DETERMINATION OF SEX FROM MASTOID PROCESS BY DISCRIMINANT FUNCTION ANALYSIS.

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ABSTRACT

Sex determination is vital for the identification of an individual. Often fragmentary remains are available for forensic identification making sex determination difficult. The mastoid region, a fragmentary piece of skull, is ideal for studying sexual dimorphism as it is resistant to damage due to its anatomical position at the base of skull. The skull measurements vary significantly in different ethnic groups and the discrimination models for Indian populations are rare.

In the present study, 60 adult human skulls of North Indian individuals were studied to determine accuracy of mastoid process in sex determination. Mastoid length, breadth and antero-posterior diameter of the mastoid process were measured to calculate the size of mastoid process.

Discriminant function analysis revealed that mastoid process correctly classified the sex in 76.7% of the subjects and mastoid length was found to be the best determinant for sex although the classification rate dropped to 66.7%. A discriminant function equation specific for North Indian population has also been derived from mastoid variables.

Key words: sex determination; mastoid process; discriminant analysis; craniometry

INTRODUCTION

Determination of sex is critical for the identification of an individual[1]. Advanced decomposition, mutilation or incineration of body necessiates the examination of skeletal remains for sex determination[2]. The sex is best assessed from the pelvis but it is very often damaged[3]. The skull is the second best area for sex determination, but the determination of the sex from the skull is not reliable until well after puberty[4].

Success in sex determination depends upon the completeness of the skeleton[5]. Often fragmentary remains are available, instead of, complete skeletons for forensic identification[6]. Henceforth, individual parts of the skull like mastoid, hard palate have been analysed by few researchers for sex determination. The mastoid region is favourable for sex determination, as it is the most protected region and resistant to damage, due to its anatomical position at the base of the skull[7]. The mastoid process is sexually dimorphic has been affirmed non-metrically by Hoshi[8]; Larnach and Macintosh[9,10]; Williams and Rogers [11] and metrically by De Moulin[12]; Sarangi et al[13]; Saavedra de Paiva and Segre[7]. Discriminant function analysis is an entirely objective statistical technique for sex determination[14]. It selects the minimum number of traits yielding maximum discriminatory effectiveness[3]. The efficacy of sex discriminant functions is not sure in populations other than the ones from which they have been derived[15]. Faced with a skull of unknown provenance it is obviously wisest to determine first its race and then its sex by the function appropriate to sex within that race [16].

The present study aims to select the mastoid measurement that has maximum sex discriminatory power among all mastoid variables via Discriminant function analysis. Logistic regression was also applied on mastoid variables to validate the results of Discriminant function analysis. Discriminant function equation has also been derived in present study which will help in determination of sex of skulls of North Indian population from a fragmentary piece of skull.

MATERIALS AND METHODS

60 adult macerated human skulls (30 of either sex) of North Indian individuals were studied to determine

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the accuracy of mastoid process in sex determination. The sample for the study were drawn from the Department of Anatomy and Forensic medicine, Government Medical college, Patiala.

The skulls of known sex in which spheno-occipital junction was synostosed and the mastoid part of temporal bone was intact were included for the study.

The skulls with physical damage, apparent deformity, defect and disease or in which spheno-occipital junction was not synostosed (juvenile skullls) or in which ecto-cranial sutures have completely disappeared (senile skulls) were excluded from the study.

The mastoid measurements were obtained with sliding caliper to the nearest millimeter (mm) as per standard anthropological conventions and then the size of mastoid process was calculated.

The mastoid measurements were taken on both sides, that is right and left side and then the average of both was considered for statistical analysis.

All the measurements were taken after taking biometric training and by single observer to avoid any inter-observer error.

1. **Mastoid Length:**

The length of the mastoid is measured from a point on the Frankfort plane vertically downwards to the tip of the mastoid process[9]. **(Photograph 2)**

Frankfort plane: is a horizontal plane passing through the upper margin of the external acoustic meatus and the lower margin of the orbital opening. **(Photograph 1)**

With the skull lying on its right side and facing the observer, the calibrated bar of the caliper was placed just behind the process on the left side, so that the fixed arm was tangent to the upper border of the auditory meatus and pointing by (visual sighting) to the lowest point on the border of the orbit. The calibrated bar should be perperndicular to the Frankfort plane of the skull. The measuring arm was moved until it was level with the tip of the process, using the flat surface of the arm once more as control to sight across the tip of process and, where possible, to tip of the opposite process as well.

2. Mastoid Breadth (Medio-lateral Diameter): **(Photograph 3)**

It is taken from the highest part of the medial surface of the mastoid process within the digastric fossa to the most lateral point of the process on the same level[9].

3. Antero-Posterior Diameter of the Mastoid Process : **(Photograph 4)**

It is taken from the lowest point at which the tympanic plate abuts against the anterior surface of the mastoid process to the posterior border of the process on the same level[9].

4. **Size of the Mastoid Process)[9]:**

$$\frac{\text{Length x Antero-Posterior Diameter x Breadth}}{100}$$

The data obtained was tabulated and analysed using SPSS-14 software.

RESULTS

The mastoid process was intact and measurable for all the 60 skulls (30 male, 30 female). The univariate analysis revealed significant differences across gender for all mastoid measurements (Table I). The relationship was further explored by discriminant function analysis.

DISCRIMINANT FUNCTION EQUATION

The discriminant function equation for the determination of sex is :

D = -7.35 + 0.199 X Mastoid Length + 0.233 X Mastoid Breadth + 0.04 X A-P Diameter 0.016 X Size of Mastoid Process.

The cut-off point for discrimination between the gender is

½ (0.675+ (-0.675)) = 0.

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 zero, the case is classified as "Male".

The discriminant function analysis was performed including all the mastoid variables which correctly classified 76.7% of the cases (80% males and 73.3% females). Cross validation using "Leave one out method" proves that the model was fairly reliable (Table II).

Exploring the data with step wise analysis showed that the mastoid length was best predictor for sex determination among the four mastoid variables although the overall classification rate dropped from 76.7% to 66.7%. The stepwise model was indeed found highly reliable (Table III).

The external validity of the model was checked by Logistic regression (data not shown) which is robust against violation of normality and homoscedasticity.

	Male		**Female**		**p-Value**
	Mean	SD	Mean	SD	
Mastoid Length	28.3	4.04	23.18	4.24	<0.0001
Mastoid Breath	11.46	2.7	8.68	2.59	0.0001
A- P Diameter	17.52	4.69	13.69	3.67	0.0008
Size of Mastoid process	60.18	31.33	30.99	22.67	0.0001

Table I : Group Statistics for mastoid measurements

		Predicted Group Membership	
		Male	Female
		n(%)	n(%)
Observed	Male	24 (80)	6 (20)
	Female	8 (26.7)	22 (73.3)
Cross-validated	Male	23 (76.7)	7 (23.3)
	Female	9 (30)	21 (70)

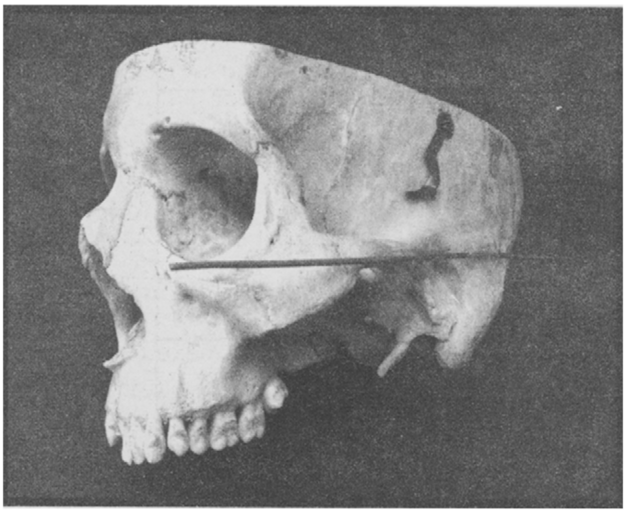
Table II : Classification results of all mastoid variables

		Predicted Group Membership	
		Male	Female
		n(%)	n(%)
Observed	Male	21 (70)	9 (30)
	Female	11 (36.7)	19 (63.3)
Cross-validated	Male	21 (70)	9 (30)
	Female	11 (36.7)	19 (63.3)

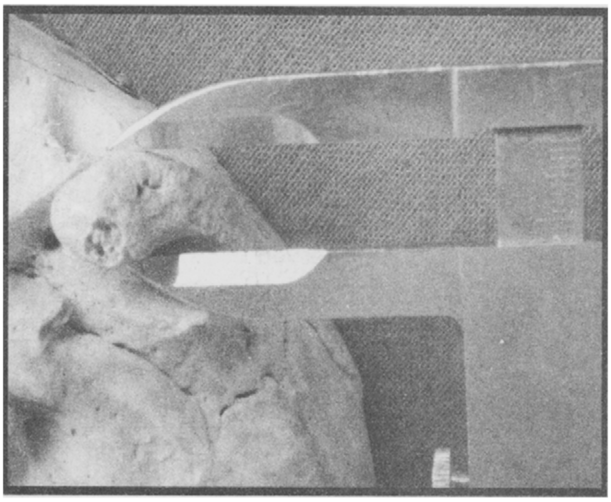
Table III : Classification results of mastoid length

Authors	Males	Females	Region of Study
Keen (1950)	29.3	26.5	Cape coloured population
Giles and Elliot (1963)	28.067 30.320	25.213 26.347	Whites Negroes
Present study	28.3	23.18	North Indian

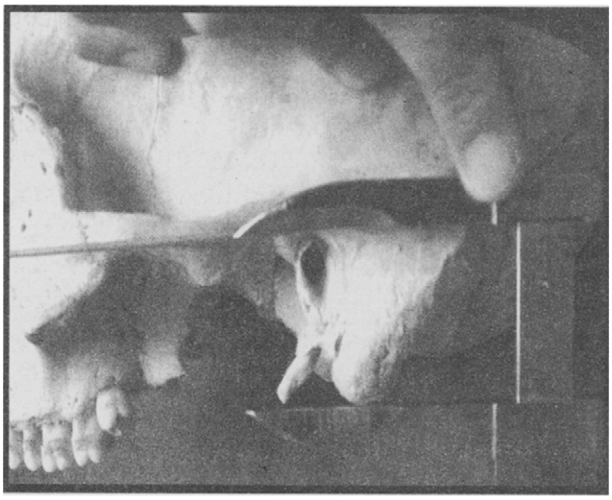
Table IV : Mean mastoid length of skulls of male and female individuals (Present study compared to earlier published data)



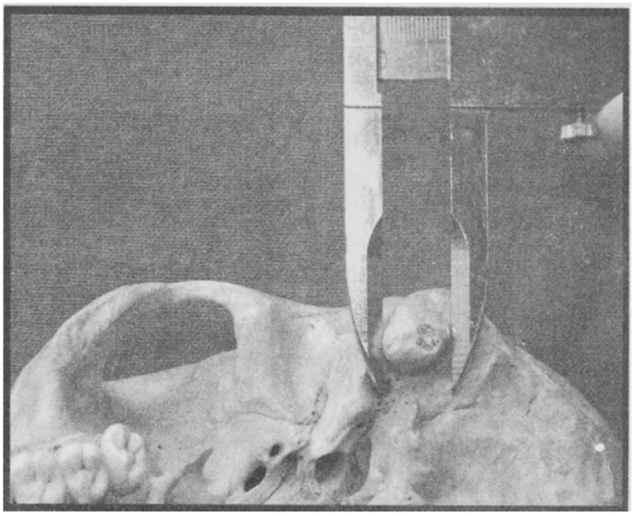
Photograph 1 : Frankfort Plane



Photograph 3 : Mastoid Breadth



Photograph 2 : Mastoid Length



Photograph 4 : Antero- posterior Diameter of the Mastoid Process

The results were very much similar but a bit higher correct classification rate in stepwise analysis (68.3% in logistic method vs. 66.7% in discriminant analysis).

DISCUSSION

The present study has provided a baseline data for sex determination of skulls of North Indian individuals from the fragmentary piece of skull bone, mastoid process.

The sexual dimorphism of the mastoid process have been studied both by non- metric and metric techniques.

Klaatsch[17] observed that female skulls generally preserve infantile type of small mastoid process, while the male present great variability.

Hoshi[8] classified the mastoid processes into three main types, viz. M, N and F type (M- male, N-neutral, F- female type), based on the direction of the mastoid process in relation to a vertical plane as assessed visually. He also suggested that when skulls were placed on flat surface, the male skulls rest on the mastoid processes while female skulls on occipital condyles or other portions of the skull.

Larnach and Macintosh[9,10] calculated size of mastoid process and divided it into five grades (very small, small, medium, large or very large). They concluded from their consecutive studies that females have predominantly very small to small sized mastoids in comparison to males who have predominantly medium to large sized mastoids.

Williams and Rogers [11] identified mastoid size as one of the high quality trait (>=80% accuracy and =<10% intraobserver error) for sex determination in comparison to Rogers[18] who proved it to be of tertiary consideration.

Few researchers studied the sexual dimorphism in mastoid process by metric approach as non-metric approach is entirely subjective, accurate in hands of experienced and trained persons.

Keen [19]; Giles and Elliot[20] observed that mean mastoid length was more in skulls of male individuals as compared to skulls of female individuals irrespective of race or region.

De Moulin[12] and Sarangi et al[13] concluded subsequent to their study on French and Indian sample that value of mastoid module was extremely significant for sex determination.

Saavedra de Paiva and Segre [7] affirmed that the value of mastoid triangular areas defined by three distinct craniometric landmarks: porion, mastoidale and asterion was useful in sexing of the skulls but Kemkes and Gobel[21] have hypothesized that population-specific variability of the asterion location undermine the value of the mastoid triangle as a sex determinant.

Patil and Mody [4] studied lateral cephalometric radiographs of Central Indian individuals and selected 10 cephalometric variables that helped in sex determination. These cephalometric variables included mastoid height and mastoid width. A discriminant function equation based on 10 cephalometric variables has also been derived.

In the present study, 60 adult human skulls were studied to know the accuracy of mastoid process in sex determination. It was found that the mean values of mastoid length, breadth, antero-posterior diameter and size of mastoid process was more in males as compared to females and all four mastoid variables were highly significant for sex determination as revealed from its 'p' value. The four mastoid variables were statistically analysed by Discriminant function analysis. The results showed that the four mastoid variables correctly sexed 76.7% of the sample. Subsequent to stepwise discriminant function analysis, mastoid length was found to the best sex determinant that alone correctly sexed the sample with an accuracy of 66.7%.

It is evident from Table IV that mean values of mastoid length is more in skulls of male individuals as compared to skulls of female individuals irrespective of race or region.

Hoshi [8] stated that male skulls when placed on flat surface rest on mastoid processes where as females on occipital condyles. This observation indirectly indicates that males skulls have more mastoid length as compared to female skulls, that is why, male skulls rest on mastoid processes but not female skulls.

Larnach and Macintosh[9,10]; Present study results affirm that the size of mastoid process is important for sexual diagnosis. Larnach and Macintosh [9,10] stated that females have very small to small sized mastoids and males have medium to large sized mastoids. In the present study, the mean value of the size of mastoid process was more in skulls of male individuals (60.18) as compared to skulls of female individuals (30. 99).

In addition to the technique (metric or non-metric), the accuracy depends partly upon the statistical method employed, therefore stringent statistical technique need to be employed to obtain reliable effects. Thus, in present study, Discriminant function analysis which is the entirely objective and widely used statistical technique for sex determination from skeletal remains has been employed. Further the external validity of the model has been checked with robust statistical tool viz. Logistic regression to ensure generalizability of the model in North Indian populations.

In present study, four mastoid variables correctly sexed 76.7% of the sample, where as mastoid length correctly sexed 66.7% of the sample. This suggests that the predictive value of sexual dimorphism depends upon the sex discriminatory power of variables rather than on the number of variables.

The discriminant function equation for sex determination has been derived by few researchers like Song et al[22] for Chinese skulls, Patil and Mody[4] for Central Indian population. The equation derived by them was based on many cephalometric variables, but in the present study, the discriminant equation that has been derived is based only on mastoid variables. Thus, with the help of the discriminant equation derived in present study, the sex of an individual can be determined from fragmentary piece of skull.

Johnson et al[16] found that the best discriminators for race are not necessarily the best for sex. The sex within each race is best described by a unique discriminant function. Thus, the discriminant function equation obtained in present study is unique to skulls of North Indian population only.

CONCLUSIONS

1. Mastoid process correctly sexed 76.7% of the sample
2. Mastoid length was found to be the best sex determinant amongst four mastoid variables (mastoid length, breadth, antero-posterior diameter and size of mastoid process).
3. The discriminant function equation obtained in present study is specific for skulls of North Indian population.

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