DOI: 10.7860/IJARS/2021/48636:2722

Original Article

Anatomy Section

Sex Determination of Dry Human Mandible Using Metrical Parameters in Mahakaushal Region of Madhya Pradesh, India: A Cross-sectional Study

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ABSTRACT

Introduction: Determination of sex and age from skeletal remains is not only important for forensic science but also for Anatomy, Forensic Odontology, Anthropology and Palaeontology examination. Mandible next to the pelvis in human remains help us in the identification of age, sex, and race.

Aim: To determine sex by using metrical parameters in dry human mandible.

Materials and Methods: This cross-sectional study contained 104 dry human mandibles of undetermined age and unknown sex (as they were not recorded at the time of acquisition) belonging to the Indian population was obtained from NSCB Medical College, Jabalpur, Madhya Pradesh, India. All adult (mandible with presence of bilateral molar teeth; prominent alveolar sockets; intact condylar and coronoid processes; well-developed bone), intact and well-formed mandible were taken and broken, deformed, pathological bones were excluded. Statistically analysed by using Statistical Package for Social Sciences (SPSS) for Windows, version 16.0.

Results: Out of the 13 parameters studied statistically highly significant difference in sex was observed in bicondylar breadth, bigonial breadth, coronoid breadth, angle of mandible, mandibular length, diagonal length and coronoid height, length of lower jaw.

Conclusion: The present study utilises the 13 different metrical parameters. The application of these 13 metrical parameters along with morphological features could be a useful tool for sex determination of the mandible.

Keywords: Bicondylar breadth, Determination of sex, Mandibular length

INTRODUCTION

Determination of sex and age from skeletal remains is not only important for forensic science but also for Anatomy, Forensic Odontology, Anthropology and Palaeontology examination. After attainment of pubertal age, sex can be more accurately determined. The differences are well marked in the bony pelvis and skull. Mandible next to the pelvis in human remains helps in the identification of age, sex, and race [1]. The accuracy of sex determination directly depends on the availability of the complete skeleton. It is 100% with a complete skeleton, 95% with pelvis and 90% with skull [2]. In most of the circumstances complete pelvis is not available in that condition skull becomes second most important source of sex determination. In skull bone mandible is most durable and second most sexual dimorphic bone [3].

Many studies have been reported on morphological feature and metrical parameter by various authors, which were done in different ethnic groups and on populations of different races, but such studies which have been reported in the in Mahakausal region are sparse. Hence, an attempt was made in the present study, to determine the sex by using human mandible in Mahakausal region, which may be useful for the future implications in Mahakausal region, Madhya Pradesh, India.

MATERIALS AND METHODS

This cross-sectional study contained 104 dry human mandibles of undetermined age and unknown sex (as they were not recorded at the time of acquisition) belonging to the Indian population was obtained from Netaji Subhash Chandra Bose Medical College, Jabalpur, Madhya Pradesh, India, study was conducted from August 2020 to January 2021. Ethical clearance is taken from the Institutional Ethical Committee (NSCB Medical College Jabalpur M.P.No.ICE/2021/1725).

Inclusion criteria: All adult (mandible with presence of bilateral molar teeth; prominent alveolar sockets; intact condylar and coronoid processes; well developed bone), intact and well-formed mandible were taken.

Exclusion criteria: Broken, deformed, pathological bones were excluded.

Sample size calculation: Based on the reported mean indices in the previous study following values were taken in the power analysis for sample size estimation:

Alpha=0.05 (95% Confidence limit)

Power (1-beta)=0.80

Delta (effect size)=4.43

Mean 1 (Male)=108.48 and SD=4.57

Mean 2 (Female)=104.05 and SD=8.87

Study Procedure

The power analysis revealed that minimum 84 study samples was required to test the study null hypothesis (H0: μ2=μ1) that no difference in mean values between sexes. Further 20% sample were added more to adjust the possible sample losses due to any reasons. Finally, minimum of 101 samples were considered in the study. The power analysis to determine the sample size was performed using R v4.0.0 for Windows (statistical computing software).

Total 13 metric parameters were measured by using vernier caliper, measuring scale and protector on both the right and left sides. Sex of mandible was identified by general size, chin shape, gonial flaring and muscular marking. The bones collected for study roughly belonged to 18-60 years of age. Following parameter were measured-

1) Bicondylar breadth; 2) Bigonial breadth; 3) Coronoid breadth; 4) Mandibular length; 5) Angle of mandible; 6) Length of lower jaw;

7) Mandibular index; 8) Diagonal length; 9) Coronoid height; 10) Bimental breadth; 11) Symphyseal height; 12) Body thickness; 13) Mandibular height.

STATISTICAL ANALYSIS

All parameters were evaluated on both sides but because there were no statistically significant differences between right and left sides, only right side measurements were included. Values were statistically analysed by using Statistical Package for Social Sciences (SPSS) for Windows, version 16.0. The mean and Standard Deviation (SD) for each parameter for male and female mandible were calculated. Sample t-test was applied and p-value of significance was determines to assess the significance of observations.

Demarking points and limiting points were obtained for the parameters that showed significance. By using mean and SD, a "calculated range" was arrived at by the formula "Mean±3SD." A calculated range for male (a and b) and for female (c and d) was obtained. From these values, the minimum in male range and the maximum in the female range were taken as "demarking points," and the limiting point was determined by known statistical standards. The demarcating point for each parameter was calculated, demarcating point is average of mean values for each sex and limiting point is an absolute value found within the range of demarcating points. The limiting point was so chosen that the huge number of male mandibles showed values greater than it and the majority of female mandibles showed values lesser than the chosen limiting point.

RESULTS

On the basis of morphological feature, the bones were categorised into male and female mandibles. The [Table/Fig-1] summarises the descriptive statistics for mandibular measurements obtained for both sex. Out of 104 mandibles, 58 were male and 46 were female. The demarcating point for each parameter was calculated demarcating point is average of mean values for each sex [Table/Fig-2].

S. No.	Variable	Male	Female	t-value	p-value	Significance
		Mean±SD	Mean±SD			
1	Bicondylar breadth (mm)	110.12±4.15	107.85±5.43	2.42	0.017	Significant
2	Coronoid breadth (mm)	93.77±3.98	90.8±6.07	3.00	0.003	Significant
3	Angle of mandible (°)	123±7.65	126.53±7.75	-2.32	0.022	Significant
4	Bigonial beadth (mm)	94.87±5.02	90.09±6.67	4.17	<0.001	Significant
5	Mandibular length (mm)	74.56±5.41	71.67±4.84	2.83	0.006	Significant
6	Length of lower jaw (mm)	64.26±4.65	61.58±5.69	2.65	0.009	Significant
7	Mandibular index (mm)	58.36±3.96	57.12±4.56	1.48	0.143	Non significant
8	Diagonal length (mm)	85.69±3.87	81.08±6.28	4.62	<0.001	Significant
9	Coronoid height (mm)	60.79±4.68	56.56±5.86	4.10	<0.001	Significant
10	Bimental breadth (mm)	44.33±2.73	44.28±3.55	0.08	0.940	Non significant
11	Symphyseal height (mm)	27.02±4.75	26.08±3.86	1.08	0.283	Non significant
12	Body thickness (mm)	11.09±1.56	11.62±1.45	-1.78	0.078	Non significant
13	Mandibular height (mm)	26.69±4.45	26.38±3.84	0.37	0.710	Non significant

[Table/Fig-1]: Showing mean, standard deviation, t value, p-value of different parameter of mandible.
Student t-test assuming unequal variances was done; p<0.05 statistically significant

Bicondylar breadth [Table/Fig-3]: The demarking point of bicondylar breadth for male was 91.58 mm [a] and 124.12 mm [b] and for female was 97.68 mm [c] and 122.55 mm [d]. Limiting point for bicondylar breadth was 107 mm. The gender differences in mean values of bicondylar breadth of male and female was statistically significant (p=0.017) for mandible. The t-value of bicondylar breadth was 2.42.

Significant parameter	Demarking point, mean±3SD				
	Male		Female		Limiting factor
	Mean-SD [a]	Mean+SD [b]	Mean-SD [c]	Mean+SD [d]	
Bicondylar breadth (mm)	91.58	124.12	97.68	122.55	107
Coronoid breadth (mm)	72.61	108.99	81.84	105.69	89
Angle of mandible (°)	103.29	149.76	100.06	145.94	125
Bigonial breadth (mm)	70.08	110.10	79.83	109.90	90
Mandibular length (mm)	57.16	86.18	58.34	90.77	74
Length of lower jaw (mm)	44.53	78.62	50.32	78.19	61
Mandibular index (mm)	43.47	70.77	46.48	70.22	57
Diagonal length (mm)	62.26	99.89	74.10	97.28	80
Coronoid height (mm)	38.99	74.12	46.74	74.85	57

[Table/Fig-2]: Determination of limiting factor.

Average bicondylar breadth is varied amongst different region worldwide. Bicondylar breadth varies in the individual mandibles, it depend upon shape of condyle of mandible [4]. Sexual dimorphism in bicondylar breadth could also depend on different chewing habits and nutritional factors [5]. Apart from medicolegal importance bicondylar breadth has been considered as a possible predictor for the quality of mandibular reconstruction. Intercondylar distance preoperatively and postoperatively measurements of bicondylar breadth found no significant change in the pre and postsurgical bicondylar breadth [6].

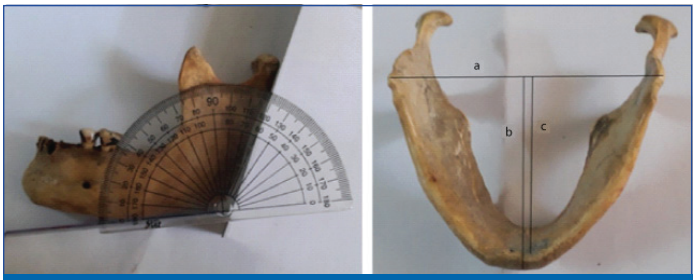
Coronoid breadth [Table/Fig-4]: The demarking point of coronoid breadth for male was 72.61 mm [a] and 108.99 mm [b] and for female was 81.84 mm [c] and 105.69 mm [d]. Limiting point for coronoid breadth was 89 mm. The t-value of coronoid breadth was 3.00. The gender differences in mean values of coronoid breadth of male and female was statistically significant (p=0.003) for mandible.

[Table/Fig-3]: Measurement of bicondylar breadth; **[Table/Fig-4]:** Measurement of coronoid breadth. (Images from left to right)

Angle of mandible [Table/Fig-5]: The demarking point of angle of mandible for male was 103.29 mm [a] and 149.76 mm [b] and for female was 100.06 mm [c] and 145.94 mm [d]. Limiting point for mandibular angle was 125°. The t-value of angle of mandible was -2.32. The gender differences in mean values of mandibular angle of male and female was statistically significant (p=0.022) for mandible.

Women possess more obtuse gonial angle compare to men [7]. Difference in mandibular angle could be because subjects with maximum masticatory force have more acute gonial angle and on average men have greater masticatory force than do women [8].

Bigonial breadth [Table/Fig-6]: The demarking point of bigonial breadth for male was 70.08 mm [a] and 110.10 mm [b] and for female was 79.83 mm [c] and 109.90 mm [d]. Limiting point for bigonial width was 90 mm. The t-value of bigonial breadth was 4.17. The gender differences in mean values of bigonial width of male and female was statistically highly significant (p<0.0001) for mandible.



[Table/Fig-5]: Measurement of angle of mandible; **[Table/Fig-6]:** Bigonial width (a), Mandibular length (b), Length of lower jaw (c). (Images form left to right)

The bigonial breadth depend upon the eversion or inversion of gonial angle. Eversion of gonial angle is characteristic of male and inversion is that of female [9].

Mandibular length [Table/Fig-6]: The demarking point of mandibular length for male was 57.16 mm [a] and 86.18 mm [b] and for female was 58.34 mm [c] and 90.77 mm [d]. Limiting point for mandibular length was 74 mm. The t-value of mandibular length was 2.83. The gender differences in mean values of mandibular length of male and female was statistically significant (p=0.006) for mandible.

Length of lower jaw [Table/Fig-6]: The demarking point of length of lower jaw for male was 44.53 mm [a] and 78.62 mm [b] and for female was 50.32 mm [c] and 78.19 mm [d]. Limiting point for length of lower jaw was 61 mm. The t-value of length of lower jaw was 2.65. The gender differences in mean values of length of lower jaw of male and female was statistically significant (p=0.009) for mandible.

Mandibular index: The demarking point of mandibular index for male was 43.47 mm [a] and 70.77 mm [b] and for female was 46.48 mm [c] and 70.22 mm [d]. Limiting point for mandibular index was 57 mm. The t-value of mandibular length was 1.48. The gender differences in mean values of mandibular index of male and female was statistically not significant (p=0.143) for mandible.

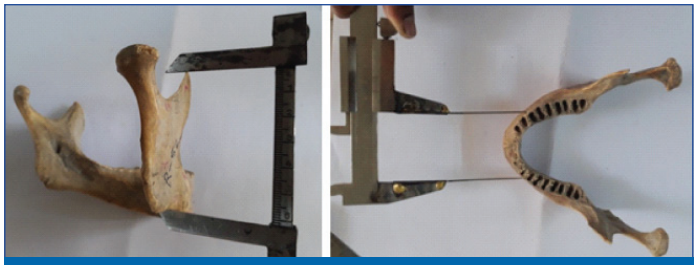
Diagonal length: The demarking point of diagonal length for male was 62.26 mm [a] and 99.89 mm [b] and for female was 74.10 mm [c] and 97.28 mm [d]. Limiting point for diagonal length was 80 mm. The t-value of diagonal length was 4.62. The gender differences in mean values of diagonal length of male and female was statistically highly significant (p<0.001) for mandible.

Coronoid height [Table/Fig-7]: The demarking point of coronoid height for male was 38.99 mm [a] and 74.12 mm [b] and for female was 46.74 mm [c] and 74.85 mm [d]. Limiting point for coronoid height was 57 mm. The t-value of coronoid height was 4.10. The gender differences in mean values of coronoid height of male and female was statistically highly significant (p<0.001) for mandible.

Coronoid process may be enlarged in some pathological conditions like osteochondroma, exostosis, osteoma and other developmental anomalies [10]. The coronoid process is of clinical significance to reconstructive purposes for the maxillofacial surgeons [11]. The coronoid process is used as a donor site for sinus augmentation. A coronoid process graft can be used for orbital floor repair, alveolar defects repair, maxillary augmentation, repair of non union fracture of mandible [12].

Bimental breadth, symphyseal height, body thickness of mandible [Table/Fig-8-10] and mandibular height did not showed any gender differences.

The morphology of mandibular symphysis is important for orthodontic and orthognathic surgery [13].



[Table/Fig-7]: Measurement of coronoid height; **[Table/Fig-8]:** Measurement of bimental breadth. (Images form left to right)

[Table/Fig-9]: Measurement of Symphysial height; **[Table/Fig-10]:** Measurement of mandibular body thickness. (Images form left to right)

DISCUSSION

Generally male mandible is larger in size with prominent mascular attachment sites and slightly more robust than female mandible. The features irregular outer appearance, gonial flaring, a brad ascending ramus, high symphysis and small mental eminence are non metric traits of mandible associated with male sex [14-16]. There are several studies on sex determination of human mandible using morphologic and morphometric parameter. In present study authors have utilised the discriminate function analysis to establish deferent mandibular parameter that gives the most reliable information to differentiate male and female mandible in Mahakaushal region of Madhya Pradesh, India. The mean value of bicondylar in male mandible was greater as compared to female, p-value of the bicondylar breadth showed statistically significant sexual difference and has been noted by all authors mentioned in [Table/Fig-11] [2,3,16-24].

Sr. No.	Authors	Male mean±SD (mm)	Female mean±SD (mm)
1	Present study	110.12±4.15	107.85±5.43
2	Sreelekha D et al., [17]	112.34±6.393	105±7.94
3	Kujur B et al., [18]	111.2±5.73	107.89±4.03
4	Sikka A and Jain A, [2]	116.1±6.5	107.7±5.2
5	Datta A et al., [19]	112.72±5.57	107.48±7.68
6	Rahul S et al., [3]	112.2±6.8	101.7±5.8
7	Deepak NK et al., [20]	112.69±6.46	107.5±6.61
8	Vinay G et al., [21]	113.4±5.5	108.2±7.00
9	Ongkana N and Sudwan P [16]	123.8±6.3	116.1±0.59
10	Vallabhajosyula R et al., [22]	109.8±14.8	115.1±0.93
11	Franklin D et al., [23]	113.6±6.0	108.6±0.58
12	Jayakaran F et al., [24]	112.6±5.3	107.7±0.53

[Table/Fig-11]: Comparison of the data of bicondylar breadth measured in present study with other studies [2,3,16-24].

Coronoid breadth of mandible in males were 93.77±3.98 mm and in female were 90.8±6.07 mm with p-value=0.003. A clear difference was observed in the present study. This was in agreement with study done by Pillai TJ et al., [25]. The present study is in agreement with finding of those that considered as females presented with higher angle of mandible than males. Conversely, found that angle of mandible was greater in female but when statistically analysed did not find any statistically significant differences between both sex [Table/Fig-12] [17-19, 26].

In present study, bigonial breadth of mandible in males were greater than female having p-value <0.05 which was highly significant.

Conversely, other researchers found that males showed statistically higher mean bigonial breadth [Table/Fig-13] [16,18,19,21-24].

Sr. No.	Authors	Male Mean±SD (°)	Female Mean±SD (°)
1	Present study	123±7.65	126.53±7.75
2	Sreelekha D et al., [17]	106.8±5.05	116.36±5.53
3	Sharma M et al., [26]	124±6.27	124.03±5.3
4	Kujur B et al, [18]	126.73±2.71	135.42±2.58
5	Datta A et al., [19]	126.6±6	135.72±8

[Table/Fig-12]: Comparison of the angle of mandible measured in present study with other studies [17-19,26].

Sr. No.	Authors	Male mean±SD (mm)	Female mean±SD (mm)
1	Present study	94.87±5.02	90.09±6.67
2	Kujur B et al., [18]	94.69±2.46	88.27±7.84
3	Datta A et al., [19]	95.70±5.19	88.75±6.78
4	Vinay G at al., [21]	94.5±5.3	87.4±0.54
5	Ongkana N and Sudwan P [16]	96.8±7.7	89.7±0.59
6	Vallabhajosyula R et al., [22]	86.8±13.7	86.2±0.72
7	Franklin D et al., [23]	93.5±5.7	87.0±0.56
8	Jayakaran F et al., [24]	93.8±5.4	87.1±0.48

[Table/Fig-13]: Comparison of the data of bigonial breadth measured in present study with other studies [16,18,19,21-24].

The mandibular length in the present study was 74.56±5.41 mm in male and 71.67±4.84 mm in females with p-value 0.006 (statistically significant). In the present study, parameter with value is greater in males than females was found to be sexually dimorphic. Similar finding were found in study done by Ongkana N and Sudwan P, Vallabhajosyula R et al., Jayakaran F et al., with the almost similar mean value of mandibular length [16,22,24]. The length of lower jaw of male mandible's mean is 64.26 mm with standard deviation 4.65 mm. The length of lower jaw of the female mandible's mean is 61.58 mm with standard deviation 5.69. The mean difference between the male and female length of lower jaw is 0.009. Study conducted by Datta A et al., also found significant difference between male and female [19]. Study conducted by Pillai TJ et al., stated that length of lower jaw in the known sex the difference between the male and female is insignificant and therefore, length of lower jaw was not applied to identify the sex of the mandible [25].

In the present study, authors observed that the mean value of the mandibular index was 58.36±3.96 mm in males and 57.12±4.56 mm in females. The values in the female mandible were lesser as compared to that obtained in male mandible. Study done by Ongkana N and Sudwan P, Kujur B et al., Vinay G at al., also observed that the values in the female mandible were lesser as compared to in males but statically insignificant [16,18,21]. The difference between the two mean values in present study was statistically insignificant. This was similar to previous works. The mean value of the diagonal length in male (85.69±3.87 mm) was greater than female and the p-value <0.001 show statistically significant difference between male and female mandible for diagonal length. Compared with Ongkana N and Sudwan P, Kujur B et al., and Sharma M et al., also found that the males have significantly greater diagonal length than the females [16,18,26].

The mean coronoid height was higher in males (60.79±4.68 mm) as compared to females (56.56±5.86 mm). The difference between two sexes using student's test was significant. This was in agreement with previous authors, Ongkana N and Sudwan P, Datta A et al., [16,19]. Veenita S et al., found in their study that coronoid height was the single best parameter providing an accuracy of 74.1% [27]. The present study also shows almost similar findings and the mean values of coronoid height in males and females were statistically significant (p-value <0.001). In the present study, mean value of the body thickness was found to be 11.09±1.56 mm in males and 11.62±1.45 mm in females. The mean value of body height was found to be 26.69±4.45 mm in males and 26.38±3.84 mm in females. Mean value of mandibular body height and body height was statistically non significant in present study. Study done by Deepak NK et al., Pillai TJ et al., were statistically non significant for both male and female mandibles [20,25].

Bimental breadth in the present study was found to be 44.33±2.73 mm in males and 44.28±3.55 mm in females. Study conducted by Kranioti EF et al., on Greek mandible observed the mean value of bimental breadth in male and female was statistically not significant [28]. The present study also shows statistically not significant correlation between the male and female mandibles. This was not in same line with Datta A et al., Pillai TJ et al., observed that there was statistically significant correlation in the mean values of bimental breadth between the male and female mandibles [19,25].

In present study, the mean value of symphyseal height was larger in male but statically non significant. Study done by Deepak NK et al., Pillai TJ et al., also observed finding like present one [20,25].

Strengths of study: Study utilised 13 different metrical parameters and establishes a discriminate function analysis that gives most reliable information of sexual dimorphism in the population of Mahakausal region, Madhya Pradesh, India which has not been cited in earlier study.

Limitation(s)

During study, it was felt that, there was a need of further study on larger sample size in Mahakaushal region. This study was also unable to assess the gender in case of edentulous mandibles.

Future recommendations: These metrical parameters along with morphological features could be applied as a useful tool of mandible in planning facial and dental reconstructive surgery. Comprehensive knowledge about various parameters of mandible will give an insight to the forensic medicine personel in creating facial reconstruction using these anthropometric measurements of mandible and will provide a novel platform for further interpretations of post mortem findings.

CONCLUSION(S)

The present study utilised 13 different metrical parameters. The application of these 13 metrical parameters along with morphological features could be a useful tool for sex determination of mandible. Present study proves that adult mandibles exhibit sexual dimorphism and can be used to identify genders and population affinity with increased sensitivity and specificity. All the parameters measured were higher in male mandibles compared to female mandibles except for mandibular angle, which showed higher values in females. Statistically significant differences were observed in eight parameters, i.e., in bicondylar breadth, bigonial breadth, coronoid breadth, angle of mandible, mandibular length, diagonal length and coronoid height.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jan 30, 2021
- Manual Googling: May 25, 2021
- iThenticate Software: Jul 01, 2021 (24%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Jan 26, 2021**
Date of Peer Review: **Apr 07, 2021**
Date of Acceptance: **May 29, 2021**
Date of Publishing: **Oct 01, 2021**