

# Sex Determination by Applying Discriminant Functional Analysis on Mandibular Morphometry: A Cross-Sectional Study of Gujarat's Population

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## ABSTRACT

**Background:** 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.

**Aim and objective:** The present study was aimed at to investigate the sex-discriminating potential of the metric data from the mandible in the people of the Gujarat, and to develop a discriminant function scores for sex determination using mandibular parameters. The objectives of the study were to measure and compare various mandibular parameters viz. bi-gonion diameter (Bi-go), minimum ramus breadth (MnRB) and maximum ramus height (MxRH) between males and females in the Gujarati population to evaluate the significance of these parameters in determining sex; to develop discriminant function scores that can accurately classify mandibles as male or females based on these parameters; and to assess the accuracy of the discriminant function scores in determining sex from unknown mandibles.

**Results:** A total of 400 dry and adult mandibles with intact alveolar margin of unknown sex obtained from the Department of Anatomy of Medical Colleges of Gujarat, were studied. Mean values for all the three parameters; bi-gonion diameter, minimum ramus breadth (MnRB) and maximum ramus height (MxRH) 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 MnRB in correctly sexing mandible was 80.97% for males, 81.98% for females and 94.50% overall and MxRH in correctly sexing mandible was 81.45% for males, 87.90% for females and 94.75% overall. The same for bi-go in correctly sexing mandible was 82.57% for males, 85.53% for females and 91.58% overall.

**Conclusion:** The discriminant function scores analysis proved to be a useful diagnostic tool in the field of forensic anthropology and provide a valuable tool for sexual dimorphism.

**Key words:** Dry mandibles, Mandibular ramus, bi- gonion diameter, Discriminant functional analysis, Sex determination by skeleton.

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## 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 [1]. The mandible is not only one of the most sexually dimorphic bones in the human body, but also the strongest bone of the skull [2], and hence this bone is usually preserved either intact or in fragments even in centuries-old skeletons exhumed from archaeological sites [3]. The mandible as a whole has been studied in great detail for its use in determination of sex using non-metrical discrete traits [4-12]. However, when discrete traits are used for sexing a fragment of the mandible like the ramus, it becomes indeed very unreliable even in expert hands.

Metrical methods like discriminant function analysis are better options in such situations. The discriminant function analysis is a widely used metrical statistical method that was developed in 1936 as reported by Thieme and Schull [13] and since then it has been widely used for the purpose of sex estimation. A large number of studies on the mandible using metrical methods are also available in the literature. Although some researchers have devised discriminant functions that make use of parameters pertaining to individual parts of the mandible [14-19], the literature is substantially scarce when it comes to fragments of the mandible. We are aware that patterns of sexual dimorphism vary among populations and that the functions obtained could not have a similar accuracy if applied to different populations. So this study confirms the usage of discriminant functional analysis with mandibular parameters for sexual dimorphism in western Indian Population. This bone gains importance in sexual dimorphism.

## METHODS

A total 400 dry and adult mandibles with intact alveolar margin of unknown sex were studied belonging to western Indian (Gujarat) population from the collections of

the Department of Anatomy, Medical Colleges of Gujarat, India. Sex had been marked on mandibles, 190 mandibles were of males and 210 those of females by using presence of flexure on posterior border of ramus of mandible as male trait [8]. 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. Bones with any pathological signs or eroded margins from where measurements to be taken were also excluded from this study. Following three parameters were taken for the study:

1. Minimum ramus breadth (MnRB) (Fig. 1)
2. Maximum ramus height (MxRH) (Fig. 2)
3. Bi-gonion diameter (Bi-Go) (Fig. 3)



Fig. 1: Measurement of minimum ramus breadth (MnRB)



Fig. 2: Measurement of maximum ramus height (MxRH)



Fig. 3: Measurement of Bi-gonion diameter (Bi-Go)

All the measurements were made in millimeters using digital Vernier 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).

The discriminant function used was

$$F(X) = A + A1X1 + A2X2 \text{ where,}$$

F(X): Discriminant function score,

A: Constant

A1 and A2: Unstandardized coefficients of X1 and X2

X1 and X2: variable (parameters of mandibles)

The 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 [20]:

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

Nm = number of mandibles of males

Nf = number of mandibles of females

The values of minimum ramus breadth and maximum ramus height of each of 800 rami were placed in function analysis and scores calculated. The Demarcation/ sectioning point/ cut of point was calculated from group centroids. In cases where the DFA score was less than sectioning point, was considered female and for values of DFA above sectioning point were considered male. The same procedure was repeated for function analysis using Bi-Go.

## RESULTS

**Table 1:** Mean, maximum, minimum, standard deviation, and range (all parameters are in mm).

Mean values of all three measurements taken 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.

| Parameter | Group | Max    | Min   | Mean  | Standard Deviation | Range        |
|-----------|-------|--------|-------|-------|--------------------|--------------|
| Bi-go     | T     | 106.59 | 78.26 | 94.59 | 4.94               | 79.77-109.41 |
|           | M     | 106.59 | 95.08 | 98.85 | 2.11               | 92.52-105.18 |
|           | F     | 98.88  | 78.26 | 90.75 | 3.35               | 80.7-100.8   |
| MxRH      | T     | 68.8   | 28.52 | 50.49 | 6.41               | 31.26-69.72  |
|           | M     | 68.8   | 28.52 | 51.96 | 6.36               | 32.88-71.04  |
|           | F     | 63.78  | 28.7  | 49.17 | 6.18               | 30.63-67.71  |
| MnRB      | T     | 49.54  | 22.99 | 39.97 | 3.58               | 29.23-50.41  |
|           | M     | 49.54  | 26.68 | 40.82 | 3.6                | 30.02-51.62  |
|           | F     | 46.11  | 22.99 | 39.18 | 3.38               | 29.04-49.32  |

**Table 2:** Co-efficient and standard error.

| Parameter | Constant raw co-efficient | Raw co-efficient | Standard error |
|-----------|---------------------------|------------------|----------------|
| Bi-go     | -7.354                    | 0.054            | 0.003          |
| MxRH      | -7.361                    | 0.001            | 0.008          |
| MnRB      | -7.58                     | 0.013            | 0.01           |

After using the constants and coefficients discriminant functions were calculated.

**Table 3:** Discriminant function score

| Parameter    | Z score male | Z score female |
|--------------|--------------|----------------|
| Bi-go        | 0.935        | 0.058          |
| MxRH         | 0.827        | 0.152          |
| MnRB         | 0.829        | 0.153          |
| Cut of point | 0.475        |                |

**Table 4:** Accuracy in %

| Group  | Bi-Go | MxRH  | MnRB  |
|--------|-------|-------|-------|
| Total  | 91.58 | 94.75 | 94.5  |
| Male   | 82.57 | 81.45 | 80.97 |
| Female | 85.53 | 87.9  | 81.98 |

The accuracy of discriminant function for bi-gonion was 91.58%, maximum ramus height was 94.75% and minimum ramus breadth 94.50% among all studied mandible.

## DISCUSSION

Sexual dimorphism based on morphological marks is subjective and probably to be inaccurate, but methods based on measurements and morphometry are accurate and can be used in determination of sex [20].

It was established that discriminant function derived from one specific population cannot be applied to another as magnitude of sex-related differences varies significantly among regional populations. So, there is

always a need to develop population-specific standards for accurate sex determination based upon the ethnic origin. Hence, standards have been developed for many studies in different populations worldwide. But no study was conducted in the western Indian (Gujarat) population using Mandibular measurements.

Discriminant function for using ramus height parameter showed a good overall accuracy of 94.75%, and its ability to correctly sex a female was high at 87.90%. Hence this function can be of value for practical purposes.

Indira AP et al, reported 76% accuracy in sex identification using the Mandibular ramus in Indian population by orthopantomographs of 50 males and 50 females of Bangalore, India, in the age group between 20 and 50 years [21]. Giles 1964 reported mandibular ramus height, maximum ramus breadth, and minimum ramus breadth as highly significant factors with classification accuracy of 85% in American white and Negroes [1]. Steyn and Iscan observed an accuracy of 81.5% with five mandibular parameters (Bi-gonial breadth, total mandibular length, Bi-condylar breadth, minimum ramus breadth, and gonion-gnathion) in South African whites which is comparable with the current study [16]. Dayal et al. found mandibular ramus height as the best parameter in their study with 75.8% accuracy [22]. Previously, Franklin et al. reported a very high accuracy of 95% with 10 variables employing geometric and morphometric technique on South African population. They reported that in South African blacks, the condyle and ramus of mandible express the greatest sexual dimorphism with an accuracy of 87.5%, which is lower than the present study [23].

The variation in prediction accuracy in width measurements on mandible may be because of ethnic differences in size and expression of dimorphic characteristics, which is of low degree in Indian population. It can also be attributed to the difference in musculoskeletal development between males and females of various population groups. Hence these differences emphasize the need for population-specific osteometric standards for each

population group in the world [24]. These accuracies in sexing are not less than those produced by discriminant functions using whole mandibles.

## CONCLUSION

Hence fragments of mandible with only ramus can be used for the sexing of unknown human skeletons. The predictive value yielded by bi-gonion 91.58% alone was not low and can utilize it as a diagnostic tool. Minimum ramus breadth and maximum ramus height also showed very promising results, and can be used for sexing the mandible in the population from which the constants and coefficients were obtained. This result proved that mandibular ramus serves the best sexual dimorphism features both metrically and non-metrically.

## ABBREVIATIONS

**MnRB** - Minimum ramus breadth

**MxRH** - Maximum ramus height

**Bi-Go** - Bi-gonion diameter

## Author Contributions

All authors mentioned in title page have made substantial contributions to conception and design, acquisition of data, analysis of data and interpretation of data. All authors have been involved in drafting the manuscript and have given final approval of the version to be sent for publication.

## Conflicts of Interests: None

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