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ORIGINAL ARTICLE

Sexing of mandible using ramus and condyle in Indian population: a discriminant function analysis

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Summary

The mandible is the strongest bone of the skull, and it is commonly utilized in forensic anthropology for determination of sex from skeletal remains. It has been extensively studied by both metric and non-metric methods, but for this purpose an intact mandible is often required. This study was conducted in Indian population using discriminant function analysis to calculate the accuracy of two parameters each from ramus and condyle, for their use in sexing. Discriminant functions (1) and (2) were devised using parameters of ramus and condyle respectively. Data analysis was carried out using SPSS 19.

A total of 158 rami from 79 intact mandibles of known sex obtained from dissection hall of Armed Forces Medical College were studied. Mean values for all the four parameters; condyle length (CL), condyle breadth (CB), minimum ramus breadth (MnRB) and maximum ramus breadth (MxRB) were greater for males than for females, and difference in means calculated using student's t test was significant at P value less than 0.01. The accuracy of discriminant function (1) (MnRB and MxRB) in correctly sexing mandible was 89.6% for males, 69.2% for females and 82.9% overall. The same for function (2) (CL and CB) was 90.6% for males, 30.8% for females and an overall of 70.9%.

This accuracy is comparable to those achieved using parameters from whole mandible, as seen from several studies done in various populations in the past. Hence fragments of mandible with just ramus or condyle can be used for sexing with results as good as that of whole mandible.

Key words: Mandible – Mandibular condyle – Ramus – Discriminant analysis – Sex determination by skeleton

Introduction

In forensic anthropology, determination of sex is one of the most important steps in identification of individuals from skeletal remains. Sexing can be done using either non- metric discrete traits, or by more objective anthropometric methods, in addition to newer molecular methods.

The skull, followed by the pelvis, is the most commonly employed component of skeleton for the purpose of sexing. The mandible shares this property as a part of skull, but the discrete non-metrical traits in it are neither as abundant nor as well described as those of the skull (Giles, 1964). The

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mandible is not only one of the most sexually dimorphic bones in the human body, but also the strongest bone of the skull (Standring et al., 2008), and hence this bone is usually preserved either intact or in fragments even in centuries-old skeletons exhumed from archaeological sites (Vodanović et al., 2006).

The mandible as a whole has been studied in great detail for its use in determination of sex using non-metrical discrete traits (Murphy, 1957; Giles, 1964; Zivanovic, 1970; Krogman and İşcan, 1986; Loth, 1996; Loth and Henneberg, 1996, 2001; Berg, 2001; Kemkes-Grottenthaler et al., 2002; Sutter, 2003; Hu et al., 2006). However, when discrete traits are used for sexing a fragment of the mandible like the ramus or condyle, it becomes indeed very unreliable even in expert hands. Metrical methods like discriminant function analysis are better options in such situations. A large number of studies on the mandible using metrical methods are also available in the literature (Hanihara, 1959; Giles, 1964; Potsch-Schneider et al., 1985; Steyn and Iscan, 1998; Muñoz et al., 2001; Vodanović et al., 2006; Simona et al., 2007; Saini et al., 2011). Although some researchers have devised discriminant functions that make use of parameters pertaining to individual parts of the mandible (Giles, 1964; Saini et al., 2011), the literature is substantially scarce when it comes to fragments of the mandible. This study was conducted to test the accuracy of fragments of the mandible like the ramus and the condyle in correctly predicting sex in Indian population.

Materials and Methods

A total of 158 rami and condyles from 79 intact mandibles of known sex were studied belonging to Indian population from the collections of the Department of Anatomy, Armed Forces Medical College, Pune, India. These mandibles were obtained from dissection-hall cadavers of the abovementioned department. Sex had been marked on mandibles, 53 mandibles were of males and 26 those of females. The age of these individuals was unknown, but edentulous mandibles and bones without sockets for third molar teeth were excluded from the study considering them to be of extreme ages. Four parameters; two from ramus and two from condyles were taken (Figs. 1 and 2), which are:

1. Minimum ramus breadth (MnRB)
2. Maximum ramus breadth (MxRB)
3. Maximum condylar length (CL)
4. Maximum condylar breadth (CB)

All the measurements were made in millimeters using digital calipers with precision of 0.01 mm. Descriptive statistics were calculated, sexual difference analyzed by student's t test, and discriminant function analysis was performed using statistical package for social sciences version 19 (SPSS 19). Two discriminant functions were devised, one using minimum and maximum ramus breadth [Function (1)], and the other using length and breadth of condyle [Function (2)].

The discriminant function used was

$$F(X) = A + A1X1 + A2X2$$ where,

F (X): Discriminant function score, A: Constant

A1 and A2: Unstandardized coefficients of X1 and X2

X1 and X2: first and second variable

The constants and coefficients were calculated using SPSS for the values obtained from

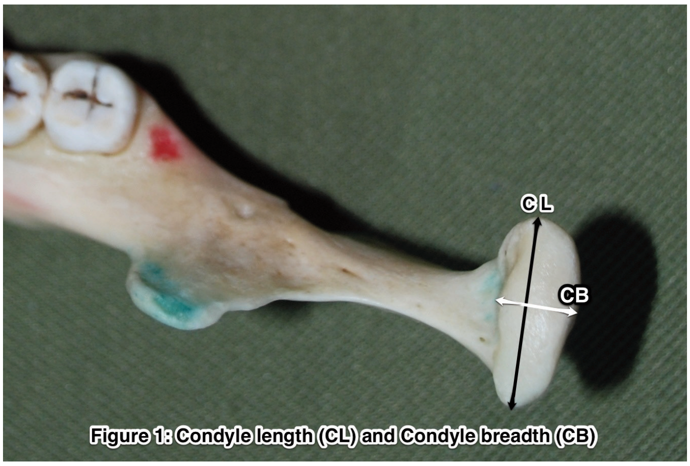

Figure 1: Condyle length (CL) and Condyle breadth (CB)

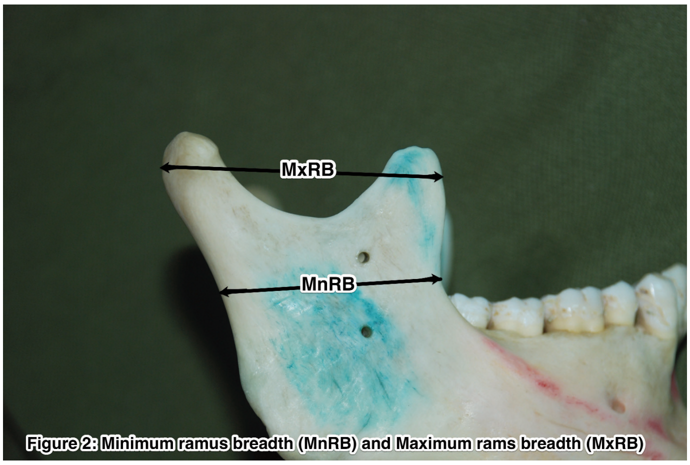

Figure 2: Minimum ramus breadth (MnRB) and Maximum rams breadth (MxRB)

sample under study. The function applied to means of male and female values for MnRB and MxRB gave the value at group centroids for males (Zm) and group centroids for females (Zf). Demarcation point (Z0) was calculated taking the weighted mean of values at group centroids for males and females, using the following formula (Xavier, 2003):

$$Z0 = \frac{(Zm * Nf) + (Zf * Nm)}{Nm + Nf}$$

Nm = number of mandibles of males
Nf = number of mandibles of females

The values of minimum and maximum ramus breadth of each of 158 rami were placed in function (1) and scores calculated. Discriminant score falling towards the male side of the demarcation point was classified as male and those falling towards female side as female. Since the rami were of known sex, overall accuracy of function (1) in correctly sexing the rami was calculated. The same procedure was repeated for function (2) using CL and CB (Table 2). Coefficients, constants, and classification results of both these functions are mentioned in Table 2.

Results

Mean condyle length for males was 19.30 ± 1.74 mm and 17.74 ± 2.28 mm for females; condyle breadth were 9.15 ± 1.18 mm and 8.56 ± 1.22 mm for males and females respectively. Similarly mean minimum ramus breadth for males and females were 36.59± 6.01 mm and 28.71 ± 2.72 mm respectively. Mean maximum ramus breadth were 46.11± 6.39 mm for males and 36.72 ± 5.40 mm for females (Table 1). Mean values of all four measurements taken from rami and condyle were greater for males as compared to females with the difference between the means being statistically significant at P value less than 0.01 (Table 1). This signifies that the parameters chosen were sexually dimorphic and hence can be used for sexing.

After using the constants and coefficients of discriminant function calculated for sample under study (see Table 2), functions (1) and (2) were defined as:

$$F(1) = (-7.150) + (0.094 * MnRB) + (0.092 * MxRB)$$
$$F(2) = (-11.125) + (0.433 * CL) + (0.333 * CB)$$

The accuracy of discriminant function (1) (MnRB and MxRB) in correctly sexing mandible was 89.6% for males, 69.2% for females and 82.9% overall. The same for function (2) (CL and CB) was 90.6% for males, 30.8% for females and an overall of 70.9% (Table 2).

Discussion

Discriminant function (2) using parameters of condyle showed a good overall accuracy of 90.6%, but its ability to correctly sex a female was unacceptably low at 30.8%. So, though it has good positive predictive value for males, it can give ambiguous results when the skeleton to be sexed is of a female. Function (1), even if it has lower overall accuracy of 89.6% classifies rami belonging to both males and females with respectable accuracies of 69.2% and 82.9% respectively. Hence this second function can be of value for practical purposes.

Table 1. Descriptive statistics.

SN	Parameter	Male (n = 106)		Female (n=52)		Total (n= 158)		P Value
		Mean	SD	Mean	SD	Mean	SD	
1	Condyle length	19.30	1.74	17.74	2.28	18.78	2.06	$5 * 10^{-6}$
2	Condyle breadth	9.15	1.18	8.56	1.22	8.95	1.21	0.0036
3	Min Ram breadth	36.59	6.01	28.71	2.72	33.99	6.34	$7.3 * 10^{-16}$
4	Max Ram breadth	46.11	6.39	36.72	5.40	43.02	7.50	$3.6 * 10^{-16}$

Table 2. Constants, coefficients, values at group centroids, demarcation points and accuracy of two functions. Zm: discriminant scores at group centroids for males. Zf: discriminant scores at group centroids for females. Z0: demarcation points. M: Males. F: Females. T: Total.

Function	Parameters used	Raw coefficients	Constants				Accuracy		
				Zm	Zf	Z0	M	F	T
1	MnRB, MxRB	0.094, 0.092	-7.150	0.528	-1.07	-0.54	89.6	69.2	82.9
2	CL, CB	0.433, 0.333	-11.125	0.287	-.58	-0.29	90.6	30.8	70.9

These accuracies in sexing are not less than those produced by discriminant functions using whole mandibles, as shown by other studies done in various population groups in the past (Table 3).

Table 3. Accuracies in sexing mandible using discriminant function analysis in various populations.

Author(s) with population	No. of Parameters used	Accuracy %
(Hanihara, 1959), Japan	4	88.6
(Giles, 1964), USA	3-6	82.0-88.0
(Potsch-Schneider et al., 1985), Germany	17	71.6-81.7
(Steyn and Iscan, 1998), South Africa	5	81.5
(Barthélémy et al., 1999), France	2-7	87.3
(Muñoz et al., 2001), Spain	1-14	78.3-88.7
(Vodanović et al., 2006), Croatia	1-9	74.12-92.06
(Simona et al., 2007), Romania	5-7	86.0
(Saini et al., 2011), India	1-5	60.3-80.2
Current study, 2012, India	2	70.9-82.9

Hence fragments of mandible with only condyle or ramus can be used for the sexing of unknown human skeletons. The predictive value yielded by condyle alone was low and further studies may be required before utilizing it as a diagnostic tool. Minimum and maximum ramus breadth on the other hand showed very promising results, and can be used for sexing from ramus of mandible in the population from which the constants and coefficients were obtained.

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