Original Article

Morphometric analysis of mastoid process for sex determination among Marathwada population

S B Sukre[1], P R Chavan[2*], S N Shewale[3]

[1]Professor and HOD, [2,3]Assistant Professor, Department of Anatomy, Government Medical College, Aurangabad, Maharashtra, INDIA.
Email: drpallavichavan22@gmail.com

Abstract

Background: Sexing the human skull and skeletal remains has been an important task of the physical anthropologist, forensic anthropologist and archaeologist. It is achieved by using the knowledge of human anatomy concerning osteology. Mastoid process is one of the most dimorphic bone which remains least damaged due to its anatomical position at the basolateral region of skull. Its size varies; it is larger in male than in females. In present study, an attempt has been made to evaluate the use of mastoid process measurement in the determination of sex in an unidentified skeleton and also to test the accuracy of sex determination using discriminant function analysis. **Material and Methods:** The present study was carried out in department of Anatomy, Government Medical College, Aurangabad. A total 132 dried adult human skull (80 male, 52 female) of Marathwada region were studied to determine accuracy of mastoid process. The mastoid length, medio-lateral diameter, antero-posterior diameter were measured with vernier caliper to calculate mastoid process index. Also the distance between asterion to mastoidale, asterion to porion, and porion to mastoidale were studied. **Results:** We observed that, out of seven mastoid variables, except mastoid index the mean of all remaining variables were more in males than that of in females. The difference observed for six mastoid variables was statistically significant ($p<0.005$) except mastoid index. Discriminant function analysis revealed that the mastoid process correctly classified the sex in 76% of the subjects and mastoid length was found to be an excellent discriminant for sex. A discriminant function equation specific for Marathwada population has also been derived from mastoid process variables. The present study provides a baseline data for sex determination of mastoid process of skull in Marathwada population.
Key Words: Discriminant function analysis; mastoid process; sex determination.

***Address for Correspondence:**
Dr. P. R. Chavan, "Shardashilp", 216 F, Near St. Lawrence Marathi Highschool, N-1, CIDCO, Aurangabad-413 503 Maharashtra, INDIA.
Email: drpallavichavan22@gmail.com
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INTRODUCTION

The mastoid process is a prominent breast like inferior projection from the mastoid part of temporal bone and is located posteroinferiorly to the external acoustic meatus[1]. Determination of sex in fragmented remains is often a difficult task, as no isolated characteristic of any particular bone can perfectly determine the sex of a skeleton. The highest accuracy in sex determination is achieved when complete skeleton is available [2]. The sex is best assessed from the pelvic bones and pelvis than the skull, but whole and complete pelvis is not always available for analysis[3]. Several studies have shown that cranium is also an excellent indicator for sexual dimorphism by morphologic and morphometric analysis. Skull is probably the second best region of the skeleton to determine sex[4]. The measurements of the skull vary significantly in different populations of the world. Dimorphism in skull is based on its size and robustness. The mastoid process is the most dimorphic bone of the skull which plays significant role in sexual dimorphism. Due to its anatomical position at the basolateral region of the skull, this part is most protected and resistant to damage, so that the mastoid region is favourable for sex determination[5]. Usually mastoid process is larger in males than in females. Hoshi H[6] analyzed the morphology of mastoid process non-metrically and specified 3 main types by the direction of the tip of mastoid process. But it is subjective and it cannot be relied. The osteometric

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studies of mastoid process have been employed by Paiva and Segre[7] (2003), Nagaoka[8] (2008), Sumati Patnaik[9] (2010), and A D Gupta[10] (2012). Very few works have been done on this in Marathwada region of Maharashtra. Considering this entire scenario, the present study aims to evaluate the use of mastoid process measurements in determination of sex in unidentified human skeletal remains, decomposed and mutilated body. The present study also intends to assess the dimorphic reliability of different morphological parameters of mastoid process by using discriminant function analysis in Marathwada population. It is expected that the observations, inferences and sex discriminating functions thus obtained will be very useful for anatomist, anthropologist, and forensic experts in solitary homicidal cases, mass-disaster and multiple burials leaving mere charred and mixed incomplete remains to be recovered [11].

MATERIAL AND METHODS

The present study was conducted in the department of Anatomy, Government medical college, Aurangabad on 132 dried adult human skulls of known sex (80 Males and 52 Females).The skulls were studied to determine the validity of the mastoid process variables in sexual dimorphism. Skulls with no apparent deformity, intact mastoid process and already synostosed spheno-occipital junction were included in the study. Deformed skulls were excluded from the study. The mastoid measurements were taken on the skull by using sliding vernier caliper to the nearest millimeter (mm) as per standard anthropological conventions. All the measurements were done by single observer to avoid inter-observer error.

Frankfort plane was chosen and marked on the skull. It is a horizontal plane passing through upper margin of external acoustic meatus and the lower margin of the orbital opening. The following measurements were taken on the mastoid process of skull.

1. Mastoid length: It was measured from a point on the Frankfort plane vertically downward to the tip of the mastoid process[12]. The skull was placed on one side facing towards the observer; the fixed arm of the vernier caliper was positioned tangentially on the upper border of auditory meatus. [Figure 1]
2. Medio-lateral diameter: The measurement was taken from the highest part of medial surface within digastric fossa to the most lateral point of the mastoid process at same level[12]. [Figure 2]
3. Antero-posterior diameter (Mastoid breadth): It was measured as a straight distance from the posterior end of incisura mastoidea (PEIM) to the nearest point on the posterior border of the external acoustic meatus[12].[Figure 3]
4. Mastoid process index = Maximum Mastoid breadth / Maximum Mastoid length X 100.

For further mastoid measurements following points were used. Asterion (AST): is the meeting point of lambdoid, occipitomastoid and parietomastoid sutures. Porion (Po): Superior point of external acoustic meatus. Mastoidale (Ms): is the tip of mastoid process. The points were located and marked [Figure 4]. The following readings were measured in millimeter.

5. Asterion to Mastoidale (AST- Ms)
6. Asterion to Porion (AST-Po)
7. Porion to Mastoidale (Po-Ms)

The data obtained was tabulated and analysed using IBM SPSS 21 version software. Univariate analysis was obtained for all the above parameters by calculating mean, standard deviation and p value. Then discriminant function analysis was performed with each single variable.




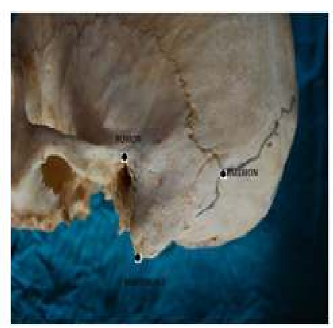

Figure 1: Mastoid length
Figure 2: Medio-lateral diameter of the mastoid process
Figure 3: Anteroposterior diameter of the Mastoid process
Figure 4: showing location of asterion, porion and mastoidale

RESULTS

Total 132 dried adult human skulls (80 Male, 52Female) with intact and measurable mastoid process were studied. The univariate analysis revealed that, the mean of mastoid variables like mastoid length (25.32), medio-lateral diameter (10.71), antero-posterior diameter (21.60), AST-Ms (48.33), AST-Po (44.96) and Po-Ms (29.86) were more in males than that of in females. All the mastoid measurements differ significantly among males and females and the measurements were statistically significant ($p<0.005$). Whereas the mean mastoid index was found to be less in males (84.79) than in females (85.07) and the difference was statistically insignificant [Table No.1]

Table 1: Descriptive statistics for mastoid measurements (n=132)

Sr. No	Mastoid variable	Female (n=52)		Male (n=80)		Significance (2tailed)
		Mean	SD	Mean	SD	
1	Mastoid length	20.17	0.60	25.32	0.37	0.0000*
2	Medio-lateral diameter	8.42	0.27	10.71	0.22	0.0000*
3	Antero-posterior diameter	18.21	0.51	21.60	0.32	0.0000*
4	Mastoid index	85.07	28.72	84.79	13.98	0.9407
5	Asterion-Mastoidale	42.59	1.12	48.33	0.64	0.0003*
6	Asterion-Porion	40.46	1.03	44.96	0.57	0.0017*
7	Porion-Mastodale	25.17	0.69	29.86	0.41	0.0000*

All measurements were in millimeters (mm); *significant

The discriminant function equation formula derived for the determination of sex is: y= -3.814+ (3.19 x Mastoid length) + (1.716 x medio-lateral diameter) + (0.220 x anteroposterior diameter) – (0.938 x Asterion-mastoidale) + (0.169 x Asterion-porion) – (0.913 x Porion-mastoidale) + (0.005 x Mastoid index). That means if the calculated discriminant score using the above equation is less than zero, the case is classified as “female” and if the score is greater than or equal to zero, the case is classified as “male”.

Table 2: Classification results of all mastoid variables [a,b]

		Predicted group membership	
		Female n (%)	Male n (%)
Observed	Female	31 (59.6%)	21 (40.4%)
	Male	8 (10.0%)	72 (90%)
Cross-validated	Female	29 (55.8%)	23 (44.2%)
	Male	10 (12.5%)	70(87.5%)

a. 78.0% of original grouped cases correctly classified.
b. 75.0% of cross-validated grouped cases correctly classified.

The discriminant function analysis was performed including all mastoid variables which correctly classified 75% of the cases. Cross-validation classification procedure proves that the model was fairly reliable. [Table no. 2]

Table 3: Discriminant function analysis for mastoid variables

Parameter	Wilk’s lambda	Standardized canonical correlation	Unstandardized canonical correlation	Structure matrix	Functions at group centroid	Average accuracy
Mastoid length	0.781	1.526	3.190	0.884	M=0.480 F= -0.738	M= 90% F= 59.6% Overall= 76%
Medio-lateral diameter	0.828	0.424	1.716	0.760		
Antero-posterior diameter	0.857	0.090	0.220	0.682		
Mastoid index	1.000	0.101	0.005	-0.011		
Asterion-Mastoidale	0.903	-0.810	-0.938	0.546		
Asterion-Porion	0.927	0.133	0.169	0.467		
Porion-Mastodale	0.845	-0.492	-0.913	-0.011		

The discriminant function analyses for mastoid parameters were presented in table 3. The overall accuracy of sex determination by using all mastoid variables was 76%. For males, the average accuracy is 90% and for females it was 59.6%. Out of all mastoid variables, the mastoid length showed lowest wilk’s lambda (0.78), highest canonical correlation (1.526) and highest structure matrix (0.884) which shows excellent discriminant function. The second best discriminant function was obtained by medio-lateral diameter. On the other hand, the discriminant function obtained by mastoid index showed far less discriminative capacity, as it includes highest wilk’s lambda (1.000), and lower structure matrix (-0.011). Thus we may conclude that, the mastoid length is the best discriminator and medio-lateral diameter is the second and porion-mastoidale is the third best discriminator in sex determination from fragmented remains.

DISCUSSION

Each mastoid parameter is discussed by comparing them with the findings of previous workers. Mastoid process has been selected because it is well preserved and most protected part of a fragmentary skull. The present study has provided a baseline data for sex determination of skull and also stressed the accuracy of mastoid process in Marathwada population. In present study, the mean values of mastoid length, medio-lateral diameter, antero-posterior diameter, asterion-mastoidale, asterion-porion and porion-mastoidale were more in males and are statistically highly significant for sex determination as revealed from its ‘p’ value.

Table 4: Comparison between present study and studies conducted by previous workers for mastoid length, medio-lateral and antero-posterior diameter

Parameter/ Authors	Population studied	No. of skulls (n)	Mastoid length (mm)	Medio-lateral diameter (mm)	Antero-posterior diameter (mm)
Giles and Elliot[13] (1963)	White Caucasian and Negroes	-	M= 28.07 F= 25.21 and M=30.32 F=26.35	--	--
Sumati *et al*[9] (2010)	North India	M= 30 F= 30	M=28.3±4.0 F=23.18± 4.2	M=11.46± 2.7 F=8.68±2.6	M=17.52± 4.69 F=13.69± 3.67
Gupta AD *et al.*[10] (2012)	South India	M= 35 F= 35	M=29.23± 2.42 F=22.44± 3.77	M=11.24±2.0 F=8.59± 1.5	M=16.55± 3.82 F=12.78± 2.47
Vineeta Saini *et al*[14]. (2012)	North India	M= 104 F= 34	M=35.82± 3.55 F=31.86± 3.32	--	M=25.58± 1.89 F=22.77± 2.37
Nidugala H[15] (2013)	South India	M= 40 F= 40	M=35.63± 3.91 F=30.55± 4.09	--	M=21.97± 2.60 F=20.03±2.74
Shobha verma[16] (2015)	UP population	M= 50 F= 50	M=28.62± 0.63 F=23.92± 1.54	M=12.33±0.86 F= 12.38± 1.56	M=17.36± 1.03 F= 15.39± 1.81
Present study (2017)	Marathwada population	M= 80 F= 52	M=25.32± 0.37 F=20.17± 0.60	M=10.71±0.22 F=8.42±0.27	M=21.60± 0.32 F=18.21±0.51

M= male; F= female mm= milimeter

Table no.4 shows the studies of various mastoid parameters done by different workers in different regions. Each study showed that, the mastoid length is more in males than that of females which correlates with our study. Hoshi H [6] studied the mastoid length and he divided the mastoid process into 3 categories viz. male, neutral and female categories. He stated that, when the skulls were kept on flat surface, it lies on mastoid process in males and on occipital condyles in females. This observation indirectly confirms that the male skulls have more mastoid length. Giles and Elliot[13] conducted study of mastoid length in Caucasian population and Negroes. They concluded that mean mastoid length was more in males and in Negroes than in Caucasians. Like the above, the present study also revealed lesser mean value of mastoid length among females (20.173) than males (25.32). The mastoid medio-lateral diameter[9,10,16] and antero-posterior diameter[9,10,14,15,16] was calculated by previous workers, they noted that both the parameters are more in males. So the present study coincides with the findings of previous workers. The mastoid process index has been studied separately on right and left side[17], they concluded that the mastoid process index was significantly more in females than in males. In present study, the mastoid process index was more in females (85.07) than in males (84.79) but it is statistically insignificant. Very few work done on mastoid process index, thus mastoid index help to sex the skull. Table no.5 showing comparison between present study and previous studies for mastoid parameters. (AST-Ms; AST-Po; Po-Ms)

Table 5:

Parameter/Authors	Population studied	No. Of skulls (n)	AST-Ms (mm)	AST-Po (mm)	Po-Ms (mm)
Vineeta Saini *et al*[14]. (2012)	North India	M= 104 F= 34	M=47.83± 4.06 F=43.0±4.32	M=47.89± 3.17 F=44.69± 3.75	M= 31.77± 3.07 F=27.98± 3.47
Nidugala H[15] (2013)	South India	M= 40 F= 40	M=50.11±4.54 F=46.51± 4.12	M=44.48±4.14 F=42.87±3.08	M=29.52±3.3 F= 24.26±3.7
Present study (2016)	Marathwada population	M= 80 F= 52	M=48.33± 0.64 F=42.59± 1.12	M=44.96± 0.57 F=40.46± 1.03	M=29.86±0.41 F=25.17±0.69

M= male; F= female mm= milimeter

Present study showed a statistically significant difference for AST-Ms (asterion to mastoidale distance), this coincides to other studies[14,15]. But this is in contrary to the 1observation of Kemes and Gobel[18], who found the AST-Ms distance insignificant and stated the cause, may be the asterion position which varies with progression of age in a population-specific manner. [Table no. 5] In addition to the metric and non-metric analysis, the highly objective discriminant function analysis was applied. The discriminant function equation for sex determination has been computed by few researchers like Song *et al*[19] for Chinese population, Sumati *et al*[9] for North Indian population, and for South Indian population[10,15]. They revealed that sex within a given race can be best described by unique discriminant function equation. In present study, the discriminant function equation derived for Marathwada population will be unique to determine sex. The accuracies obtained by using mastoid variables in the present study (76%) is similar to the study conducted in North Indian population (76.7%)[9] and is less than the accuracies in South Indian population (90%)[10]. In Japanese population, the accuracy obtained was much higher (85%) from a single variable (mastoid width) and 92% by using mastoid height and width together[8]. The diversity observed in different populations can be attributed to population-specific variability in cranial size and shape. In present study, Mastoid length is the best discriminant which is in agreement with other studies[9,10]. In another study among North Indians yield AST-Ms and Mastoid breadth as best discriminant[14] and among South Indians, Ms-Po as best discriminant[15].

CONCLUSION

The mastoid process is sexually dimorphic bone. The accuracy of sex determination by using mastoid variables was 76%. Mastoid length was found to be the best discriminant for sex determination and medio-lateral diameter was the second. The discriminant function equation obtained in this study is specific for skulls of Marathwada population.

REFERENCES

1. Gray's Anatomy the anatomical basis of clinical practice 40th edition. Susan Standering. Elsevier Churchill Livingstone. London; 2008: p1223.
2. Krogman WM. The human skeleton in forensic medicine. Springfield, IL: Charles C Thomas, 1962.
3. Phenice TW. A newly developed visual method of sexing the os pubis. American Journal of Physical Anthropology 1969; 30: 297-301.
4. Bass WM. Human Osteology: A Laboratory, Field Manual of the Human Skeleton. Special Publications of the Missouri Archaeological Society, Columbia 1971.
5. Kalmey JK, and Rathbun TA. Sex determination by discriminant function analysis of petrous portion of temporal bone. J Forensic Sci 1996; 41: 865-867.
6. Hoshi H. Sex difference in the shape of the mastoid process in norma occipitalis and its importance to the sex determination of the human skull. Okajima's Folia Anat Japonica 1962; 38: 309-317.
7. Paiva LAS, Segre M. Sexing the human skull through the mastoid process. Rev Hosp Cl_n Fac Med Sao Paulo 2003; 58(1):15–20.
8. Nagaoka T, Shizushima A, Sawada J, Tomo S, Hoshino K, Sato H, et al. Sex determination using mastoid process measurements: standards for Japanese human skeletons of the medieval and early modern periods. Anthropol Sci 2008; 116(2):105–13.
9. Sumati, Patnaik VVG, and Phatak A. Determination of sex from mastoid process by discriminant function analysis. J Anat Soc India 2010; 59(2): 222-28.
10. Gupta AD, Banerjee A, Kumar A, Rao SR, and Jose J. Discriminant Function Analysis of Mastoid Measurements in Sex Determination. J Life Sci 2012; 4(1): 1-5.
11. Introna F Jr, Di Vella G, Campobasso CP. Sex determination by discriminant analysis of patella measurements. Forensic Sci Int 1998; 95:39–45.
12. Laranch SL, Macintosh NWG. The craniology of the arborigines of Coastal New South Wales. The Oceania Monographs No.13. 1966; 43-4.
13. Giles E, Elliot O. Sex determination by discriminant function analysis of crania. American Journal of Physical Anthropology 1963; 21: 53–58.
14. Vineeta S, Rashmi S, Rajesh KR, Satya NS, Tej BS and Sunil KT. Sex estimation from the Mastoid Process among North Indians. J Forensic Sci 2011; 1-6.
15. Nidugala H, Avadhani R, Bhaskar B. Mastoid process- A tool for sex determination, an anatomical study in South

Indian skulls. International J Biomed Res 2013; 04(02): 106-10.
16. Verma Shobha, Ramesh Babu C.S. Sex determination by mastoid process in Western U.P. population. Journal of research in Human Anatomy and Embryology 2015; 1(1): 1-5.
17. Ghule SB, Mahajan AA,Wagh KB, Ambali MP. Sexual dimorphism in foramen magnum and mastoid process. International jr of recent trends in science and technology 2014; 12(1):56-9.
18. Kemkes A, Gobel T. Metric assessment of the ‘‘mastoid triangle’’ for sex determination: a validation study. J Forensic Sci 2006; 51:985–9.
19. Song HW, Lin ZQ, Jia JT. Sex diagnosis of Chinese skulls using multiple stepwise discriminant function analysis. Forensic Sci Int, 1992; 54(2): 135-140.

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