Original Article

Sexual dimorphism of inferior alveolar canal location: A record- based CBCT Study in Eastern India

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Abstract

Background: Sex determination from unidentified skeletal remains a daunting task in forensic odontology. The mandible is the strongest and most durable of bones available for post-mortem profiling and its morphometric characteristics have been investigated. Less explored is the location of the mandibular canal which in a few populations has shown gender dimorphism.

Aim: The present cross-sectional study explores sexual dimorphism in an eastern Indian population of Odisha from an analysis of cone-beam CT system (CBCT) images for the relative position of the mandibular canal and its foramina.

Method and Materials: A total of 120 CBCT images from either gender (1:1 ratio) of adult dentate individuals aged 18–60 years were analysed for the relative position of the mandibular canal. Ten measurements (8- coronal and 2- from axial slices) concerning the mandibular canal; at the level of the mandibular foramen, mandibular first molar and mental foramen were performed. Unpaired Student's t-test was employed to compare variables between the sexes at $P < 0.05$ level of significance.

Results: The results revealed statistically significant differences ($P < 0.05$) between the genders in most of the variables (8/10), with higher mean values in males compared to females except in the distance between mandibular foramen and anterior border of the ramus (2.648 ± 0.67 mm in females, 2.527 ± 0.75 mm in males) and in the distance between the canal and lingual cortical plate in the region of the first molar (14.515 ± 1.33 mm in females, 14.288 ± 2.01 mm in males).

Conclusion: The relative position of the mandibular canal and its associated foramina show sexual dimorphism in an adult eastern Indian population.

Keywords: CBCT, forensic odontology, mandibular canal, mandibular foramen, mental foramen, sex determination

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INTRODUCTION

Gender determination is an important parameter in establishing identity and reconstruction of the biological profile of individuals, especially from skeletal and fragmented remains as found in mass disasters.[1] Distinct morphologic and morphometric manifestations

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of sexual dimorphism have been observed in different populations in most countries throughout the world, including the United States, China, Japan and Europe and so was determined in several reports.[2,3] Studies opine that osteometric parameters for sex diagnosis from skeletal measurements are more reliable, reproducible and less subjective compared to non-metric parameters.[4,5] Though the accuracy of predicting the gender from pelvis and skull is very high, in the fragmented skeleton and/or fractured pelvis and non-intact skull, the availability of certain craniofacial structures and especially the mandible which tends to be well preserved have a high diagnostic value in forensic identification.[6] A few studies from Egypt, Japan and Brazil have assessed sexual dimorphism using mandibular osteometric measurements and relative position of the anatomical foramina in the mandible like mandibular foramen, mental foramen (MF) and the mandibular canal (MC) directly on dry skulls/disarticulated mandible as well as indirectly by imaging techniques and found differences in their populations.[7-11]

To circumvent the pitfalls of 2-D and 3-D imaging modalities like orthopantomograms (OPG) and conventional computed tomography (CT), respectively, a fairly new cone-beam CT system (CBCT) has been advocated and widely accepted for head and neck applications.[12-14] For craniometric assessment including anthropometric landmark identification and measurements between landmarks, CBCT is both reliable and accurate.[9,15]

Amidst the scarcity of population-specific osteometric standards, a few authors have explored the presence of sexual dimorphism by undertaking morphological measurements of the mandible[6,16,17] while others have attempted to study the position of the MF in a few Indian subpopulations with varying results.[18-20] The influence of gender on the relative position of the inferior alveolar canal (IAC) at different locations has not been investigated in the Indian population except for a single study.[21] The present study, therefore, aims to analyse sexual dimorphism in an eastern Indian population by the study of IAC at different locations as visualised on CBCT images of the mandible.

MATERIALS AND METHODS

A retrospective study was performed to determine the relative position of the IAC at three different locations in the mandible to assess sex differences in our population and plausible forensic utility. CBCT images of 120 adult dentate individuals (60 males, 60 females) ranging in age from 18 to 60 years were drawn from the institutional files of Oral Medicine and Radiology by random selection. Subjects below 18 years of age or with alveolar bone resorption, developmental disturbances or pathologies, deformities or fractures of jaw bones or any disease (systemic, nutritional or endocrinal) that could affect general growth and development were excluded from the study. If mandibular teeth were missing in the region between canine to first molar or images were unacceptable, such cases were also excluded. The study received institutional ethical approval.

The CBCT scans had been done using the Hyperion X9 digital imaging system (Myray, Italy). The occlusal plane was positioned horizontally and the mid-sagittal plane was centred. The images were obtained at 70–75 kV, 8–10 mA and 11–12.3 s exposure time. The field of view (FOV) size was 11 mm × 8 mm with a 300-μm image resolution. The acquired volumes were reformatted to images of a thickness of 300 μm. The NNT Imaging Software (v4.6) Windows edition (Myray, Italy) was used. For evaluation of the CBCT scans, a 21-inch LCD monitor (HP L1910, Hewlett-Packard Development Co., Palo Alto, CA, USA) with 1,280 pixel × 1,024 was employed. The volume of the CBCT scans was sliced into three dimensions. The planes on the three axes (X, Y and Z) of the CBCT images were sequentially analysed. The sections were reformatted in the three axes to avoid discrepancies while taking the measurements. In the sagittal section, the annotations were adjusted along the long axis of the first molar and in the region of mandibular and MF accordingly. In the axial section, annotations were adjusted along the arch to capture exact measurements as per Timock *et al.*'s protocol[15] [Figure 1].

Ten measurements were sought, eight from coronal slices and two from axial slices. Sections were so chosen that

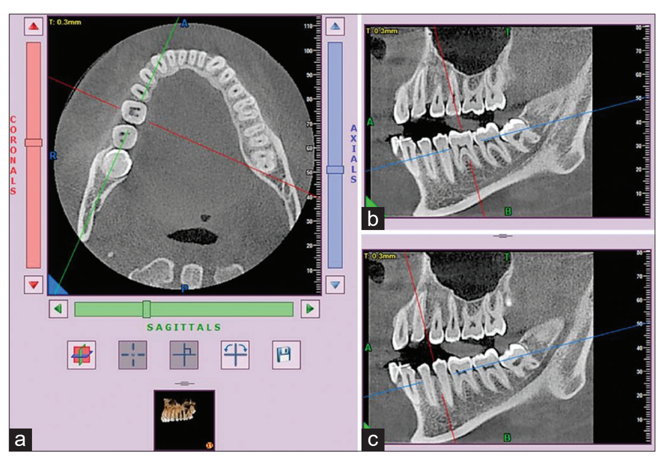

Figure 1: CBCT image slice selection and reformatting: (a) Axial image showing adjustment of annotations along the mandibular arch, (b) Coronal image showing the adjusted annotations along the long axis of the mandibular first molar, (c) Annotations adjusted along the long axis of the mental foramen

maximum diameter of the canal and foramina at the three regions (mandibular foramen, IAC at first molar area and MF) were used for assessment [Figure 2]. Two examiners (RR and SN) were calibrated to perform the evaluations. In the region of the mandibular foramen, two measurements were recorded from coronal images— SMaF and IMaF and two measurements were taken from the axial view—AMaF and PMaF. In the region of the first molar, four measurements were documented for MC from coronal CT slices, namely BMaC, LMaC, SMaC and IMaC. Two measurements in coronal slices were also taken in MF region—SMeF and IMeF. Table 1 defines the variables used for measurements. Figures 3 and 4 depict the different measurements as computed in a female and male mandible, respectively. The data were entered into a Microsoft Excel worksheet and analysed using Statistical Package for Social Sciences, IBM Corporation, SPSS Inc., Chicago, IL, USA version 18 software package (SPSS). Descriptive statistics with mean and standard deviation were computed. The mean difference and Unpaired Student's *t*-test were employed to compare study variables between genders. A $P < 0.05$ was considered significant for all statistical inferences. The inter-observer variations were not significant.

Table 1: Outcome variables and defined landmarks for respective distance measurements

Variables	
SMaF	distance from point of maximum curvature of superior border of mandibular foramen to most superior part of ramus of mandible
IMaF	distance from point of maximum curvature of inferior border of mandibular foramen to most inferior part of mandibular ramus
AMaF	distance from point of maximum curvature of anterior border of mandibular foramen to most anterior part of mandibular ramus
PMaF	distance from point of maximum curvature of posterior border of mandibular foramen to most posterior part of mandibular ramus
BMaC	distance from point of maximum curvature of mandibular canal buccally to buccal cortical plate
LMaC	distance from point of maximum curvature of mandibular canal lingually to lingual cortical plate
SMaC	distance from point of maximum curvature of mandibular canal superiorly to lingual alveolar crest ridge
IMaC	distance from point of maximum curvature of mandibular canal inferiorly to lower edge of mandible
SMeF	distance from point of maximum curvature of superior border of mental foramen to lingual alveolar crest ridge
IMeF	distance from point of maximum curvature of inferior border of mental foramen to base of mandible

RESULTS

The sample included 120 CBCT images equally divided between both genders. The mean values were compared by the analysis of mean and standard deviation for all 10 measurements in both genders [Table 2]. Generally, all the distance measurements were greater in males as compared to females except for AMaF and LMaC. There was a significant difference in most of the analyses excluding LMaC and AMaF (*P*p < 0.05). In case of six measurements— IMaF, PMaF, SMaC, IMaC, BMaC and IMeF, the gender differences were found to be very highly significant ($P < 0.001$). Thus, the overall results demonstrated that the relative position of the MC and its associated foramina demonstrate dimorphism concerning sex.

DISCUSSION

It is a known fact that males and females have different growth trajectories and differences in musculoskeletal development. Sexual dimorphism study in adults is enhanced due to hormonal and endocrinal stimulus that regulates sex differentiation.[5] The sex differentiation standards too are population-specific as different cultures exhibit different patterns of occupational stress that influence bone changes.[7]

Among craniofacial bones, the mandible is the strongest bone in the human body and is very well preserved

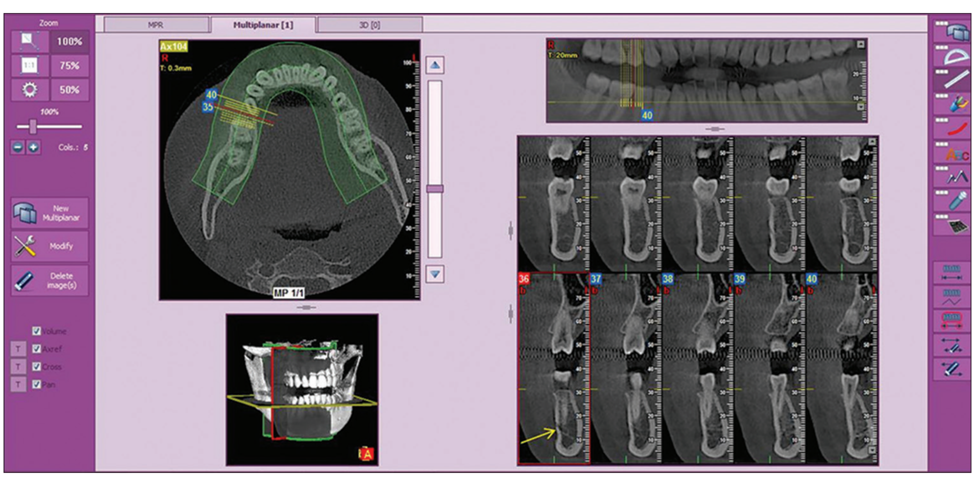

Figure 2: Diameter selection. Depicts the selection of the maximum diameter of mental foramen (yellow arrow) in the coronal slice

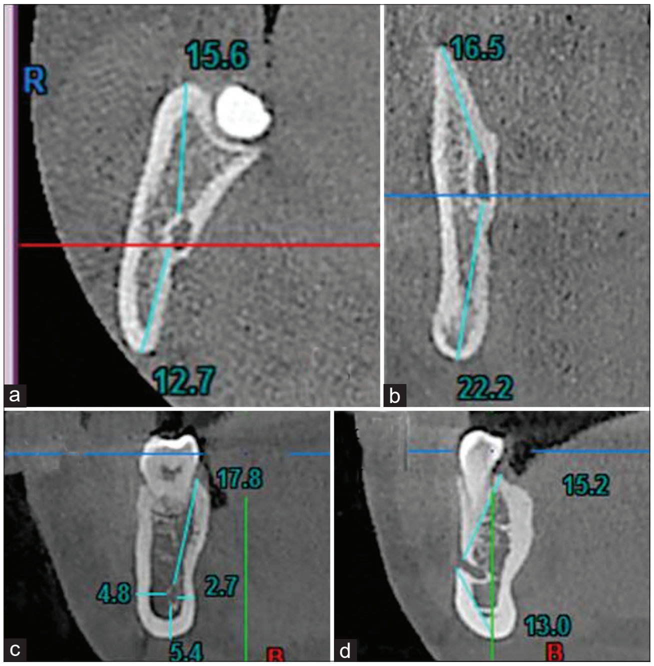

Figure 3: Inferior alveolar canal measurements in coronal and axial slices of a female mandibular CBCT image: Computed measurements from CBCT images- (a) AMaF = 15.6 mm, PMaF = 12.7 mm, (b) SMaF = 16.5 mm, IMaF = 22.2 mm, (c) SMaC = 17.8 mm, IMaC = 5.4 mm, LMaC = 2.7 mm, BMaC = 4.8 mm, (d) SMeF = 15.2 mm, IMeF = 13 mm

Table 2: Gender-wise comparison of study variables

Variable	Group	Mean	Std. Deviation	Mean Difference	*p*
SMaF	male	18.883	2.56	1.01	0.049*
	Female	17.878	2.95		
IMaF	male	22.397	1.80	2.24	<0.001*
	Female	20.155	2.78		
SMaC	male	18.532	2.27	1.87	<0.001*
	Female	16.658	2.19		
IMaC	male	8.065	1.77	1.71	<0.001*
	Female	6.362	1.06		
LMaC	male	2.527	0.75	-0.12	0.356
	Female	**2.648**	0.67		
BMaC	male	5.862	1.01	0.79	<0.001*
	Female	5.070	1.36		
SMeF	male	16.208	1.97	0.98	0.002*
	Female	15.222	1.33		
IMeF	male	14.212	2.23	2.05	<0.001*
	Female	12.162	0.86		
AMaF	male	14.288	2.01	-0.22	0.468
	Female	**14.515**	1.33		
PMaF	male	15.635	1.48	2.7883	<0.001*
	Female	12.847	1.86		

*Indicates values which are statistically significant ($P<0.05$). Values highlighted in bold, though non-significant are greater in females than in males

making it amenable for forensic investigations.[1,6] Dry skull studies on mandibles though involve unambiguous direct measurements often lack data related to age, gender or any disease process.[5,6,22]

Most studies have focused on gender dimorphism about mandibular osteometric measurements related to gonial angle/ramus/coronoid or condylar process.[7,17,23] or position of the MF on panoramic radiographs.[18,19,24,25] With the increasing utilisation of CBCT as a routine dental radiological technique in recent times, its value as an ante mortem tool rises and given its ascertained reliability in assessing mandibular parameters,[13-15] a few recent studies have investigated sexual dimorphism in the relative position of the IAC and its foramina in adults[9,10,21] using CBCT images showing either the presence of dimorphism or the lack of it.

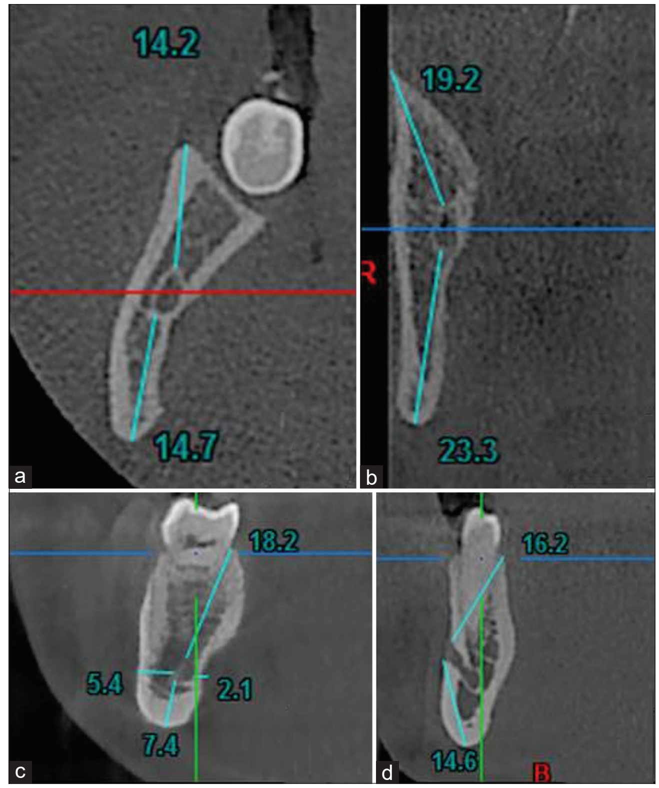

Figure 4: Canal measurements of a male mandible in the coronal and axial CBCT slices: Computed measurements from CBCT images- (a) AMaF = 14.2 mm, PMaF = 14.7 mm, (b) SMaF = 19.2 mm, IMaF = 23.3 mm, (c) SMaC = 18.2 mm, IMaC = 7.4 mm, LMaC = 2.1 mm, BMaC = 5.4 mm, (d) SMeF = 16.2 mm, IMeF = 14.6 mm

CBCT produces a cone-shaped X-ray beam that captures an image in a single shot rather than in separate slices and provides accurate 3-D visualisation of the complex maxillofacial region.[15] It overcomes the inherent limitations of panoramic radiography[8,12,14] like geometric distortion, superimposition, alteration of vertical dimension, etc., as well as that of conventional CT in providing better resolution with low radiation dose and less cost.[13,14] Hence, the present study utilised 120 CBCT images to assess sexual dimorphism in the position of the MC in an adult eastern Indian population.

It is noteworthy to mention that in the limited studies that investigated the relative position of the IAC, the points of reference taken for measurements differed. For instance, a few authors have measured the distance from the canal and MF superiorly till the alveolar crest ridge[5,10,26-28] while others have considered the occlusal plane of the mandibular first molar/premolar as the most superior point.[9,21] We selected the lingual crest ridge as the superior landmark to elude the effects of tooth attrition on measurements. Additionally, authors have variously considered the centre or bony boundary of foramina as landmarks or points along the course of the mental canal (in lieu of MF per se).[9-11] Timock[15] has cautioned against the comparison of results of different studies without knowledge of measurement protocol.

To standardise measuring parameters, the landmarks were precisely defined but a direct comparison with mean values in other studies was not consistently feasible. Broadly, the current study agrees with the outcome in other populations that showed sex differentiation.[10,11,18-21,26]

CT studies in a Taiwanese population showed significant sex differences in the position of mandibular and mental foramina.[29] In a US cadaveric study, small but significant differences were found in the position of MF in the sexes as also verified by Amorim *et al*.[26,30] In contrast, a US study by Angel *et al*.[9] using 165 CBCT images showed that the relative position of IAC remains fairly constant with age and sex. Afsar *et al*.[8] in a Canadian study found no correlation in the position of mandibular foramen with age or sex.

The mean values of most measurements in males were higher than in females in the current study except for LMaC and AMaF. The distance between the canal and lingual portion of the mandible and the anterior distance from the mandibular foramen was greater in females. In a Brazilian population study of 160 CBCT images, AMaF in females was higher as also in another CBCT study in a South Indian population.[10,21] The distances of mandibular foramen from the superior most and inferior most points on the ramus have hitherto not been investigated. We found higher mean values in males.

With regards to the relative position of IAC in the region of the first molar, our results were in partial agreement with Gamba's study[10] whose mean values for distance between the lower border of MC and base of the mandible were 9.13 mm in males and 7.34 mm in females which were marginally higher than our results (8.07 mm in males and 6.36 mm in females). The average distance of the superior aspect of IAC from the alveolar crest in Levine's CT study was 17.4 mm which was close to our values (18.53 mm in males, 16.66 mm in females) though they could not find any dimorphism related to gender.[27] However the mean distance of the canal from the lingual plate was considerably greater in Gamba's study (LMaC- 5.42 mm in males, 4.64 mm in females) in comparison to ours (2.53 and 2.65 mm in males and females, respectively) irrespective of gender. The distance of IAC from the buccal plate (BMaC- 4.1 mm in males, 4.01 mm in females) showed lower values compared to our results (5.86 mm in males and 5.07 mm in females). Levine *et al.* found BMaC to measure 4.9 mm on average and devoid of significant sex differences.[10,27] The above findings may be indicative of population-specific configurations.

There was concordance in our results of gender effect on the relative position of the MF, with a Turkish study analysing 420 CBCT images that found significantly lower values in females as compared to males.[28] Apinhasmit *et al*.[11] found that the distance between the middle of the MF and the lower edge of the mandible in dry skulls was 15.40 ± 1.73 mm in males and 13.89 ± 1.40 mm in females while the same in our study was 14.212 mm in males and 12.162 mm in females which was about 1–2 mm lower than their results as we carried out measurements from the lower border of the MF. Similarly, a Brazilian study recorded the mean value of the distance between the upper border of MF and alveolar crest as 15.7 mm in males and 14.65 mm in females and distance between the lower border of MF and base of the mandible as 15.4 mm and 13.75 mm in males and females, respectively, whilst our mean values for both distances varied by 1–2 mm, which may be attributed to racial differences.[10] The only Indian study that has exclusively evaluated the relative position of MF from 115 CBCT images with gender and side in a South Indian population found that males exhibited higher values of IMeF (13.44 mm) as compared to females (11.79 mm) considering the right side, which is asper our results.[20]

The values of IMeF in the present study agreed with other Indian studies.[18,19] though differences in the mean values per se may be due to diverse radiographic techniques (3D vs. 2D) employed but the results were in contrast to the finding of a Croatian study on dry skulls where the mean value of IMeF did not exhibit dimorphism.[5]

CONCLUSION

The results of the present CBCT study indicate that there exists sex dimorphism in the relative position of the MC and its foramina in the eastern Indian population. To overcome the limitation of a small sample size employed in the current study, future large-scale research studies with additional parameters can aid in developing a comprehensive forensic database in specific populations and enable comparison with other races/ethnicities.

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Conflicts of interest

There are no conflicts of interest.

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