Sex Determination of Mandible: A Morphological and Morphometric Analysis

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ABSTRACT

Introduction: Mandible is the most durable and sexually dimorphic bone of the skull. It resists post mortem changes too. Bones are an important evidence in establishing the biological profile of an individual. Sex determination is pivotal in this because rest of the methods of age and stature determination are dependent on sex.

Material and Methods: Morphological and morphometric parameters were studied in 126 mandibles to determine their sex. The morphological parameters were analysed using chi square test of independence. The metric parameters were analysed using student t test, Hotelling T^2 square test for multivariate analysis and discriminant function analysis.

Results: The mean values of all the metric parameters were higher in males as compared to females. This difference was statistically significant for all parameters. By multivariate analysis also, *P* value was less than 0.001. We could correctly classify 81% bones using discriminant function analysis.

Conclusion: Mandible exhibits significant sexual dimorphism. A combination of morphological and morphometric parameters is ideal to determine the sex of the mandible.

Keywords: Mandible, sex determination, morphological, metric parameters, discriminant function analysis

INTRODUCTION

With increasing incidence of violence, accidents and mass disasters identification of mortal remains becomes very important. It is further compounded by the fact that only fragmentary remains are usually available. Bones are an important tool in establishing the identity of an individual and they also help in establishing the process of evolution, race and demographic profile.[1] Of these, sex determination is most important because it reduces the possible matches by half and also, the other parameters i.e. age and stature are highly sex dependent.[2,3]

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.[4] Mandible is the most durable and sexually dimorphic bone of the skull and resists post mortem changes too.[2,3] Sexual dimorphism is seen in stages of mandibular development, growth rates and duration.[3] By simple observation, clear difference in size, height, thickness and muscle markings can be noted.[5]

Physical anthropologists traditionally study variations in the human skeleton with the use of metric and non-metric parameters. A long-standing controversy exists about the comparative utility of metric and non-metric traits as biological indicators in population studies.[6] Although, there have been previous studies to determine sex from the mandible, they are more so qualitative. Hence the current study was undertaken to establish metric parameters in addition to morphologic parameters to determine sex from mandible as use of both is likely to improve the efficacy and accuracy of sex determination.

MATERIAL AND METHODS

The present study was conducted on 126 mandibles of unknown sex over a period of one year. The bones were already present in the Department and had been collected from dissected cadavers. All intact, well-formed and adult mandibles were included in the study. Pathological, deformed, damaged, or broken bones were excluded from the study.

A total of nine parameters i.e. three non-metric and six metric parameters were observed for each mandible.

Non metric parameters:[2]

- Shape of chin - square in males and rounded in females
- Gonial flare - everted in males and inverted in females
- Muscle markings - more prominent in males as compared to females.

Metric parameters:[2,3,7]

- Bicondylar Breadth (BCB) - The straight distance between the most lateral points on the two condyles.
- Bigonial Breadth (BGB) - The straight distance between the two gonia.
- Mandibular Body Height - The direct distance between the alveolar process to the inferior border of the mandible perpendicular to the base at the level of mental foramen.
- Symphyseal Height - The direct distance between the alveolar process to the inferior border of the mandible perpendicular to the base at the level of symphysis menti.
- Maximum Breadth of Ramus - The distance between the most anterior point on the mandibular ramus and a line connecting the most posterior point on the condyle and the angle of mandible.
- Maximum Height of Ramus - The distance between the midpoint of mandibular notch to the angle of mandible.

Initially the non-metric parameters were observed and the bones classified into males and females accordingly.

The metric parameters were measured using Vernier callipers. All measurements were in centimeters(cm). The measurements were recorded, tabulated and analysed statistically.

STATISTICAL ANALYSIS

Non metric parameters: To test the relationship between morphological characters and sex, chi square test of independence was used.

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Metric parameters: Mean and Standard Deviation (S.D.) for each parameter for each gender were worked out. To assess the efficacy of statistical tests in determining sex and to predict the proportion of individuals which can be identified correctly either male or female, a limiting value was worked out, either side of which represented a particular sex. To determine this, demarcating and limiting values were calculated assuming normal distribution. Calculated range is mean ± 3 S.D., covering 99% population. For instance, in males mean – 3 S.D. be denoted as 'a', mean + 3S.D. denoted as 'b'; then a to b is calculated range for males. Similarly, mean – 3 S.D. be denoted by 'x' and mean + 3S.D. be denoted as 'y'; then x to y is calculated range for females. The demarcating point for females is 'a' below which all will be females and 'y' is demarcating point for males above which all will be males. Based on the above values, limiting value was worked out. A limiting value is the value above which majority bones were male and below which most bones were female.

Statistical tests used were student's t test, Hotelling T^2 test for multivariate analysis and discriminant function analysis with SPSS. Discriminant function analysis is used to develop an index to have maximum discrimination among two groups where variation is maximum among groups and minimum within groups. We developed a discriminant function on 84 bones (2/3 of the total 126) taken randomly and then based on this, predicted the sex of the rest of 42 (which were not a part of the model) bones to test the efficacy and validity of the function developed.

RESULTS

The current study was carried out on 126 mandibles to determine their sex. Initially they were categorised into male and female with the help of non-metric parameters. This categorisation was done on the basis where two traits clearly suggested a particular sex. On studying the morphological parameters, the bones were categorised into 78 male and 48 female mandibles.

As is evident from table-1, 85.9% male bones had a square chin whereas, 87.5% females had a rounded chin. Gonial flare was everted in 88.4% males and inverted in 75% females. Muscle markings were more prominent in 81% males while it was less prominent in 89.6% females. On analysing with chi square test of independence *P* for all the three parameters was found to be < 0.001 which is highly significant. A significant Chi square test of independence indicates that the two factors are not independent. For all the three morphological parameters, *P* value indicates that they are all influenced by sex.

The metric parameters are summarised in Table-2. As is clear from Table-2, the mean values for all parameters are greater in males as compared to females. Using student's t test, this difference is highly significant for all parameters except those related to the ramus of mandible. The difference is significant for the maximum height and breadth of ramus. The standard deviation is also higher in males for all the above parameters denoting that males show greater variability as compared to females.

The demarcating points and limiting values are summarised in table-3. It is an extension of sex determining values for metric traits. Limiting value of bicondylar diameter could correctly classify 84.6% males and 70.8% females. With bigonial breadth, 82.1% males and 70% females could be correctly categorised. Considering the mandibular height, 69.2% males could be correctly classified. 80.8% males could be categorised using

	Shape of Chin		Gonial Flare		Muscle Markings	
	square	rounded	everted	inverted	more	less
Male	67	11	69	9	63	15
Female	6	42	12	36	5	43
Chi square	65.7		52.12		59.2	
P	< 0.001		< 0.001		< 0.001	

Table-1: Morphologic Parameters to Differentiate Sex of the Mandible

Parameter	Male (n = 78)		Female (n = 48)		P
	Mean(cm)	S.D.	Mean (cm)	S.D.	
Bicondylar Breadth	11.61	0.65	10.77	0.52	< 0.001
Bigonial Breadth	9.64	0.64	8.93	0.58	< 0.001
Mandibular Body Height	2.49	0.46	2.28	0.42	< 0.01
Symphyseal Height	2.54	0.45	2.32	0.37	< 0.008
Max. Ramus Breadth	3.71	0.62	3.47	0.55	< 0.03
Max. Ramus Height	4.67	0.58	4.47	0.53	< 0.04

Table-2: Descriptive Analysis of Metric Parameters in Males and Females

Parameter	Males (n = 78)	Females (n = 48)	Limiting value (cm)
	Demarcating point 'y' (cm)	Demarcating point 'a' (cm)	
Bicondylar Breadth	12.3	9.7	11.0
Bigonial Breadth	10.4	7.9	9.1
Mandibular Body Height	3.5	1.1	2.3
Symphyseal Height	3.4	1.2	2.3
Max. Ramus Breadth	5.1	1.9	3.5
Max. Ramus Height	6.1	2.9	4.5

Table-3: Demarcating Points and Limiting Values for Metric Parameters

the limiting value of symphyseal height. For the parameters of ramus, 75% females were correctly identified using maximum breadth of ramus whereas with maximum height 71.8% males could be correctly identified.

As the probability value for different parameters varies indicating different level of significance, Hotelling T^2 test was applied to understand how these parameters behave collectively, in determining sex. The calculated variance at $F_{6\,119}$ by Hotelling T^2 test for multivariate analysis is 77.3, which is highly significant, with a *P* value of < 0.001. This demonstrates that all parameters when taken together, exhibit effective sexual dimorphism.

For the model (n_1=84) bones, using discriminant function analysis, 70 bones could be correctly classified i.e. a correct classification of 83.3%. When this model was tested on the rest of the 42 bones), 34 bones could be correctly classified i.e. with an accuracy of 81%.

On using different combinations of various parameters, we found that maximum accuracy was achieved with bicondylar breadth and mandibular body height taken together. We were able to correctly classify 80% bones which is similar to when all bones were taken together.

DISCUSSION

Human mandible morphology is often thought to play a role in function history and not so much in population history.[8] This has been often debated and studies on mandible have proven that it shows significant ethnic, racial and sexual differences. The present study was undertaken to determine the gender of 126 mandibles present in the department.

The current study uses a combination of morphological and morphometric parameters. Morphological parameters are better determinants of sex but are dependent on the observer's ability and expertise.[9] Metric parameters are objective and reproducible with low intra and inter observer error but they can be influenced by dietary habits, lifestyle and environment etc.[10] So the ideal way to determine sex is by using a combination of both. Although there are previous studies on sexual dimorphism in mandible, all the parameters observed in the present study have not been taken together by previous workers.

Estimation of sex and hence, age and identity of remains is of significance not only in Forensic Science but also in Anatomy, Forensic Odontology, Anthropology and Palaeontology.[7,11] Morphological features and metric parameters of the human mandible are useful in diagnosis and treatment of dentofacial conditions also.[7] Dimorphism in the mandible is reflected in its shape and size. As the mandible is the last skull bone to cease growth, it is sensitive to adolescent growth spurt. The stages of mandibular development, growth rates and its duration are distinctly different in both the sexes so it becomes particularly useful in differentiating between sexes. In addition, masticatory forces exerted are different for males and females, which influence the shape of the ramus.[3,11]

In general, the male mandibles are large, slightly more robust with prominent muscle attachment sites than the female mandibles.[2] The outer appearance of male mandible is usually irregular, whereas that of females is likely to be even.[12]

In the present study; gonial flare is everted, chin is square and muscle markings are more prominent in males, whereas, it is inverted, round and less prominent respectively in females and this difference is highly significant. This has also been observed by workers in previous studies.[1,2,12]

In the current study, the values for the metric parameters were found to be higher in males as compared to females. Also, the range was higher in males. This is in concordance with previous studies.[5]

In the present study the mean bicondylar breadth was 11.61±0.65cm whereas it was 10.77±0.52cm in females. The difference between the two was statistically highly significant. This is similar to previous studies.[2,13,14] In a study on Thai population by Ongkana et al, the mean values for bicondylar diameter were 12.38 cm and 11.61 cm respectively.[15] This difference in the means between the Thai population and our study further underlines the necessity of population specific standards.

In the present study the mean bigonial breadth was 9.64±0.64cm whereas it was 8.93±0.58cm in females. Anupama Datta et al in a study on 50 bones found the mean bigonial breadth to be 9.6cm and 8.9 cm in males and females respectively.[13] Vinay G, in a study on 250 bones found the mean values to be 9.45 cm and 8.74 cm in males and females respectively.[7] The difference between the two mean values in our study was statistically highly significant. This is similar to previous works.

The mean values for the mandibular body height and symphyseal height, showed significant difference between males and females. The values were larger for the males as compared to females. Many workers in earlier studies also observed findings like the present one. This is different from the results of a study by Kawale et al., where this difference was found to be statistically insignificant.[14]

Mean maximum ramus breadth and mean maximum ramus height were higher in males as compared to females. The difference between the two sexes using student's t test was significant for both the parameters. This was in agreement with previous authors.[7,9,14]

The use of demarcating values and limiting values further improves the accuracy of the present study. Proportion of correctly identified sex through limiting value helps us in predicting the efficacy and validity of the technique used.

The present study also uses multivariate analysis which has not been done by previous workers. The multivariate analysis clearly demonstrates that all the parameters when studied collectively, show significant sexual dimorphism.

The results of discriminant function analysis also exhibit a high degree of accuracy in classifying bones according to sex. We could categorise 81% bones correctly. This accuracy is higher than many previous studies.[3,7] It is similar to a study done by Franklin D et al.[16] The use of the model and subsequent testing of the function developed further increases the sensitivity of the current study. This study also demonstrates the best combination of two parameters for determining the gender of the mandible. Franklin D et al. also concluded that the most dimorphic regions of the mandible were the condyle and the ramus.[16]

CONCLUSION

The present study proves that the adult mandible exhibits sexual dimorphism and can be used to identify both sex and population affinity with increased sensitivity and specificity. Since all the parts of the mandible studied i.e. ramus, body, bicondylar

breadth and bigonial breadth show significant dimorphism, sex can be determined from fragmentary remains too.

The current study clearly demonstrates that all statistical techniques are individually as well as collectively effective in sex determination. It also establishes the morphological and morphometric criteria and recognizes a significant sexual dimorphism in the mandible. In addition, the demarcating values and limiting values found out in this study can help set up baseline parameters for sex determination in the North Indian population.

REFERENCES

1. Jembulingam S and Thenmozhi MS. Sexual Dimorphism of Adult Mandibles: A Forensic Tool. Journal of International Academy of Forensic Science and Pathology. 2016;03:3-5.
2. Singh R, Mishra SR, Sushobhana, Passey J, Kumar P, Singh S, et al. Sexual dimorphism in adult human mandible of north indian origin. Forensic Medicine and Anatomy Research. 2015;3:82-8.
3. Saini V. Metric study of fragmentary mandibles in a north indian population. Bulletin of the International Association of Paleodontology. 2013;7:157-62.
4. Krogman WM and Iscan MY. The human skeleton in forensic medicine. 2nd edition, Charles C. Thomas, Springfield.
5. Fabian FM and Mpembeni R. Sexual dimorphism in the mandibles of a homogenous black population of Tanzania. Tanzania Journal of Science. 2002;28:47-54.
6. Thakur KC, Choudhary AK, Jain SK, Kumar L. Racial architecture of human mandible- an anthropological study. Journal of Evolution of Medical and Dental Sciences. 2013;2:4177-88.
7. Vinay G, Mangala GSR, Anbalagan J. Sex determination of human mandible using metrical parameters. Journal of Clinical and Diagnostic Research. 2013;7:2671-3.
8. Nicholson E and Harvati K. Quantitative analysis of human mandibular shape using three – dimensional geometrical morphometrics. American Journal of Physical Anthropology. 2006;131:368-83.
9. Vinay G, Mangala GSR. Determination of gender by anthropometric measurement of human mandible using ramus breadth and mandibular angle: A cross sectional study from South India. Medical science. 2013;1:28-32.
10. Zvando MDA, Suazo GIC, Smith RL. Sexual dimorphism determination from lineal dimensions of skulls. International Journal of Morphology. 2009;27:133-7.
11. Raj JD and Ramesh S. Sexual dimorphism in mandibular ramus of north indian population. Antrocom Online Journal of Anthropology. 2013;9:253-8.
12. Ongkana N and Sudwan P. Morphologic Indicators of Sex in Thai Mandibles Using Metric Analysis. Chiang Mai Medical Journal. 2010;49:123-8.
13. Datta A, Siddappa SC, Gowda VK, Channabasappa SR, Shivalingappa SBB, Srijit, et al. A study of sex determination from humen mandible using various morphometrical parameters. Indian Journal Forensic and Community Medicine. 2015;2:158-66.
14. Kawale DN, Kulkarni PR, Shivaji SB, Chaya DV. Sexual dimorphism human mandible: a morphometric study. IOSR-Journal of Dental and Medical Sciences. 2015;14:42-5.
15. Franklin D, O'Higgins P, Oxnard CE, Dadour I. Sexual dimorphism in the subadult mandible: quantification using geometric morphometrics. Journal of Forensic Science. 2007;52:6-10.
16. Ongkana N, Sudwan P. Gender differences in Thai mandibles using metric analysis. Chiang Mai Medical Journal. 2009;48:43-48.

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