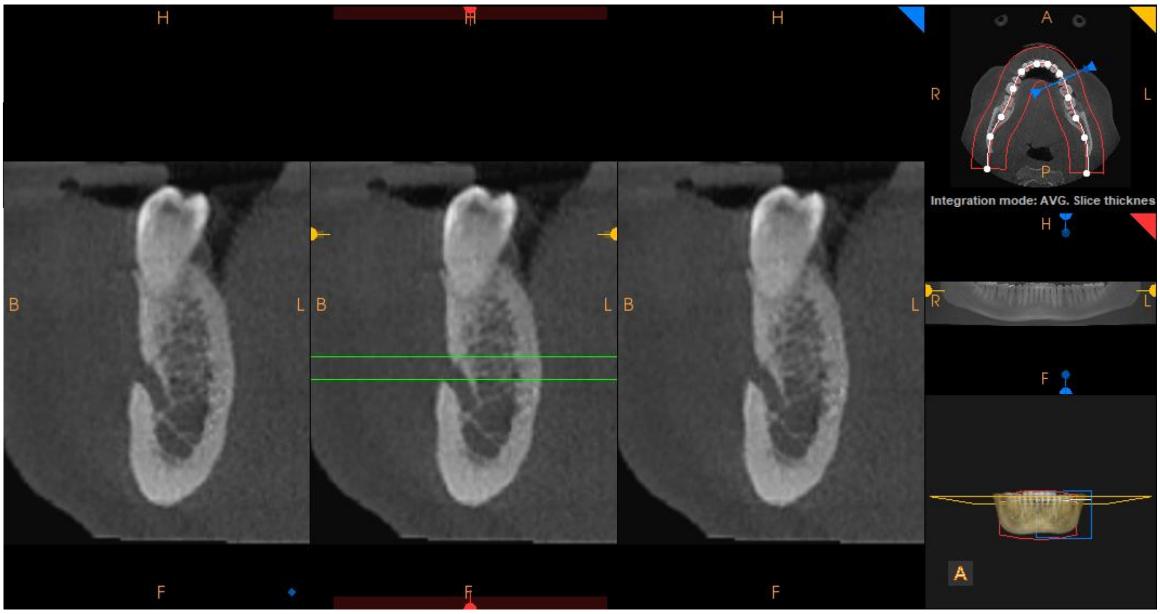
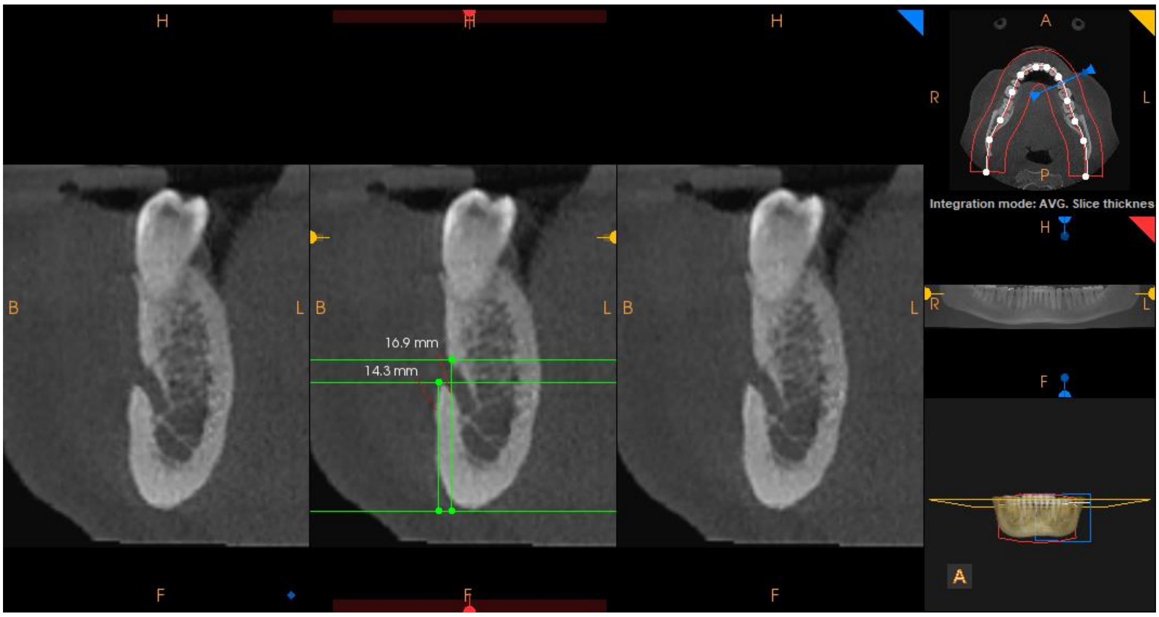


Figure 7: Measuring the superior and inferior border of mental foramen to the inferior border of mandible.



Results

All the data gathered was statistically analyzed by SPSS VERSION 20.0 software with Paired t test, Unpaired t test and One Way ANOVA with a level of significance $P \leq 0.05$.

Out of 92 study subjects, 51 were male and 41 were female subjects. Here, SBIBM is the distance from SBMF to IBM, IBIBM is the distance from IBMF to IBM, SBMF is superior border of mental foramen, IBMF if inferior border of mental foramen and IBM is inferior border of mental foramen.

Gender wise distribution on right and left side is shown in Table 1. The mean SBIBM value was high in male study subjects (16.75 ± 1.51) than female study subjects (14.84 ± 1.50). Statistically, significant difference was observed in SBIBM value between male and female study subjects on right side ($P \leq 0.05$). The mean SBIBM value was high in male study subjects (16.76 ± 1.57) than female study subjects (14.62 ± 1.54). Statistically, significant difference was observed in SBIBM value between male and female study subjects on left side ($P \leq 0.05$). The mean IBIBM value was high in male study subjects (13.71 ± 1.47) than female study subjects (12.33 ± 1.28). Statistically, significant difference was observed in IBIBM value between male and female study subjects on right side ($P \leq 0.05$). The mean IBIBM value was high in male study subjects (13.68 ± 1.67) than female study subjects (11.96 ± 1.20). Statistically, significant difference was observed in IBIBM value between male and female study subjects on left side ($P \leq 0.05$).

Table 2 shows right and left side wise distribution among male and female study subjects. In male study subjects, mean SBIBM value was 16.75 ± 1.51 on right side and 14.76 ± 1.57 on left side. Statistically, no significant difference was observed in SBIBM value between right and left side in male study subjects ($P > 0.05$). In male study subjects, mean IBIBM value was 13.71 ± 1.47 on right side and 13.68 ± 1.67 on left side. Statistically, no significant difference was observed in IBIBM value between right and left side in male study subjects ($P > 0.05$). In female study subjects, mean SBIBM value was 14.84 ± 1.50 on right side and 14.62 ± 1.54 on left side. Statistically, no significant difference was observed in SBIBM value between right and left side in female study subjects ($P > 0.05$). In female study subjects, mean IBIBM value was 12.33 ± 1.28 on right side and 11.96 ± 1.20 on left side. Statistically, no significant difference was observed in IBIBM value between right and left side in female study subjects ($P > 0.05$). In all study subjects, mean SBIBM value was 15.90 ± 1.78 on right side and 15.81 ± 1.88 on left side. Statistically, no significant difference was observed in SBIBM value between right and left side in all study subjects. In all study subjects, mean IBIBM value was 13.09 ± 1.54 on right side and 12.92 ± 1.70 on left side. Statistically, no significant difference was observed in IBIBM value between right and left side in all study subjects.

TABLE 1: GENDER WISE DISTRIBUTION ON RIGHT AND LEFT SIDE

Parameters	**Side**	**Gender**	**Number**	**Mean Value**		**P Value**
				Mean	**SD**	
SBIBM	**Right**	**Male**	51	16.75	1.51	0.000*
		Female	41	14.84	1.50	
	Left	**Male**	51	16.76	1.57	0.000*
		Female	41	14.62	1.54	
IBIBM	**Right**	**Male**	51	13.71	1.47	0.000*
		Female	41	12.33	1.28	
	Left	**Male**	51	13.68	1.67	0.000*
		Female	41	11.96	1.20	

Level of Significance P ≤ 0.05, * Significant, ** Non-Significant.

TABLE 2: RIGHT AND LEFT SIDE WISE DISTRIBUTION AMONG MALE AND FEMALE STUDY SUBJECTS

Gender	**Side**	**Side**	**Number**	**Mean Value**		**P Value**
				Mean	**SD**	
Male	**SBIBM**	**Right**	51	16.75	1.51	0.942**
		Left	51	16.76	1.57	
	IBIBM	**Right**	51	13.71	1.47	0.867**
		Left	51	13.68	1.67	
Female	**SBIBM**	**Right**	41	14.84	1.50	0.390**
		Left	41	14.62	1.54	
	IBIBM	**Right**	41	12.33	1.28	0.076**
		Left	41	11.96	1.20	
Total	**SBIBM**	**Right**	92	15.90	1.78	0.558**
		Left	92	15.81	1.88	
	IBIBM	**Right**	92	13.09	1.54	0.178**

		Left	92	12.92	1.70	

Level of Significance $P \leq 0.05$, * Significant, ** Non-Significant

Discussion:

Forensic dentistry, also known as forensic odontology, is a rapidly growing branch of forensic medicine that encompasses all dental specialties, proving to be important in the proper handling and examination of the dental evidence, as well as the proper evaluation and presentation of all dental findings for human identification. Estimating ethnicity, sex, age, and size in living or dead individuals is a crucial stage in any legal investigation. In forensic medicine, determining the sex of the remains is regarded a cornerstone because it essentially halves the possibilities of the remains. As science progresses, forensic odontology applications expand to a much greater extent. The dentist can help with difficulties such as ageing, ethnic origins, and jobs, in addition to identifying steps for whole or fragmented bodies. It has a wide range of uses, including dental age estimation, rugoscopy, bite mark analysis, lip print (cheiloscopy), craniofacial reconstruction, and gender identification.

Radiography is a fantastic tool that has evolved into an important part of modern medical practice, and it plays an important role in forensic dental decision-making. Radiographs are a simple and quick way to obtain information about both living and deceased people in a non-destructive manner; they are less expensive than DNA methods and, more importantly, they are accepted as legal evidence in the judiciary because their interpretation provides useful proof in criminal and civil jurisdictions.

The mandible is employed for sexual dimorphism since it is readily available and can withstand numerous disintegration processes. However, due to a mix of genetic and environmental variables, levels of sexual dimorphism vary per population. The mental foramen is a permanent marker on the mandible, among several anatomical landmarks in the human skull. The basal bone and mental foramen were chosen as a point of reference for the current study because of their stability.9 It is located on each side of the buccal cortex of the mandibular bone, near the apices of the premolars, and has been shown to be located exactly at the same level on most humans, with a few exceptions ranging from the mesial root of the mandibular first molar up to the canine.15 Mental Foramen (MF) is a funnel-like opening through which the mental neurovascular bundle emerges and is the exit of the mandibular canal. MF is a medically and anthropologically significant anatomical marker. It's crucial to have a good understanding of the foramen's exact location and anatomy. If the MF's common position is unknown, it may be misinterpreted as a pathosis on a radiograph. On panoramic radiographs, MF appears radiolucent, much like radiographic lesions. Knowing its exact location will assist avoid it from being mistaken as a lesion on a panoramic radiograph. The MF's identification can be tricky. There are no definitive anatomical features to use as a guide, and the foramen cannot be seen or felt clinically. As a result, many methodologies have been used in an attempt to evaluate and estimate its positioning. Macroscopic evaluation of the dry mandible, computed tomography, and dental panoramic radiography are among them.

In a panoramic radiograph, both the maxilla and the mandible are projected at the same time with a reasonably low radiation dose and the advantage of projection at a cheap cost when compared to CT scans. However, the final image is frequently magnified, resulting in loss of definition and superimposition of anatomic structures. In comparison to CT and intraoral imaging, such images have a lower diagnostic value. CBCT has been extensively used in forensic odontology, with several research findings evaluating its use in estimating age based on pulp/tooth ratio, providing data on gender differences in foramen magnum and mandibular measurements, facial reconstruction, and others, and finding it to be a remarkable innovation.12

Our analysis utilized CBCT (Kodak Cs 9500 3D imaging) where it sections all through the mental foramen, which provides us a 1:1 quantitative relation to scale back the errors that ordinarily occur in panoramic radiographs corresponding to magnification of 15%–20%, −50° angulation, and therefore the object has got to be within the focal trough. Subhash et al. in a similar study has stated that, “Correct reproducible vertical and horizontal angulations and bone density and direction of mental foramen, all play a very important role resulting in radiograph artifacts that occasionally may lead to important errors within the precise prediction of location, size, and form of the mental foramen.”4

In the present study, out of 92 study subjects, 51 were male and 41 were female subjects. The statistical analysis was done using paired t test, unpaired t test, one way ANOVA by SPSS VERSION 20.0. Banoub CA. noted in their study that, “the mean values of males are higher than females regarding the superior index of mental foramen position, inferior index of mental foramen position and ramus height.” 27 In our study, we can reflect similar results with the gender wise distribution on right and left side, which showed mean SBIBM value high in male study subjects (16.75 ± 1.51) than female study subjects (14.84 ± 1.50) on the right side and the mean SBIBM value being high in male study subjects (16.76 ± 1.57) than female study subjects (14.62 ± 1.54) on the left side (Table 1) Also, the mean IBIBM value was high in male study subjects (13.71 ± 1.47) than female study subjects (12.33 ± 1.28) on the right side and the mean IBIBM value was high in male study subjects (13.68 ± 1.67) than female study subjects (11.96 ± 1.20) on the left side (Table 1). All of this was with statistically significant difference in SBIBM and IBIBM values between male and female study subjects on right and left sides with P ≤0.05; which was in accordance with the previous studies of Subash et al. and Mahima et al.4,28

Akhilesh Chandra et al.1 concluded in his study that, “the average values of S-L and I-L were significantly higher in males than in females, while the distances for the right and left sides of an individual were almost similar in both the male and the females group, and the results were non-significant” which was in accordance with our study where the right and left side wise distribution among male study subjects (Table 2), which showed mean SBIBM value as 16.75 ± 1.51 on right side and 14.76 ± 1.57 on left side and mean IBIBM value as 13.71 ± 1.47 on right side and 13.68 ± 1.67 on left side. In female study subjects, the mean SBIBM value as 14.84 ± 1.50 on right side and 14.62 ± 1.54 on left side and the mean IBIBM value as 12.33 ± 1.28 on right side and 11.96 ± 1.20 on left side. Also, in all the study subjects, the mean SBIBM value was 15.90 ± 1.78 on right side and 15.81 ± 1.88 on left side and the mean IBIBM value was 13.09 ± 1.54 on right side and 12.92 ± 1.70 on left side. All of the above had no statistically significant difference observed in SBIBM and IBIBM values between right and left side in male, female and all study subjects with P >0.05, confirming that any side can be useful in determining gender without any significant differences in measurements.

Conclusion

There is evident bilateral dimorphism in the distance between the superior and inferior border of mental foramen to the inferior border of mandible in both the gender groups, determining it as an effective tool for gender determination in radiology.

Based on the results of our study, the distance between the superior border and inferior border of mental foramen to the lower border of the mandible (SBIBM and IBIBM respectively) exhibits strong sexual dimorphism between males and females, where males have found to be having higher distance than the latter. The bilateral measurement of SBIBM and IBIBM showed no statistically significant difference amongst both gender groups, so the distance from any side of any particular gender group can be used to determine whether an individual is male or female for forensic anthropology in any investigation or mass disaster cases. The main purpose of this research was to determine and examine the common position of the mental foramen in the adults of Ahmedabad and Gandhinagar district in Gujarat, which confirmed with the presence of sexual dimorphism in our sample. To corroborate the findings, larger study groups and a full assessment of several other factors connected to the mental foramen are yet needed.

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