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Research Article

DETERMINATION OF SEX FROM HARD PALATE BY DISCRIMINANT FUNCTION ANALYSIS

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ABSTRACT

Sex determination from human skeletal remains is a subject of continuous investigation in the field of physical anthropology, as it is particularly critical for the purpose of human identification. The skull is probably the second best area of the skeleton for determining sex following pelvis. Sexing from bones in forensic cases has limited success as the bones are available in fragments. Hard palate is preserved even in severe damages to skull, hence apt for studying sexual dimorphism. 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 of known sex (30 of either) were studied to determine accuracy of hard palate measurements in sex determination. Length and breadth of the hard palate were measured to calculate size of palate and maxilloalveolar index.
Discriminant function analysis revealed that size of palate correctly classified the sex with an accuracy of 70%. Discriminant equations have also been derived in present study.

Key Words*: *Sex Determination, Craniometry, Discriminant Analysis, Hard Palate

INTRODUCTION

Sex, age and racial affinity are the three most vital determinations that must be made when dealing with skeletal remains (Iscan and Helmer, 1993). Sex determination is important for the identification of an individual since many skeletal features vary by gender. For example, regression formulae to determine statures are sex specific (Trotter and Gleser, 1958). The sex is best assessed from the pelvis but the skull also offers a number of very good sex indicators and is usually better preserved (Iscan and Helmer, 1993). Bass (1995) stated that skull is probably the second best area of the skeleton for determining sex.
Success in sex determination is limited by the fragmented, scattered, incomplete or burned remains (Reichs, 1986b), but in the forensic identification often fragmentary remains are available (Burris and Harris, 1998). Even broken parts are sufficient, if appropriate areas (pelvis, femoral heads, skull and sternum) are represented (Kerley, 1977). As often fragmentary remains are available for forensic identification, thus the sexual dimorphism of those areas/individual bones of the skeleton should be studied that are most protected and resistant to damage. This will help in identifying the areas/bones of the skeleton that are most resistant to damage as well as have higher accuracy in sex determination.
Bony and dental structures of the palate often are preserved even in the face of serious bodily damage at or following death. The sexual dimorphism of the hard palate has been affirmed by Woo (1949); Larnach and Macintosh (1966, 1970).
The technique for sex determination fall into two broad categories: metric and observational (Reichs, 1986a). Discriminant function analysis is an entirely objective statistical technique for sex determination (Hsiao *et al*., 1996). As the best discriminators for race are not necessarily the best for sex, so skulls of unknown provenance are best tested first for race and then for sex, using different variables for each purpose (Johnson *et al*., 1989).

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The present study aims to study the sexual dimorphism of hard palate variables via discriminant function analysis and discriminant function equations have also been derived, so that sex of skulls of North Indian population can be predicted from fragment of skull with intact hard palate.

MATERIALS AND METHODS

60 adult human skulls (30 of either sex) of North Indian individuals were studied to determine accuracy of hard palate in sex determination. The samples 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 all required landmarks were 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 skulls) or in which ecto-cranial sutures have completely disappeared and edentolous skulls with wasted alveolar processes (senile skulls) were excluded from the study.

All the measurements were obtained with sliding caliper to the nearest millimeter, as per standard anthropological conventions and then Maxillo-Alveolar index, Size of palate was calculated. In skulls with protruding teeth, where it was difficult to take measurement with sliding caliper, spreading caliper was used.

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

Bony landmarks

Alveolon (Figure 1): The point where the mid-sagittal plane intersects a straight wire placed against the posterior margins of the alveolar processes of the maxilla (Moore Jansen *et al.*, 1994). This point is used in the measurement of Maxillo-alveolar length.

Prosthion (Figure 2): The most anterior point on the alveolar border of the maxilla between the central incisors in the mid-sagittal plane (Moore Jansen *et al.*, 1994).

Metric Measurements

External Palate Breadth (Figur3): The greatest breadth across the alveolar borders, wherever found perpendicular to the median plane (Howells, 1973). With the skull base up, the flat arms of the caliper were applied to the bone of alveolar border to find the maximum reading, being sure the arms were parallel to the midline.

Maxillo-Alveolar Breadth (Figure 4): The maximum breadth across the alveolar borders of the maxilla measured on the lateral surfaces at the location of the second maxillary molars (Moore Jansen *et al.*, 1994).

Maxillo-Alveolar Length (Figure 5): The direct distance from prosthion to alveolon (Moore Jansen *et al.*, 1994). With the skull base up, one end of the caliper was placed on prosthion and other on the middle of the straight wire placed across the posterior edges of the alveolar processes (alveolon) of the two sides, in the mid-sagittal plane.

Maxillo-Alveolar Index:

$$\frac{\text{Maxillo-Alveolar Breadth}}{\text{Maxillo-Alveolar Length}} \times 100 \quad \text{……………. (Bass, 1995)}$$

Size of Palate:

$$\frac{\text{Maxillo-Alveolar Length} \times \text{Maxillo-Alveolar Breadth}}{100} \quad \text{…… (Larnach and Macintosh, 1966)}$$

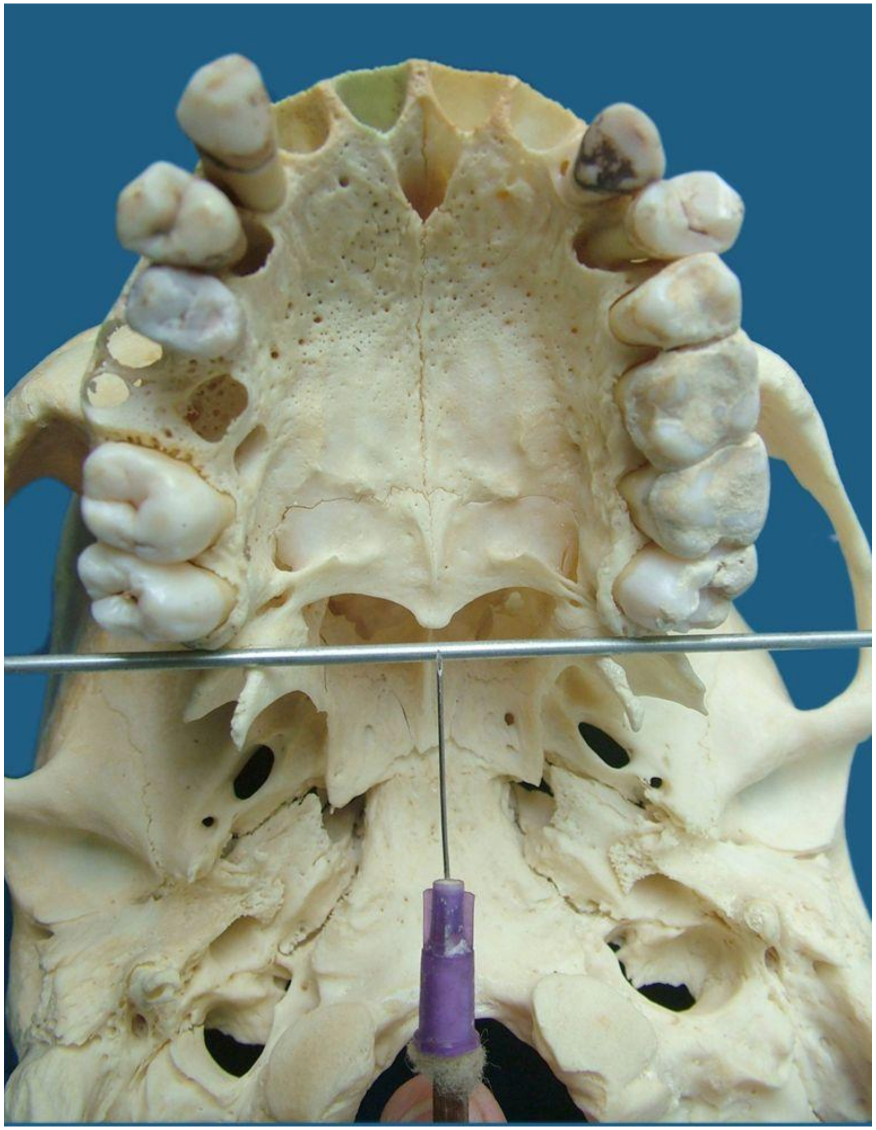

Figure 1: Alveolon

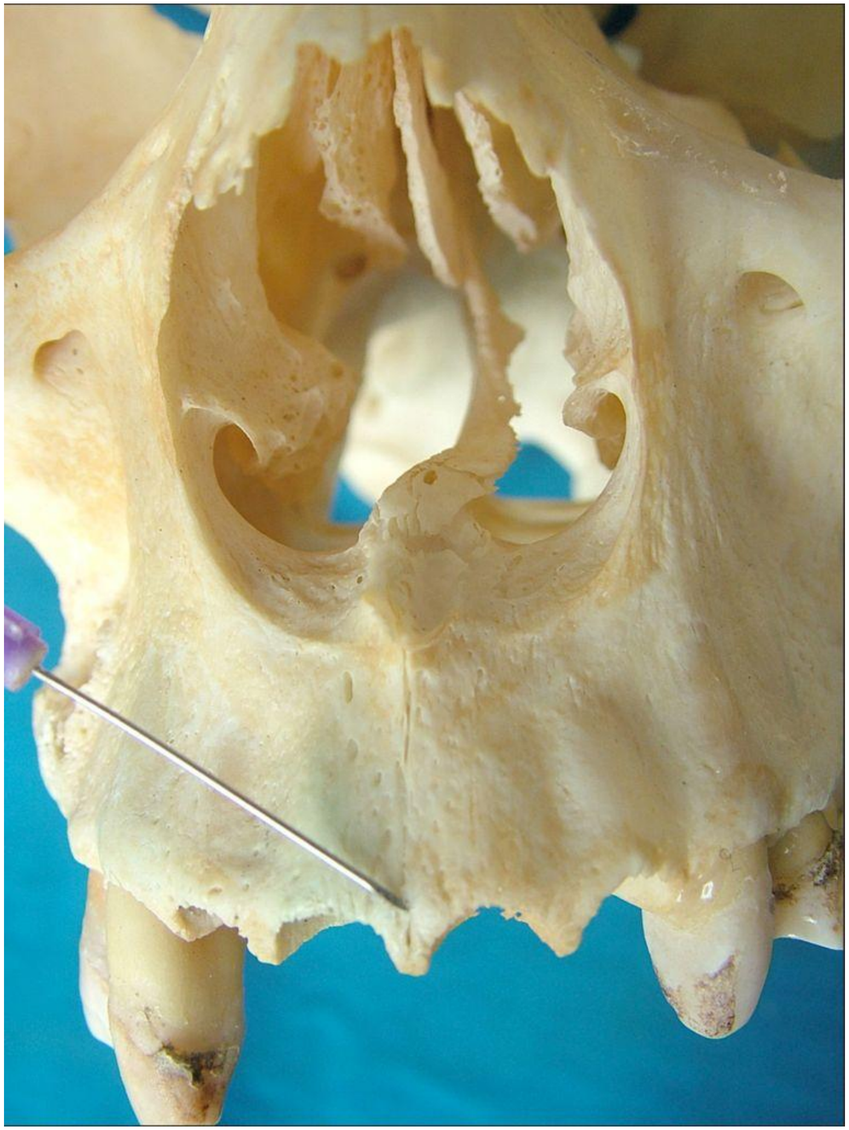

Figure 2: Prosthion

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Figure 3: External palate breadth

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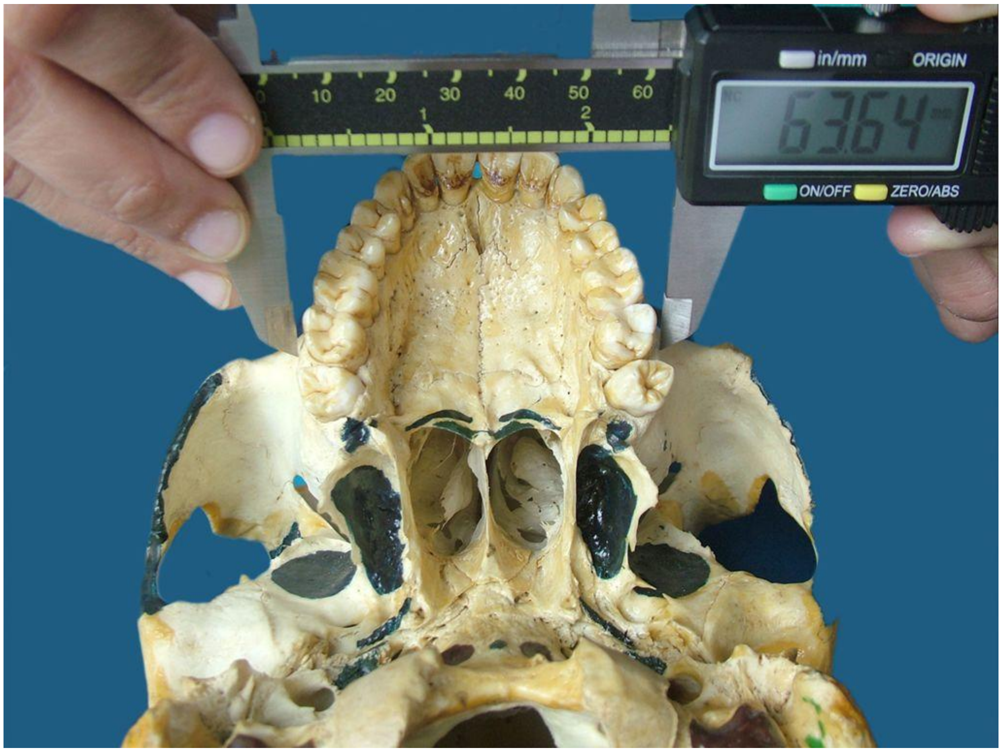

Figure 4: Maxillo-alveolar breadth

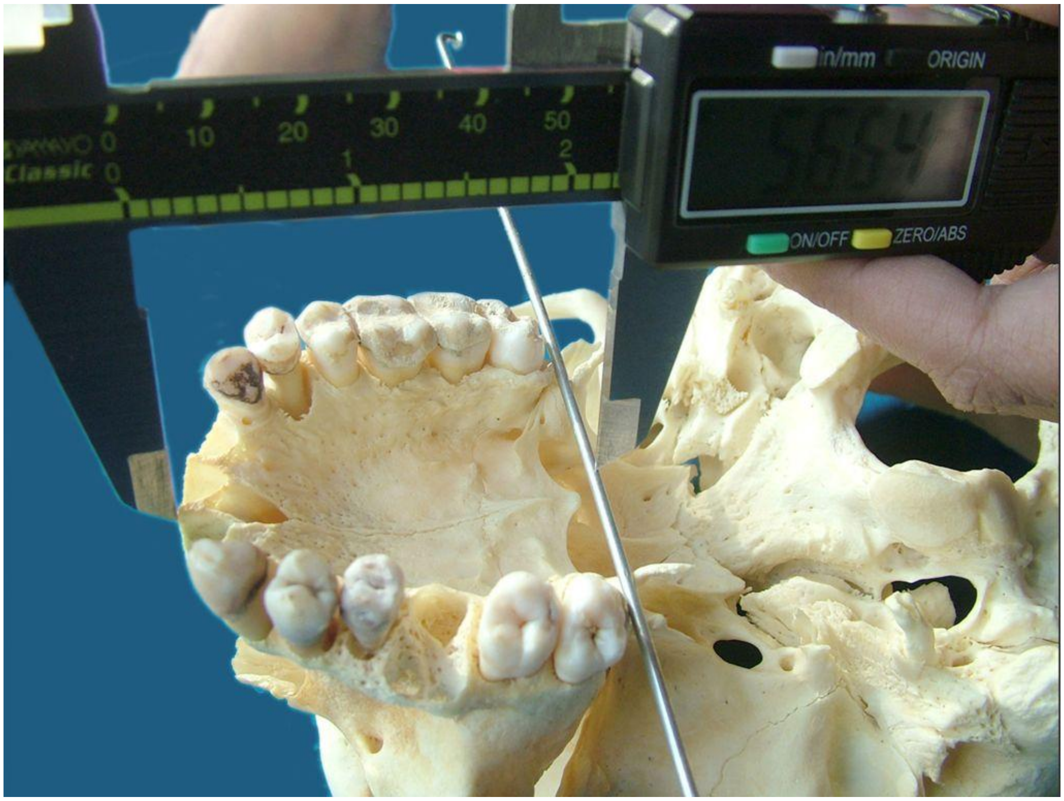

Figure 5: Maxillo-alveolar length

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The data obtained was tabulated and statistically analyzed by Discriminant function analysis.

RESULTS

The 60 skulls (30 male, 30 female) were measurable for all the hard palate measurements. The univariate analysis reveals significant differences across gender for all hard palate variables except maxillo-alveolar index (Table 1). The relationship has been further explored by Discriminant function analysis.

Table 1: Group Statistics for hard palate measurements

	Male		Female		p-value
	Mean	SD	Mean	SD	
External Palate Breadth	61.18	4.40	57.63	4.22	0.002*
Maxillo-Alveolar Breadth	60.36	4.43	56.94	4.41	0.004*
Maxillo-Alveolar Length	51.55	4.50	48.81	5.04	0.031*
Maxillo-Alveolar Index	117.83	12.30	118.05	11.90	0.95
Size of Palate	31.15	3.76	27.86	4.10	0.002*

***** *Significant at 5 % level of significance*

Discriminant Function Equation

The discriminant function equation for the determination of sex from all hard palate variables is:

Z = -11.811 - 0.325 X External palate breadth - 0.030 X Maxillo-alveolar breadth + 0.441 X Maxillo-alveolar length + 0.161 X Maxillo-alveolar index - 0.279 X Size of palate

The cut off point for discrimination between gender is ½ (0.502-0.502) = 0.

The discriminant function analysis has been performed on all the hard palate variables which correctly classified 70.0% of the cases (73.3% males and 66.7% females). Cross validation using "Leave one out method" proves that the model is fairly reliable with 65% cases correctly classified (Table II). Exploring the data further with stepwise analysis reveals that the size of palate is best predictor for sex determination among the five hard palate variables. The size of palate alone correctly classified 70.0% of the cases which is equivalent to the correct classification rate of all the five hard palate variables. The stepwise model has been found indeed highly reliable with exactly 70% cases correctly classified (data not shown).

Table 2: Classification results of all hard palate variables

		Predicted Group Membership	
		Male n (%)	Female n (%)
Observed	Male	22 (73.3)	8 (26.7)
	Female	10 (33.3)	20 (66.7)
Cross-validated	Male	20 (66.7)	10 (33.3)
	Female	11(36.7)	19 (63.3)

The external validity of the model has been checked by Logistic regression (data not shown) which is robust against violation of normality and homoscedasticity. The results show that the correct classification rate in stepwise analysis dropped from 70.0% (discriminant analysis) to 66.7% (logistic method). Subsequent to stepwise analysis in logistic regression, external palate breadth has been found to be the best sex predictor vis-a-vis size of palate via discriminant function analysis.

DISCUSSION

In the present study, 60 adult human skulls were studied to know the accuracy of hard palate variables in sex determination. It has been found that if any skull with intact hard palate is available, then sex of that skull can be determined with an accuracy of 70%. The present study has provided baseline data for the determination of sex of North Indian individuals from a fragment of skull, that is, hard palate.

The techniques for sex determination from crania are based either on visually determinable descriptive features of the cranium or on exact measurements of various parts of cranium and their ratios. The observational technique is accurate in the hands of expert, but it requires training and experience and is inaccurate when used by the layman. In addition to technique, the accuracy of sex determination 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 most 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.

The present study also suggests that the predictive value of sexual dimorphism depends upon the sex discriminatory power of the variables than on the number of variables. In case of hard palate, whether all five hard palate variables or only size of palate is considered for analysis, same correct classification rate, that is, 70% has been obtained. In the present study, the discriminant equations based on hard palate variables has been derived. Johnson *et al.,* (1990) found that the efficacy of sex discriminant equations is not sure in populations other than the ones from which they have been derived. Kemkes and Grottenhaler (2001) have stated that that the metric analysis are extremely population specific and may be less accurate when applied to individuals of unknown sample origin. Thus, the discriminant equations obtained in present study are specific for North Indian population.

Krogman (1946) enlisted palate among the characters of the skull which show maximum contrast between the sexes. Rogers (2005) has ranked palate size/shape as sixth among the 17 morphological features of the skulls used for sexing unknown skeletal remains. Bigoni *et al.,* (2010) noted significant sex differences in the region of palate.

Giles and Elliot (1963) and Song *et al.,* (1992) studied skulls for sex determination by discriminant function analysis after taking several measurements. In the Table III, the mean values of the three hard palate measurements (External palate breadth; Maxillo-alveolar breadth and Maxillo-alveolar length) have been compared with earlier accessible published data.

Table 3: Mean values of three hard palate measurements of male and female individuals (Present study compared to earlier published data)

Variable	Author	Region of study	Male	Female
External palate breadth	Giles and Elliot, 1963	Negroes	65.387	62.80
		Whites	59.867	57.027
	Present study	North Indians	61.18	57.63
Maxillo-alveolar breadth	Song *et al.*, 1992	Chinese	65.5	60.9
	Present study	North Indians	60.36	56.94
Maxillo-alveolar length	Song *et al.*, 1992	Chinese	50.6	49.0
	Present study	North Indians	51.55	48.81

Table 3 shows that the mean values of the three hard palate measurements (External palate breadth; Maxillo-alveolar breadth and Maxillo-alveolar length) in males stands at a higher level vis-à-vis females of the same region in given racial groups. The same cannot be categorically stated in mixed groups or groups of unknown races as there is evident overlap (External palate breadth - as seen in females of Negroes versus males of Whites and North Indians; Maxillo-alveolar breadth - as seen in females of Chinese versus males of North Indians). Consequently sex determination should necessarily be preceded by determination of race.

Johnson *et al.*, (1989) have also affirmed from their study that skulls of unknown provenance should be tested first for race and then for sex. This is in line with what is inferred just above.
Johnson *et al.*, (1989) selected palatal length as one of the best variable for sex determination of caucasiod skulls.
In the present study, subsequent to statistical analysis of the five hard palate variables by Logistic regression, external palate breadth has been found to the best sex determinant. External palate breadth alone correctly classified 66.7% of the sample.

Maxillo-alveolar Index

Woo(1949) studied hard palates of 2,214 skulls in five different racial groups (American Whites; Negroes; Eskimo; American Indian and Mongolian) and noted that the index of the palate of the males is smaller than that of the females with the exception of the American Indian series. He also suggested that the values of the mean palatal indices in the different series increase in the order that the percentages of the anterior direction of the transverse palatine suture of the different series decrease.
Larnach and Macintosh (1966, 1970) found in their consecutive studies on Coastal New South Wales series in 1966 and Queensland series in 1970 that the mean value of maxillo-alveolar index was more in skulls of male individuals as compared to skulls of female individuals.
In the present study, the mean value of maxillo-alveolar index is more in skulls of female individuals as compared to skulls of male individuals and the difference between mean values is not statistically significant.
The conflicting results of the studies of Woo (1949) and Larnach and Macintosh (1966 and 1970) and Present study suggests that maxillo-alveolar index is unsubtle for sex determination. It is not sex dependent but race dependent variable.

Size of palate

Woo (1949) concluded from his study that males in all five series have greater absolute size of the hard palate than do the females.
Larnach and Freedman (1964) enlisted size of palate among the seven characters of the skulls which showed maximum contrast between the sexes.
Larnach and Macintosh (1966 and 1970) concluded from their studies that the value of size of palate is important for sex determination. They graded the size of palate into small – (<35); medium – (35-39) and large – (>39). They noted that if the grades are given values of one to three for size, the mean values of the sexes in the Queensland series is 1.30 for females and 2.27 for males compared with 1.55 for females and 2.69 for males in the Coastal New South Wales series.
In the present study, the mean value of size of palate is more in males (31.15) as compared to females (27.86). The difference between the mean values is statistically significant. Subsequent to stepwise discriminant function analysis, the size of palate has been found to be the best variable for sex determination among five hard palate variables with accuracy of 70%.
Thus, the results of Woo (1949) and Larnach and Freedman (1964) and Larnach and Macintosh (1966 and 1970) and Present study are in consonance that the size of palate is important variable for sex determination from skulls.

Conclusion

a) Hard palate variables correctly classified sex in 70% of the sample.
b) Size of palate has been found to be the best sex determinant among five hard palate variables.
c) The discriminant equation obtained in present study is specific for North Indian population.

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