

**Research Article**

**Mastoid process – A tool for sex determination, an anatomical study in South Indian skulls**

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**Abstract**

**Objective:** The aim of this study is to evaluate the use of mastoid process as a tool for sex determination in unidentified skeleton.

**Methods:** Eighty (40 male and 40 female) complete undamaged skulls of known sex in book record were used for the study. Eight different measurements on the right mastoid of each skull were recorded. Measurements were made using vernier calipers (0.01mm). The values were subjected to univariate and multivariate analysis employing SPSS Windows 13.00 version program.

**Results:** Statistics revealed high significance ( $p < 0.000$ ) in five measurements except Asterion – porion, Posterior end of incisura mastoidea - depression of suprameatal triangle and Asterion-depression of suprameatal triangle. Direct method with all parameters gave discrimination accuracy of 82.5% and in step wise analysis an accuracy of 65.0%. Stepwise analysis selected Mastoidale – Porion as the best discriminant.

**Conclusion:** Reports on the use of mastoid process as a tool for sex estimation in unidentified human skeleton has been reported in different populations. The present study supports this finding among the South Indian population.

**Keywords:** Mastoid process, Sexual dimorphism, Discriminant function analysis, South Indian population

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**1. Introduction**

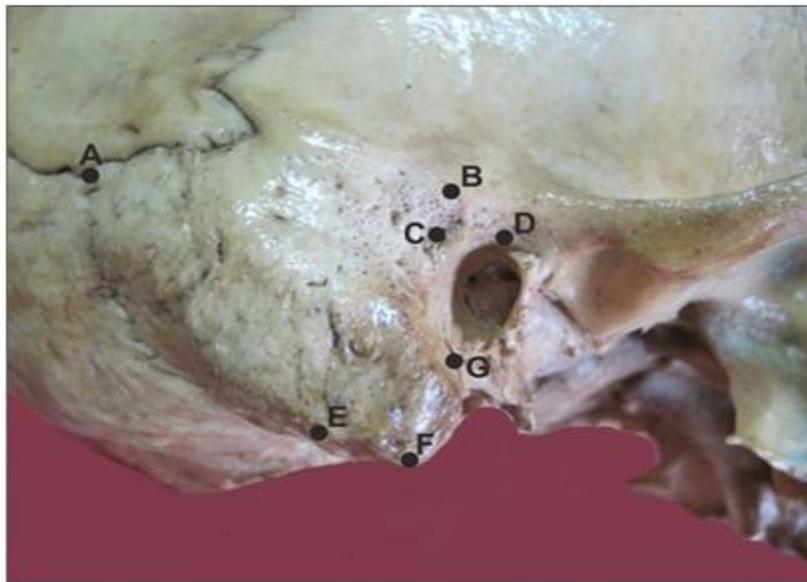
Studies on human skeletal remains for sex determination have been a topic of interest among researchers. Osteometric studies using individual bones exhibiting sexual dimorphism has been reported among different populations.<sup>1</sup> The pelvis and skull bones are widely used reporting almost 100% accuracy<sup>2-3</sup> followed by other bones such as femur<sup>4</sup>, humerus<sup>5</sup> etc. Dimorphism in skulls is based on its size and robustness. The male crania have well developed supraorbital ridges, broader palates, thicker zygomatic and larger mastoid process than those of females.<sup>6-7</sup> Skull bones such as mastoid, hard palate, craniofacial parts<sup>8</sup> have been analyzed for sex determination. A study by Demoulin<sup>9</sup> reported dimorphic traits in mastoid process. It is a bone less prone to damage due to its safe anatomical position.<sup>9</sup> Mastoid region is one of the slowest and late growing regions of cranium<sup>10</sup> and such regions show higher degree of sexual dimorphism in adulthood.<sup>11</sup> The differences in size of the mastoid process between sexes could be attributed to the variable growth duration in males

and females, along with relatively greater development of the mastoid process in males in response to stronger muscle actions of the sternocleidomastoid, splenius capitis and longissimus capitis.<sup>11</sup> So this region can be considered vital for diagnosis of sex from visual assessment as well as osteometric basis. The objective of this study is to validate the use of mastoid process for assessing the sex of the human skull and signify the use of statistical approach in estimation of sex from fragmentary crania.

## 2. Materials and Methods

The study sample includes 80 adult skulls, 40 males and 40 females aged between 35-60yrs at time of death from the Department of Anatomy, Yenepoya Medical College, Yenepoya University, South India. Skulls with good conditions with gender identified in book record were included and those which were damaged, incomplete or without identification were excluded from the study. In each cranium, from the right mastoid the following measurements were recorded using vernier calipers (Forbes, 0.01mm precision) (Fig 1). The straight distance from the tip of the mastoid process to the upper rim of the zygomatic arch was measured for the mastoid length (ML). For Mastoid breadth (MB), distance from the posterior end of the incisura mastoidea (PEIM) to the nearest point on the posterior border of the external auditory meatus was measured. Asterion-porion (AST-PO) is the length of the mastoid process measured from the asterion to the porion. In Posterior end of incisura mastoidea-depression of suprimeatal triangle (PEIM-DSMT), the distance from the posterior end of incisura mastoidea to the depression in the supra meatal triangle was measured. The length of mastoid process measured from the porion to the posterior end of the incisura mastoidea is taken for PEIM-PO. In Asterion-depression of suprimeatal triangle (AST-DSMT), the distance from asterion to the depression of the suprimeatal triangle was measured. The distance from asterion to the mastoidale was taken for Asterion-mastoidale (AST-MS) and the height of the mastoid process from Mastoidale to porion was measured for Mastoidale–porion (MS-PO).

**Fig. 1 showing the landmarks in the right mastoid for the measurements.**



ML – Length between tip of the mastoid process (F) to upper rim of zygomatic arch (B);

MB – Length between posterior end of incisura mastoidea (E) to posterior border of external Auditory meatus (G). ;

AST - PO – Length between asterion (A) to porion (D). ;

PEIM-DSMT –Length between posterior end of incisura mastoidea (E) to depression in the suprimeatal triangle ©;

PEIM - PO – Length between posterior end of incisura mastoidea (E) to porion (D).;

AST- DSMT –Length between asterion (A) to depression in the suprimeatal triangle (C).;

AST - MS – Length between asterion (A) to mastoidale (F).;

MS - PO – Length between mastoidale (F) to porion (D).

## 2.1 Statistical analysis

The data were analyzed using statistical software package SPSS 13.0 program (SPSS Inc., Chicago, IL).<sup>12</sup> Descriptive statistics, including mean and standard deviations were obtained for each of the measurements. Stepwise, univariate and multivariate direct discriminant function analysis were performed to calculate specific discriminant function equation for all parameters.

## 3. Results

The descriptive statistics for all the measurements with t-values and p-values are presented in Table 1. The t- value indicates that the five measurements except AST- PO, PEIM –DSMT and AST – DSMT shows highly significant differences between male and female (p<0.000).

**Table 1: Descriptive statistics with t-values of mastoid parameters.**

Mastoid variable	Female		Male		t-value	p-value (p<0.05)
	Mean	SD	Mean	SD		
ML	30.55	4.09	35.63	3.91	5.672	0.000*
MB	20.03	2.74	21.97	2.60	3.242	0.002*
AST- PO	42.87	3.08	44.48	4.14	1.979	0.051
PEIM- DSMT	23.96	3.80	24.10	3.94	0.164	0.870
PEIM- PO	25.72	3.43	28.75	3.08	4.160	0.000*
AST- DSMT	39.31	3.56	39.21	4.29	0.113	0.910
AST- MS	46.51	4.12	50.11	4.54	3.719	0.000*
MS- PO	24.26	3.77	29.52	3.34	6.601	0.000*

All measurements are in millimeters.

n=40 \* significant

ML- Mastoid length ,

MB- Mastoid breadth,

AST-PO- Asterion-porion ,

PEIM-DSMT- Posterior end of incisura mastoidea-depression of suprameatal triangle,

PEIM-PO - Posterior end of incisura mastoidea – porion,

AST-DSMT- Asterion-depression of suprameatal triangle,

AST-MS- Asterion-mastoidale,

MS-PO- Mastoidale–porion/mastoid height.

Table 2 shows the results of multivariate analysis using all variables. Direct method indicates that overall accuracy of sex determination by using all parameters is 82.5%. For males the average accuracy is 85.0% and for females it is 80.0%. The Wilk's lambda is 0.543. The formula derived is ---  $y = (0.068 \times ML) + (0.066 \times MB) + (0.056 \times AST- PO) + (-0.159 \times PEIM- DSMT) + (0.086 \times PEIM- PO) + (-0.071 \times AST- DSMT) + (0.073 \times AST- MS) + (0.141 \times MS- PO) + (-9.113)$ . Using stepwise discriminant function analysis only one variable is selected as the best discriminant between sexes *i.e.* MS - PO (Table 2) with Wilk's lambda 0.642. Using stepwise discriminant score, an average accuracy of 65.0% was obtained (Table 2). The formula derived is ---  $y = (0.281 \times MS- PO) + (-7.550)$ . For males average accuracy is 80.0% and for females it is 100% (Table 2).The discriminant function equation obtained in this study is unique to skulls of South Indian population.

**Table 2: Discriminant function analysis for mastoid parameters.**

Variable	Unstandardised coefficients	Standardised coefficients	Wilk's lamda	Structure matrix	Constant	Centroid	Average accuracy
<b>Direct method</b>							
ML	0.068	0.27	0.543	0.700	-9.113	M = 0.906 F = -0.906	M=80% F=85% Overall=82.5%
MB	0.066	0.176		0.400			
AST- PO	0.056	0.203		0.244			
PEIM - DSMT	-0.159	-0.617		0.020			
PEIM- PO	0.086	0.279		0.513			
AST- DSMT	-0.071	-0.279		-0.014			
AST -MS	0.073	0.317		0.459			
MS- PO	0.141	0.502		0.814			
<b>Stepwise method</b>							
MS- PO	0.28	1	0.642	1	-7.550	M = 0.738 F = - 0.738	M=80% F=100% Overall=65.0%

#### 4. Discussion

The results of this study shows that there is a sexual dimorphism in the dimensions of the mastoid region and establish its value as a sex indicator in South Indian population. Discriminant function analysis is exclusively objective and is used extensively for sex determination.<sup>13</sup> As a non- metric approach is entirely subjective and accurate in hands of experienced and trained people, few researchers studied the sexual dimorphism in mastoid process by metric approach.<sup>13</sup> The average accuracy by direct method in our study was 85% in males and 80% in females. Compared to literature data (male% vs female%) 61% vs 52%,<sup>14</sup> 60% vs 72%,<sup>14</sup> 60% vs 60%<sup>15-16</sup> our values are higher except in a study in North Indian population (males 92.3%, females 70.2%).<sup>17</sup> The overall accuracy is higher in direct method (82.5% vs 76.7%) and lower in stepwise analysis(65% vs 66.7% ) in our study compared to North Indian population.<sup>18</sup>

In the present study stepwise analysis selects MS-PO as the best discriminant which is in agreement with a study among Japanese population with an accuracy of 69.6%.<sup>19</sup> In a North Indian study<sup>18</sup> ML (mastoid length) was best determinant which is similar to Gupta's finding.<sup>20</sup> In another study among same population yield AST-MS and MB as best discriminants.<sup>17</sup> The variations in the result in different population may be due to the inconsistency in the position of landmarks of the skull in different populations.<sup>21</sup> Craniofacial growth like mastoid region, zygomatic process and the ridges of occipital bone are influenced by nutrition, environment and genetic factors.<sup>22</sup>

#### 5. Conclusion

This is an attempt to validate the osteological criterion for sex determination based on the mastoid process. The proper identification of landmarks, careful measurements and strict statistical methods will yield reliable results.

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