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Original Research Article

Sexing of Dry Mandibles of Eastern Indian Population Using Discriminant Function Analysis

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Abstract

Introduction: At times, during an autopsy, the task becomes challenging without sufficient and robust information to properly fix the sex of the person. This study was done on archived museum sets of preserved dry mandibles of the Bengali population in the Department of Forensic Medicine of a medical college in Eastern India. **Methods**: A total of 44 mandibles were included in the study of which there were 26 males and 18 females. First, the sexing of each mandible was done based on the morphological characteristics of the bones. Then, eight (8) parameters were measured and studied in each mandible- four of them were midline data, and the rest four were bilateral data. **Results:** Standardized canonical discriminant function showed Bigonial Breadth (BGB) has the most explanatory power & the best predictor of sex. Discriminating Function equation and the sectioning point (Zo) was calculated using the Xavier formula. In the present study, the discriminant Function Analysis and equation obtained there of mandibles were correctly sexed with accuracy. **Conclusion:** Thus, it has been proved that morphometric data of mandibles can be used with precision to determine the sex of unknown samples.

1. Introduction

The largest and sturdiest lower jaw bone in the face is the mandible. It provides attachment to the mastication muscles and has lower teeth. Its body is anteriorly curled and posteriorly united by two rami. The mandibular teeth are supported by the body of the jaw within the alveolar process. The coronoid and condylar processes are located on the rami. The temporomandibular joint is created by the articulation of each condylar process with the nearby temporal bone of the skull. [1,2] Identification of human skeletal remains is a serious issue and crucial to anthropological and medical research.[3]

Age and sex can be determined by looking

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close to the skull and pelvis in human remains. The mandible's morphometric analysis and its relationship to gender play an important part in anthropological diagnosis. Due to its thick covering of compact bone and its ability to keep its shape and contour, the mandible is a sturdy component of the skull. The morphological features of the mandible aid in determining sex because they are subjective and frequently unclear. On average, female bones are weaker and smaller than male bones. Various lifestyles and chewing habits might affect how the mandible is shaped. The objective data provided by morphometric characteristics makes sex determination more precise and preferred.

The sex of skull bones can be determined using more precise methods based on osteometric measures. Discriminant function analysis can produce accurate results.[4-11] Several reference works of literature are devoted to mandibular morphological anatomy-based sexual polymorphism, race, and age transformations.[12-19]

Most of the parameters in Indian mandibles differ markedly from other ethnic groups. Such a racial variation is expected to exist because of the genetic makeup and social habits of different races. Numerous studies have demonstrated that skeletal characteristics vary by population-specific standards for sex determination. The present study was done to examine information about mandibular eight morphometric parameters in the Eastern Indian Bengali population to derive discriminant factors to determine the sex of the mandible. This study will be helpful not only for Forensic Medicine experts in medico-legal works, but also for Anatomists, Anthropologists, and Dental surgeons. The research study approval was taken from the Institutional Ethical committee. [Ref no: IEC-CNMC/2022/26].

2. Methodology:

All the preserved dry mandibles in the museum of the Department of Forensic Medicine of two medical colleges in Eastern India were used in this study. Mandibles with visible evidence of Fracture, Congenital deformity, and other damages or loss of bone tissue from any place were excluded from the study.

At first, the sexing of each mandible was done based on the morphological characteristics of the bones. Male and female sex was assigned by a set of two experts examining each bone independently. In the present study, eight (8) parameters were studied in the mandible **[Figure 1]**.

1. **Bicondylar Breadth (BCB)**: The maximum perpendicular distance between the most lateral points on the two condoles.
2. **Bimental Breadth (BMB)**: The maximum axial distance between the two mental foremen.
3. **Bigonial Breadth (BGB)**: The maximum perpendicular distance between the two gonia.
4. **Coronoid Breadth (CB)**: The maximum perpendicular distance between the most lateral points on the two coronoid processes.
5. **Coronoid Height (CH)**: (both left and right) Base or lower border of the body of the mandible to the highest point of the coronoid process perpendicularly.
6. **Maximum Ramus Breadth (MxRB)**: (both left and right) Maximum antero-posterior breadth of the ramus.
7. **Minimum Ramus Breadth (MnRB)**: (both left and right) Minimum antero-posterior breadth of the ramus.
8. **Maximum Ramus Height (MRH)**: (both left and right) Direct distance from the highest point on the mandibular condyle to the gonion.

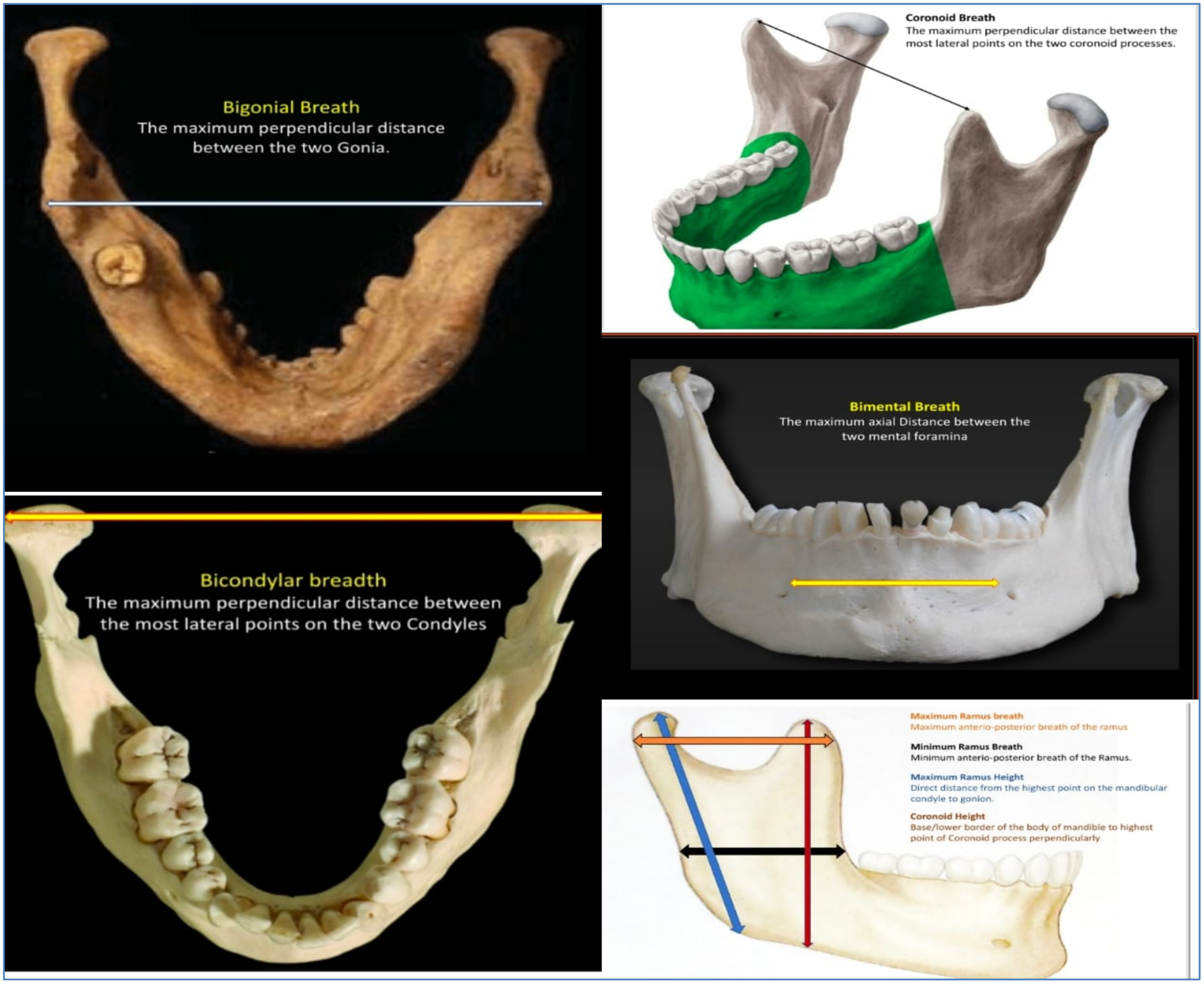
The first four parameters were singular including midline and the next four were measured on both sides of the mandible. A manual spreading caliper with fine adjustments was used. All measurements were done in centimeters and recorded to the nearest millimeter. After the measurements of all mandibles, the data were tabulated in MS Excel spreadsheet. Statistical analysis was conducted using Statistical Package for Social Sciences (SPSS) for Windows, version 29.0.1.0 (171).16. The level of statistical significance was set at $p < .05$. Firstly,

The descriptive statistics for the mandibular measurements were obtained. Then Levene's test was performed to find out the equality of variance between sexes followed by an independent student t-test to establish whether statistically significant differences existed ($p < .05$) between male and female counterparts. Then the demarking point for each variable was calculated. Then direct discriminant function analysis was done to find out the formula for sexual dimorphism.

3. Results

In this study, 44 dried mandibles were included. In three cases, there was confusion about sex initially. A third expert was involved in the examination to finalize the sex of the mandibles. Finally, 26 male (59%) and 18 female (41%) mandibles were examined. The measurements were taken by two independent observers separately and the average of them were tabulated. The descriptive statistics were compiled for midline data (BCB, BMB, BGB, CB) in **Table 1** and for bilateral data (CH, MxRB, MnRB, MRH) in **Table 2**. Levene's test for equality of variance in two groups (male and female) was performed in each set of data. The p-value of Levene's test must be <0.05 for unequal variance. In this study, the p-value of Levene's test for all eight parameters was found to be >0.05 which signifies all the parameters have equal variance.

Figure 1: Eight (8) morphometric parameters of dry mandible



Bigonial Breath
The maximum perpendicular distance between the two Gonia.

Coronoid Breath
The maximum perpendicular distance between the most lateral points on the two coronoid processes.

Bimental Breath
The maximum axial Distance between the two mental foramina

Bicondylar breadth
The maximum perpendicular distance between the most lateral points on the two Condyles

Maximum Ramus breath
Maximum anterio-posterior breath of the ramus

Minimum Ramus Breath
Minimum anterio-posterior breath of the Ramus.

Maximum Ramus Height
Direct distance from the highest point on the mandibular condyle to gonion.

Coronoid Height
Base/lower border of the body of mandible to highest point of Coronoid process perpendicularly

Table 1: Descriptive statistics of midline data measured in millimeters (n=44)

		Male	Female	Total
Bicondylar Breadth (BCB)	Max	127.6	118	127.6
	Mini	79	82.8	79
	Mean	110.65	101.25	106.80
	Median	112	105	107.45
	Standard Deviation	10.49	10.92	11.53
Bimental Breadth (BMB)	Max	49.5	51.6	51.6
	Mini	33.8	33.8	33.8
	Mean	43.66	40.98	42.57
	Median	43.3	40.7	42.6
	Standard Deviation	3.50	4.16	3.97
Bigonial Breadth (BGB)	Max	105.6	95.8	105.6
	Mini	64.9	67.3	64.9
	Mean	91.44	82.3	87.70
	Median	93.55	82.05	87.8
	Standard Deviation	8.28	7.49	9.10
Coronoid Breadth (CB)	Max	109.6	107	109.6
	Mini	63.4	70	63.4
	Mean	94.01	84.82	90.25
	Median	95.35	85.5	89.65
	Standard Deviation	9.21	9.87	10.43

Table 2: Descriptive statistics of bilateral data measured in millimeters (n=44)

		Male		Female		Total	
		Right	**Left**	**Right**	**Left**	**Right**	**Left**
Coronoid Height (CH)	Max	567	70.5	63.4	65.9	567	70.5
	Mini	31	30.7	34.6	36	31	30.7
	Mean	78.05	58.63	51.28	52.37	67.1	56.07
	Median	60.05	60.45	53.1	54	56.95	57.5
	Standard Deviation	8.39	8.61	8.31	8.37	77.64	8.97
Maximum Ramus Breadth (MxRB)	Max	42.8	42.9	40.2	40.4	42.8	42.9
	Mini	26.9	26.6	22	22.4	22	22.4
	Mean	37.45	37.1	34.71	33.95	36.33	35.81
	Median	37.75	37.35	36	35.2	37.05	36.75
	Standard Deviation	3.48	3.65	4.78	4.99	4.24	4.48
Minimum Ramus Breadth (MnRB)	Max	36.6	36.8	36.4	35.8	36.6	36.8
	Mini	25.1	25.6	19.5	20.3	19.5	20.3
	Mean	31.26	31.38	29.2	28.41	30.42	30.17
	Median	32	31.85	29.55	29.15	30.85	30.5
	Standard Deviation	3.15	2.96	4.65	3.58	3.92	3.51
Maximum Ramus Height (MRH)	Max	74.9	80	69.5	67.5	74.9	80
	Mini	38.3	36.9	39.1	39.4	38.3	36.9
	Mean	60.96	60.61	55.07	55.35	58.55	58.46
	Median	63.4	63.1	54.35	56.2	60.6	58.9
	Standard Deviation	8.18	8.80	8.14	7.38	8.59	8.56

Figure 2: Explanatory power of the variables

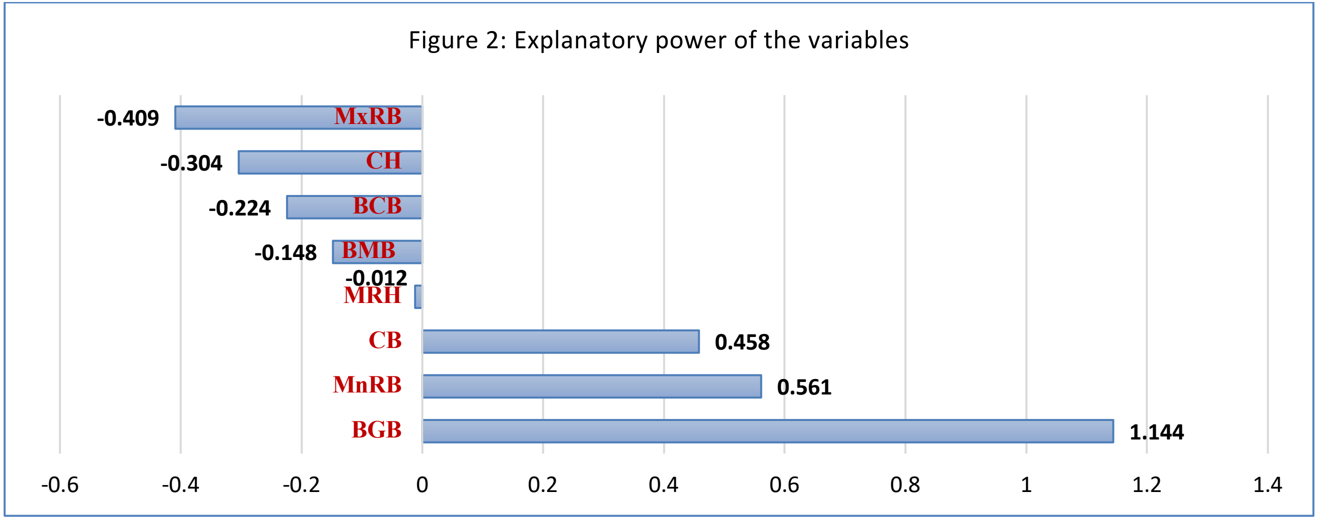
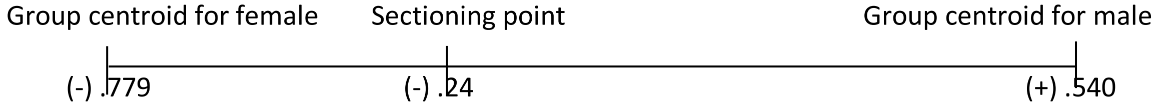


Figure-3: Group centroids for each sex and sectioning point after applying Xavier's formula



An Independent t-test for comparing the mean values (Male and female) of each parameter was then performed. The p-value of the independent t-test for all eight parameters i.e., BCB (p=.006), BMB (p=.026), BGB (p<.001), CB (p=.003), CH (p=.012), MxRB (p=.022), MnRB (p=0.20), MRH (p=0.31) were found to be statistically significant. ($p<0.05$). The discriminant function analysis was done to compare sexual dimorphism and to formulate the equations for determining the sex of the mandible. For the bilateral data, the mean value of right and left-sided measurements was obtained as a single data for calculation. The value of Wilk's Lambda was determined and observed. The value of Wilk's Lambda ranges between 0 to 1. A high value of Wilk's Lambda denotes low significance i.e., less discriminating power of the proposed model. In this study, the value was found to be .694 (df=8) which indicates the model has good discriminating power.

Standardized canonical discriminant function showed BGB has the most explanatory power with a coefficient of 1.144 and MxRB has the least explanatory power with a coefficient of (-).409 in this study. All the other six measurements have explanatory power somewhere between these two parameters **[Figure -2]**.

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions was done and structural matrix output shows BGB is the best predictor of sex with coefficient value (.869) followed by CB (.735), BCB (.668), CH (.609), MnRB (.562), MxRB (.552), BMB (.539), MRH with least coefficient value of .519.

Unstandardized coefficients were calculated to obtain the Discriminating Function equation which is given below:

$$Y = (-12.269) + BCB*(-.021) + BMB*(-.039) + BGB*(.143) + CB*(.048) + CH*(-.036) + MxRB*(-.101) + MnRB*(.165) + MRH*(-.001)$$

[where Y= Score of the Sex (Male/Female) of the mandible, Constant= (-)12.269]

Y provides the discriminant score of any mandible whose BCB, BMB, BGB, CB, CH, MxRB, MnRB, and MRH measurement is known.

This diagram (function at group centroids) shows the unstandardized canonical discriminant functions evaluated at group means. In the present study, the value of -.779 and beyond was calculated to be for females, and .540 and above value for males **[Figure- 3]**.

In the present study, the discriminant Function Analysis and equation obtained thereof show that 77.3% of mandibles were correctly sexed with accuracy. This is proven to be a good model. The Sectioning point (Z0) is calculated from the weighted mean of values at the group centroids for males and females using the formula provided by Xavier (Z0):

$$Z0 = (Zm \times Nf) + (Zf \times Nm) / (Nm+Nf)$$
$$= (0.540 \times 18) + (-0.779 \times 26) / (26+18)$$
$$= (-)0.24$$

Where Zm and Zf are the group centroids for male and female groups, Nm and Nf being the number of mandibles of males and females respectively. Any value above the sectioning point is classified as male and the values below the sectioning point are classified as female.

4. Discussion

Absolutely, the methods for determining gender, age and stature from skeletal remains can vary significantly based on the bones available and their preservation.[20,21] The dry mandible is an important source of data in identification and has been studied in different regions of India and the world with different morphological and parametric data. Eight measurements have been taken into consideration in the present study and studies done in abroad and in India with similar parameters have been compared in the following **Table 3**.

Bigonial Distance (denoted as BGB in the present study) and MRH were considered in a Brazilian study done on 66 adult skulls (34 males & and 32 females) yielded different results due to variations in ethnicity. The discriminant formula was created and sexing accuracy was found 76.47% for males & 78.13% for females which shows a similar result as in our study. It can be hypothesized that Latin American mandibles are similar in measurements to that of the Eastern Indian population (Bengali population). [29] BCB, BGB & CH were studied on 102 adult (68 males & 34 females) mandibles by Thailand researchers and all showed statistically significant differences between genders.[30] Two recent studies performed in Indian setup AP and East Asian setup Malaysia showed greater morphometric measurements in males in comparison to females.[4,19] An Iranian study done in 2014 on 45 young subjects <20 years of age showed no statistically significant difference in the mandibular anthropometric values between two genders below the age of 12 years but above 12 years showed sexual dimorphism.[24] 67% accuracy was shown in an Egyptian study done recently on child and adult mandibles (99 males & 114 females) considering ramus measurements which were found statistically significant as in the present study. [8] A recent study on the Greek population with (94 adult mandibles (105 males & 89 females)) used 20 linear and 3 angular measurements to determine sex 85.7% accurately which is higher than the present study. Another Greek study done recently on 70 adult mandibles showed a statistically significant difference between genders considering BCB, BGB & BMB, and the highest accuracy was shown 80% which is almost similar to the present study. [5,9]

Table 3: Studies with similar study parameters done worldwide

Author	Year	Region	Sample Size	Bicondylar Breadth (BCB)	Bigonial Breadth (BGB)	Bimental Breadth (BMB)	Coronoid Breadth (CB)	Coronoid Height (CH)	Maximum Ramus Breadth (MxRB)	Minimum Ramus Breadth (MnRB)	Maximum Ramus Height (MRH)
Nutcharin Ongkana et al. [22]	2009	Thailand	102 (M=68, F=34)	✓	✓			✓	✓	✓	✓
Ivan Claudio Suazo Galdames et al. [23]	2009	Brazilian	32 (M=20, F=12)	✓	✓					✓	✓
Mihai Marinescu et al. [11]	2013	Romanian	200 (M=100=F)	✓	✓						
Mitra Akhlaghi et al. [24]	2014	Iranian	45 (M=23, F=22)		✓					✓	
Elena F. Kranioti [9]	2014	Greek	70 (M=36, F=34)	✓	✓	✓					
Aspalilah Alias et al. [4]	2018	Malaysia	79 (M=48, F=31)	✓	✓			✓	✓	✓	✓
Vineeta Saini et al. [6]	2011	BHU	116 (M=92, F=24)					✓	✓	✓	✓
Vinay G. et al. [12]	2013	Bangalore & Puducherry	250 (M=175, F=75)	✓	✓						
Pokhrel and Bhatnagar [10]	2013	Pune	79 (M=53, F=26)						✓	✓	
KC Thakur et al. [25]	2013	Dehradun	60 (M=30=F)								✓
M. Punarjeevan Kumar et al. [26]	2013	Andhra Pradesh	80 (M=40, F=34, U=6)	✓	✓	✓	✓	✓	✓	✓	✓
James D. Raj et al. [18]	2013	Chennai	120 (M=60=F)							✓	
Rahul Singh et al. [14]	2015	Kanpur	50 (M=29, F=21)	✓	✓						
Anupam Datta et al. [17]	2015	Karnataka	50 (Unknown Sex)	✓	✓	✓	✓				✓
Maneesha Sharma et al. [13]	2016	Punjab & Chandigarh	120 (M=78, F=42)							✓	
J.Sarvesh Kumar et al. [15]	2016	Chennai	38 (M=25, F=13)	✓	✓		✓				
Samatha K et al. [7]	2016	Karnataka	120 (M=60=F)					✓	✓	✓	✓

B. N. V. S. Satish et al. [27]	2017	Karnataka	200 (M=100=F)	✓	✓				✓		
Najma Mobin et al. [16]	2018	Karnataka	120 (Unknown Sex)	✓	✓					✓	✓
Dr Ranjana Agrawal et al. [28]	2018	Jhansi	52 (M=29, F=23)							✓	
Dr.Praveen Vaddadi [19]	2021	Andhra Pradesh	100 (M=57, F=43)		✓			✓	✓	✓	
Present study	2023	India	22 (M=26, F=18)	✓	✓	✓	✓	✓	✓	✓	✓

Discriminant function analysis was done in a Romanian study on 200 adult mandibles with a mean age of 39 years including Bigonial Width (measured as BGB in the present study) and BCB with sexing accuracy of 84%. Most dimorphic singular measurement was found to be Bigonial Width 80.5% alone which is similar to the present study findings.[11] The measurements in males and females for different parameters are similar to the studies done in North India & South India recently.[14,15] The measurements in our study (8 parameters) showed higher value in the case of males in comparison to female samples as a whole and the difference is statistically significant proven by unpaired t-test ($p<0.05$) which is similar in studies done in different Indian set up of Chennai & Karnataka very recently. [16,17] A recent study performed in South India (Bangalore) on 250 adult mandibles (175 males & 75 females) measured BGB & BCB showed a statistically significant gender difference which is similar to the respective measurement calculated in our study. [12] A study done in North India (Chandigarh & Punjab) on 120 mandibles (93 adults, 27 old) of both sexes measured MnRB and statistically significant difference in gender difference. The accuracy of sex determination from the mandible was calculated to be 60% with the addition of 2 more parameters namely diagonal length & horizontal length. However, in our study, the accuracy of sex determination from the mandible was measured to be higher (77.3%).[13]

MxRB, MnRB & CH were analyzed in a South Indian study with discriminant function analysis and the sexual dimorphism was noted to be statistically significant as in the present study.[7] 6 dominating parameters were identified in another South Indian study in Chennai & Andhra Pradesh on 74 mandibles (40 males & 34 females) in which accuracy was found to be 75% which is comparable with the present study.[26] Two recent research articles done in the middle part of India (Madhya Pradesh) yielded statistically significant results considering MnRB in one and the other highlights important findings in the form of a systematic review that includes 36 articles of which 16 are on radiographic studies 14 out of them are on adult mandibles showing statistically significant result involving different parameters for sexing of mandibles. [28,30] Among MRH, BGB & BCB, these 3 parameters, MRH was proven to be most sexually dimorphic through a study on 200 adult mandibles (18-30 years) done in Karnataka recently.[27]

A Western Indian study showed a varied range of accuracy (69.2-89.6%) of sexing mandibles if MnRB and MxRB are considered.[10] A Northern Indian study measured ramus height at 49.4 millimeters on the right side and 48 millimeters on the left side which is comparatively shorter than the measurement in the present study.[25] Some researchers estimated sex from mandibular canine index[31] and some estimated age from radiological evaluation of maxillary third molars[32]. This study is not beyond limitation. Taking more parameters, including more samples, and performing the study over a longer period may yield better results.

5. Conclusion

Mandibles can be a good source of data for identification in a given population. Not only the intact mandible with all the teeth available in the alveolar process, but a fragmented or broken mandible can also be helpful in the identification of sex sphering the midline data as considered in this study.

This study is the first of its kind performed in eastern India (Bengali population) where discriminant function analysis has been performed for mathematically determining the sex of a dried mandible. The measurements and discriminating power are unique in this population and it is also comparable with other Indian data and that of Latin American studies. The determination of sex, thus, can be easier in the future for the identification of unknown subjects.

6. Recommendations / suggestions:

Apart from the sexing of the mandibles in forensic anthropology during investigation and postmortem examination, it is recommended to take into account the morphometric parameters in addition to the morphological attributes. India is a culturally and ethnically diverse country. A regional database can be prepared on mandible and other bones using discriminant function analysis of the morphometric parameters for future use.

Ethical Clearance: IEC approval is taken from the Institutional Ethical committee.

Contributor ship of Author: All authors equally contributed.

Conflict of interest: None to declare.

Source of funding: None to declare.

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