ORIGINAL ARTICLE

Mandibular ramus: An indicator for sex determination – A digital radiographic study

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Abstract

Background: The identification of skeletal remains is of paramount importance in medico-legal investigations. The skeletal components most often investigated for gender determination are the pelvis and skull, with the mandible being a practical element to analyze sexual dimorphism in the fragmented bones. Presence of a dense layer of compact bone makes it very durable and well preserved than many other bones. Mandibular ramus can be used to differentiate between sexes and it also expresses strong univariate sexual dimorphism. When skeleton sex determination is considered, metric analyses on the radiographs are often found to be of superior value owing to their objectivity, accuracy, and reproducibility. **Aims and Objectives:** (1) To measure, compare, and evaluate the various measurements of mandibular ramus as observed on orthopantomographs. (2) To assess the usefulness of mandibular ramus as an aid in sex determination. **Materials and Methods:** A retrospective study was conducted using orthopantomographs of 50 males and 50 females, which were taken using Kodak 8000C Digital Panoramic and Cephalometric System (73 kVp, 12 mA, 13.9 s). Mandibular ramus measurements were carried out using Master View 3.0 software. The measurements of the mandibular ramus were subjected to discriminant function analysis. **Results:** We observed each variable of the mandibular ramus to be a significant predictor in classifying a given sample ($P < 0.001$). **Conclusion:** This study on mandibular ramus measurements using orthopantomograph shows strong evidence suggesting that the ramus can be used for gender determination for forensic analysis.

Key words: Discriminant function analysis, mandibular ramus, orthopantomograph, sexual dimorphism

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Introduction

The identification of human skeletal remains is considered an initial step in forensic investigations and is crucial for further analysis.[1] In the adult skeleton, sex determination is usually the first step of the identification process as subsequent methods for age and stature estimation are sex dependent. The reliability of sex determination depends on the completeness of the remains and the degree of sexual dimorphism inherent in the population.[2] When the entire adult skeleton is available for analysis, sex can be determined up to 100% accuracy, but in cases of mass disasters where usually fragmented bones are found, sex determination with 100% accuracy is not possible and it depends largely on the available parts of skeleton.[1,2]

As evident from the earlier studies, skull is the most dimorphic and easily sexed portion of skeleton after pelvis, providing accuracy up to 92%.[1] But in cases where intact skull is not found, mandible may play a vital role in sex determination as it is the most dimorphic, largest, and strongest bone of skull.[1-4] Presence of a dense layer of

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compact bone makes it very durable, and hence remains well preserved than many other bones. Dimorphism in mandible is reflected in its shape and size.[1] Male bones are generally bigger and more robust than female bones.[2]

The relative development (size, strength, and angulation) of the muscles of mastication is known to influence the expression of mandibular dimorphism as masticatory forces exerted are different for males and females.[5] Humphrey *et al*. showed that the sites associated with the greatest morphological changes in size and remodeling during growth, mandibular condyle, and ramus in particular are generally the most sexually dimorphic. Measurements of the mandibular ramus tend to show higher sexual dimorphism, and differences between the sexes are generally more marked in the mandibular ramus than in the mandibular body.[6] Methods based on measurements and morphometry are accurate and can be used in determination of sex.[7]

Dentofacial radiography has become a routine procedure in the dental, medical, and hospital clinics. The radiographs are taken at different periods during the lifetime of large segments of the population.[8] Rotational panoramic radiography is widely used for obtaining a comprehensive overview of the maxillofacial complex.[9] In forensic anthropology, comparison of antemortem and postmortem radiographs is one of the cornerstones of positive identification of human remains. Antemortem orthopantomograms may be of great value in the identification of human remains.[10] Several studies have been conducted on dry adult mandibles for sex determination,[1,4-7] but a literature search did not reveal any studies with regard to measurements on ramus of the mandible using a digital panoramic radiograph.

Hence, this paper aims to evaluate the usefulness of mandibular ramus in sex discrimination in Bangalore population and propose the use of same in forensic analysis.

Aims and Objectives

The present study was designed with the following aims and objectives:

1. To measure, compare, and evaluate the various measurements of mandibular ramus as observed on digital orthopantomographs.
2. To assess the usefulness of mandibular ramus as an aid in sex determination.

Materials and Methods

A retrospective study was conducted using orthopantomographs of 50 males and 50 females of Bangalore population in the age group between 20 and 50 years. Ideal orthopantomographs of completely dentate patients were selected for the study. Pathological, fractured, developmental disturbances of the mandible, deformed and edentulous mandibles were excluded from the study. Radiographs taken by Kodak 8000C Digital Panoramic and Cephalometric System (73 kVp, 12 mA, 13.9 s) were used for the study. Since this study was conducted on radiographs stored in the system, ethical clearance was not applicable. Mandibular ramus measurements were carried out using Master View 3.0 software.

The following parameters were measured using mouse-driven method (by moving the mouse and drawing lines using chosen points on the digital panoramic radiograph) [Figures 1 and 2]:

1. *Maximum ramus breadth*: The distance between the most anterior point on the mandibular ramus and a line connecting the most posterior point on the condyle and the angle of jaw.[1,7]
2. *Minimum ramus breadth:* Smallest anterior–posterior diameter of the ramus.[1]
3. *Condylar height/maximum ramus height:* Height of the ramus of the mandible from the most superior point on the mandibular condyle to the tubercle, or most protruding portion of the inferior border of the ramus.[1]
4. *Projective height of ramus:* Projective height of ramus between the highest point of the mandibular condyle and lower margin of the bone.[1]
5. *Coronoid height*: Projective distance between coronion and lower wall of the bone.[1]

Statistical analysis

The data were analyzed using the discriminant procedure of the statistical package SPSS 13.0. Discriminant function analysis was used to determine variables that discriminate between male and female and is increasingly utilized for sex diagnosis from skeletal measurements.

Results

Descriptive statistics of five mandibular ramus measurements

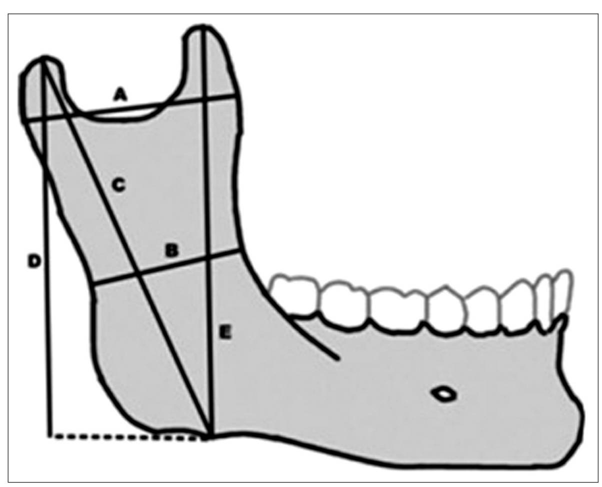

Figure 1: Diagram showing mandibular ramus measurements adapted from Saini *et al*[1]

and associated univariate F ratios for both sexes are shown in Table 1. We noticed that each variable was a significant predictor in classifying a given sample ($P < 0.001$). The mean values showed that all dimensions were higher for males compared to females. Mean measurements between males and females are shown in Figure 3. The F-statistic values indicated that mandibular measurements expressing the greatest sexual dimorphism were minimum ramus breadth followed by condylar height and projective height of ramus.

The sex could be determined from calculations using the equations given below [Table 2]:

D_{Male}: −185.622 + 1.361 (max. ramus breadth) + 1.087 (min. ramus breadth) + 2.253 (condylar height) − 0.717 (projective height of ramus) + 0.081 (coronoid height)

D_{Female}: −161.761 + 1.276 (max. ramus breadth) + 0.948 (min. ramus breadth) + 2.220 (condylar height) − 0.753 (projective height of ramus) + 0.063 (coronoid height)

For classifying a given sample as male or female, the higher/maximum value of the two equations is considered. With all the variables in consideration, 76% of the cases were classified correctly [Table 3] and the accuracy can be increased by repeated iterations. In this study, the sectioning point was found to be −0.667. Values greater than this sectioning point indicate male and values lesser than this point indicate female [Table 4].

Discussion

The identification of sex from human remains is of fundamental importance in forensic medicine and anthropology, especially in criminal investigations as well as in the identification of missing persons and in attempts at reconstructing the lives of ancient populations. One of the important aspects of forensics is to determine sex from fragmented jaws and dentition.[7] Identification of sex based on morphological marks is subjective and likely to be inaccurate, but methods based on measurements and morphometry are accurate and can be used in determination of sex from the skull.[6,11,12] Mandibles were used for the analysis for two simple reasons: firstly, there appears to be a paucity of standards utilizing this element and secondly, this bone is often recovered largely intact.[5]

The accuracy of panoramic radiography in providing anatomic measurements has been established. Orthopantomograph has been advocated routinely and widely used by the clinicians as an appropriate screening tool for the diagnosis of oral diseases. The principal advantages of panoramic images are their broad coverage, low patient radiation dose, and the short time required for image acquisition.[13] Other advantages are that interference of superimposed images are not encountered. Also the contrast and brightness enhancement and enlargement of images provide an accurate and reproducible method of measuring the chosen points.[14,15] The limitations of this technique are magnification and geometric distortion, the vertical dimension in contrast to the horizontal dimension is little altered, and this technique is quite sensitive to positioning errors because of relatively narrow image layer.[13] However, in our study, this limitation did not affect our results since all images were uniformly magnified.

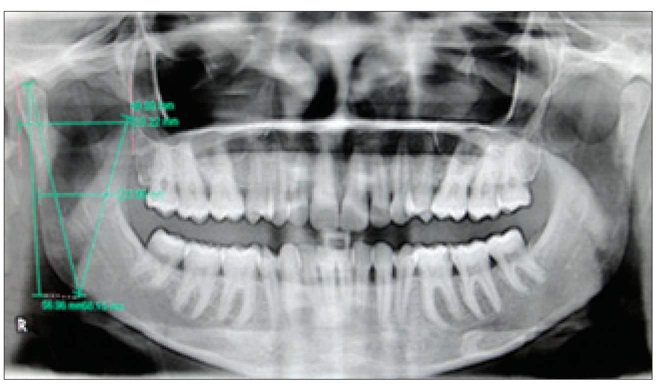

Figure 2: Measurements of mandibular ramus on orthopantomograph

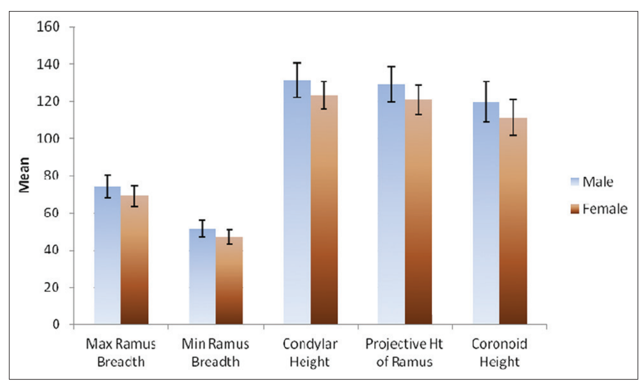

Figure 3: Mean measurements in males and females

Table 1: Descriptive statistics

Variable	Male		Female		Wilk's Λ λ	F	*P* value
	Mean	Standard deviation	Mean	Standard deviation			
Max. ramus breadth	74.20	6.34	68.98	5.75	0.841	18.538	<0.001*
Min. ramus breadth	51.35	4.43	46.96	3.83	0.777	28.100	<0.001*
Condylar height	131.30	9.26	123.27	7.36	0.810	23.008	<0.001*
Projective ht of ramus	129.05	9.51	120.82	7.85	0.815	22.277	<0.001*
Coronoid height	119.70	10.87	111.15	9.51	0.848	17.536	<0.001*

*Statistically significant

Kambylafkas *et al*.[16] concluded that the use of the panoramic radiograph for evaluation of total ramal height is reliable and an asymmetry of more than 6% is an indication of a true asymmetry. Schulze *et al*.[9] found that the most reliable measurements were obtained for linear objects in the horizontal plane and digital measurements are sufficiently accurate for clinical use.

In this study, mandibular ramus measurements were subjected to discriminant function analysis. Each of the five variables measured on mandibular ramus using orthopantomograph showed statistically significant sex differences between sexes, indicating that ramus expresses strong sexual dimorphism. The mandibular ramus demonstrated greatest univariate sexual dimorphism in terms of minimum ramus breadth, condylar height, followed by projective height of ramus. Overall prediction rate using all five variables was 76% and the accuracy can be increased by repeated iterations.

Earliest studies on mandible by Morant *et al*. (1936), Martin (1936), and Hrdlicka (1940) (cited in Humphrey *et al*.) have established the usefulness of mandible for determination of sex. They found that the sexual differences were highest in height of the ramus, thus emphasizing that sex differences are more pronounced in mandibular ramus than in body.

Humphrey *et al*.[6] emphasized that almost any site of mandibular bone deposition, or resorption, or remodeling for that matter, seems to have a potential for becoming sexually dimorphic. Hence, mandibular condyle and ramus in particular are generally the most sexually dimorphic as they are the sites associated with the greatest morphological changes in size and remodeling during growth.

Various studies have investigated the sexual dimorphism of the mandibular ramus flexure using direct visual assessment, e.g. Donnelly *et al*. (1998), Indrayana *et al*. (1998), Hill (2000), and Kemkes-Grottenthaler *et al*. (2002), and found that results of these studies were contradictory and not repeatable.[17] Haun (2000) questioned the predictive accuracy of mandibular ramus flexure as a single indicator of sexual dimorphism and suggests that caution be used when applying this technique in the absence of other morphological and osteometric indicators, especially in the case of fragmentary forensic or rare fossil remains.[18]

Giles measured mandibles of known sex using anthropometric measurements and reported mandibular ramus height, maximum ramus breadth, and minimum ramus breadth as highly significant, with an accuracy of 85% in American Whites and Negroes.[19] Steyn and Iscan (1998) achieved an accuracy of 81.5% with five mandibular parameters (i.e. bigonial breadth, total mandibular length, bicondylar breadth, minimum ramus breadth, and gonion–gnathion) in South African Whites, which is comparable with the present study results.[1,20] Dayal *et al*. (2008) found mandibular ramus height to be the best parameter in their study, with 75.8% accuracy.[1]

Saini *et al*. conducted a study on dry adult mandibles of northern part of India and found that ramus expresses strong sexual dimorphism in this population. The overall prediction rate using five variables was 80.2%. The best parameters were coronoid height, condylar height, and projective height of ramus, and breadth measurements were not very dimorphic in their sample.[1]

Minimum ramus breadth measurement was found to be the best parameter in the present study, which is consistent with other osteometric studies by Giles (1964) and Vodanovic (2006), where breadth measurements were found to be very dimorphic. This is related to the differences in musculoskeletal development and to the differences related to a different growth trajectory in males and females.[6,19]

Table 2: Linear discriminant function

Variable	Male	Female
Constant	−185.622	−161.761
Max. ramus breadth	1.361	1.276
Min. ramus breadth	1.087	0.948
Condylar height	2.253	2.220
Projective height of ramus	−0.717	−0.753
Coronoid height	0.081	0.063

Table 3: Prediction accuracy

True group	Predicted group membership		Total	% Accuracy
	Male	Female		
Male	38	12	50	76
Female	12	38	50	

Table 4: Standardized and unstandardized coefficients in original samples

Variable	Raw coefficients	Standardized coefficients	Structure coefficients	Sectioning point
Max. ramus breadth	0.064	0.388	0.795	−0.667
Min. ramus breadth	0.104	0.430	0.719	
Condylar height	0.025	0.213	0.708	
Projective ht of ramus	0.027	0.239	0.646	
Coronoid height	0.013	0.137	0.628	
Constant	−17.889	---	---	

Limitations of this study are the inability to reliably assign sex in the sub-adult range and inability to assess the gender in case of edentulous patients.

It has been established that socio-environmental factors (e.g. nutrition, food, climate, pathologies, etc.) influence the development, and thus the appearance of bones.[1,21] Numerous studies have demonstrated that skeletal characteristics differ in each population and have emphasized the need for population-specific osteometric standards for sex determination.[1,7,19]

Conclusion

Mandibular ramus can be considered as a valuable tool in gender determination since it possesses resistance to damage and disintegration processes. We found that mandibular ramus measurements using orthopantomographs were reliable for sex determination. Hence, we strongly suggest the use of mandibular ramus as an aid for gender determination in forensic analysis. In view of these findings, further studies on more diverse populations to assess the significance of these parameters are recommended.

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