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Altaf Hussain Chalkoo
Professor, Department of Oral Medicine and Radiology, Government Dental College Srinagar, Jammu and Kashmir, India

Shazia Maqbool
Postgraduate Student, Department of Oral Medicine and Radiology, Government Dental College Srinagar, Jammu and Kashmir, India

Bashir Ahmad Wani
Postgraduate Student, Department of Oral Medicine and Radiology, Government Dental College Srinagar, Jammu and Kashmir, India

Correspondence
Shazia Maqbool
Postgraduate Student, Department of Oral Medicine and Radiology, Government Dental College Srinagar, Jammu and Kashmir, India

Radiographic evaluation of sexual dimorphism in mandibular ramus: A digital orthopantomography study

Altaf Hussain Chalkoo, Shazia Maqbool and Bashir Ahmad Wani

Abstract
To determine sexual dimorphism using mandibular ramus dimensions and to assess the role of mandible used as an aid in forensics for sex determination. A retrospective study was conducted using orthopantomography of 40 males and 40 females between the age group of 18 – 50years. Mandibular ramus measurements were done on OPGs taken by New-Tom VGi Scanner (QR srl; Verona, Italy) in standard resolution mode (tube potential:50-85KV, tube current:12mA, and time:14sec. The measurements of the mandibular ramus will be subjected to Discriminant function analysis. Maximum ramus breadth, Minimum ramus breadth, Condylar height, Projective height of ramus and Coronoid height were calculated for both the sexes differently with the formula & analyzed with Discriminant functional analysis using Fischer exact test. The P value was statistically significant with the P value < 0.05 for the following parameters Coronoid height, Condylar height and Projective height of ramus. Mandibular ramus measurements can be a useful forensic diagnostic tool for gender determination in forensic studies.

Keywords: forensics, mandible, orthopantomogram, sexual dimorphism

Introduction
Sex determination by morphological assessment has been one of the oldest approaches in forensic anthropology and medico-legal cases. The teeth and the bones of the craniofacial skeleton being usually the best preserved part of the human beings and has paved a way for recognition of badly damaged human corpses. The identification of sex is of significance in cases of mass fatality incidents where bodies are damaged beyond recognition. Determination of sex becomes more accurate after attainment of puberty and is an important aspect of forensics for the study of medico legal cases in which bodies are badly disfigured. The differences are well marked in bony pelvis and skull. After both of these bony areas, mandible remains next in the human which will also help us in the identification of age, sex, and race, as it is the most dimorphic bone of the skull [1-3]. As evident from the earlier studies, the skull is the easily sexed portion of the skeleton after the pelvis, providing an accuracy of up to 92%. Mandible is composed of a dense layer of compact bone which makes it a very durable bone and hence, it remains well-preserved than many other bones. It is the hardest facial bone and retains its shape better than any other bones in the forensic and physical anthropologic fields. Dimorphism in the mandible is reflected in its shape and size; male bones are generally bigger and more robust than female bones [1, 4]. Its morphological features show changes with reference to age, sex, and race. Three basic criteria should guide the choice of skeletal elements that may be useful indicators of sex determination. First, their morphology should clearly reflect anatomic or physiologic sex differences. Second, they should be able to withstand the rigors of skeletonization and fossilization and finally there should be easily recognizable traits through time and across paleospecies [5-6]. Morphological changes of the mandible are influenced by the occlusal status and age of the subject [5]. Longitudinal studies have shown that with age, remodeling of the mandibular bone occurs. The shape of the mandibular base, especially the gonial angle, correlates with the function and shape of the muscles of mastication. With age, there occurs changes in masticatory function and structure, as seen in decreased contractile activity and lower muscle density.
Hence, this study aims to evaluate the usefulness of various mandibular parameters for gender estimation.

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 [7]. Hence the present study was conducted to evaluate the sexual dimorphism using various anatomical landmarks of mandibular ramus on orthopantomogram.

Materials and Methods

A retrospective study was conducted of forty males and forty females, using orthopantomography which were taken using New-Tom VGi Scanner (QR srl; Verona, Italy) in standard resolution mode(tube potential:50-85KV, tube current:12mA, and time:14sec). The age group ranged between 18 and 50 years. Patients having full complement of teeth were selected for OPG. Patients with a history of extraction, trauma, and any other severe developmental disturbances leading to variation in the size of mandible were excluded from the study. The following variables were measured using Newtom digital software and drawing lines using chosen points on the digital panoramic radiograph [Figures 1 and 2].

A. 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 [8, 9]
B. Minimum ramus breadth: Smallest anterior–posterior diameter of the ramus [9]
C. 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[9]
D. Projective height of ramus: Projective height of ramus is between the highest point of the mandibular condyle and lower margin of the bone [9]
E. Coronoid height: Projective distance between coronoid and lower wall of the bone [9].

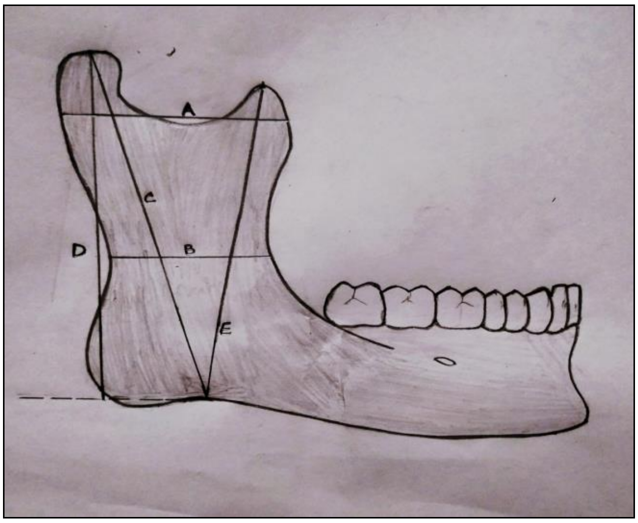

Fig 1: Mandibular ramus measurements with five variables

Statistical Analysis

The data were analyzed by the discriminant function analysis using Fischer exact test [Table-1].
The linear discriminate {D} function equation is as follows:

$$\{D\}_{Male} = -288.2 + 1.93(Max\ ramus\ breadth) + 3.65(Min\ Ramus\ Breadth) + 4.16(Condylar\ Height) + 0.86(Projective\ height\ of\ ramus) + 0.87(Coronoid\ height)$$

$$\{D\}_{Female} = -269.3 + 1.94(Max\ ramus\ breadth1) + 3.67(Min\ Ramus\ Breadth) + 4.29(Condylar\ Height) + 0.57(Projective\ height\ of\ ramus) + 0.68(Coronoid\ height)$$

Mean measurements in males were greater than females with the highest measurements for condylar height and lowest measurements for minimum ramus breadth are shown in figure-3

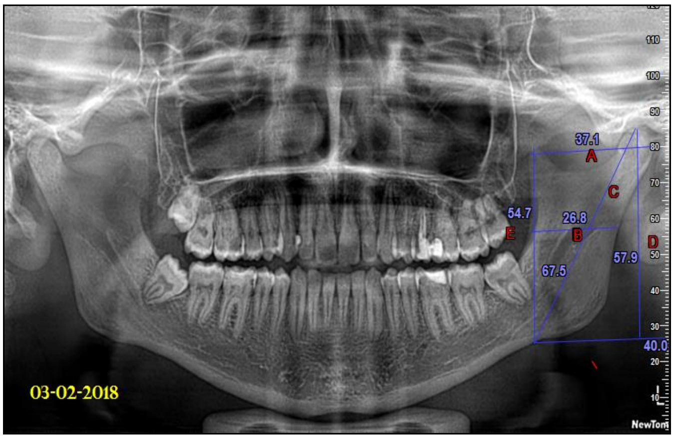

Fig 2: Mandibular ramus measurements of male patient on opg using Newtom digital software

Results

Descriptive statistics shows mean values were higher in males compared to females. Standard deviation was greater in females compared to males. F-statistic values indicated that highest sexual dimorphism was seen with projective height of ramus and least with minimum ramus breadth.

Table 1: Linear discriminant function variables

Variable	Male	Female
Constant	-288.2	-269.3
Max ramus breadth	1.93	1.94
Min Ramus Breadth	3.65	3.67
Condylar Height	4.16	4.29
Projective height of ramus	0.86	0.57
Coronoid height	0.87	0.68

Coronoid height, condylar height, and projective height of ramus were statistically significant with $P < 0.05$ as shown in Table 2.

Table 2: Descriptive statistics of mandibular ramus linear measurements

Variable	Male		Female		Wilk's Lamda	F-value	P-value
	Mean	SD	Mean	SD			
Max ramus breadth	35.78	2.96	35.37	2.29	.994	0.494	0.484
Min Ramus Breadth	27.99	1.53	29.11	3.77	.962	3.043	0.085
Condylar Height	71.07	4.37	68.21	2.50	.858	12.957	0.001*
Projective height of ramus	62.39	5.76	54.96	3.65	.622	47.500	<0.001*
Coronoid height	61.65	5.66	55.58	3.58	.704	32.819	<0.001*

Sex was accurately determined in 32 cases out of forty male mandibular measurements with prediction accuracy rate of

80% and sex was accurately determined in 38 cases out of forty female mandibular measurements with an accuracy rate of 95%.

Table 3: Prediction accuracy

True Group	Predicted Group		Total	Accuracy
	Male	Female		
Male	32	8	40	80%
Female	2	38	40	95%
Overall Accuracy = 87.5%				

Discussion

Sex determination by morphological assessment has remained as one of the oldest approaches in forensics and providing a challenging task to estimate gender from fragmented bones. The method may vary and depends on the condition of the available bones. The identification of sex is of significance in cases of mass fatalities where bodies are damaged beyond recognition. Sex can be determined up to 100% accuracy by pelvis bone. However, in cases of mass disasters where fragmented bones are found, sex determination with 100% accuracy is not possible thereby providing a questionable task [1]. Skull is the most dimorphic bone and is utilized for sex determination after pelvis. However, in cases where intact skull is not found, mandible may play a vital role in sex determination as it is the most dimorphic bone of skull and usually remains intact in mass destructions. Anthropometry of the face and intraoral regions can help in the field of forensic odontology when common forensic data are unavailable [10]. Panoramic radiographic technique remains a diagnostic modality of choice but is quite sensitive to positioning errors because of relatively narrow image layer [13]. Objects which are outside the focal trough are blurred, magnified or reduced in sizes which are sometimes distorted. The focal trough shape and location varies with the brand of the equipment used [11].

A study conducted by Kambylafkas *et al.* [14] concluded that the evaluation of total ramal height is reliable, and an asymmetry of more than 6% is an indication of a true asymmetry using panoramic radiograph.

In this study, asymmetry noted was 7% using panoramic radiograph. Dayal *et al.* [15] found mandibular ramus height to be the best parameter in their study, with 75.8% accuracy.

A study conducted by Saini, *et al.* [4] showed that coronoid height possessed the best potential for sex determination on Indian people with the accuracy of 74.1%, and the combination of it with minimum ramus breadth, maximum ramus breadth, and/or mandibular ramus length will show significant sexual dimorphism with an overall accuracy of 80.2%. In our study, all five variables that is maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus, coronoid height showed prediction accuracy of 80% for males and prediction accuracy of 95% for females.

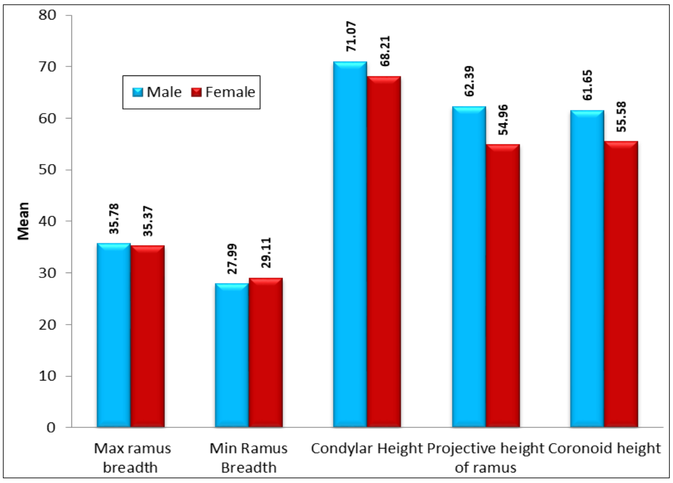

Fig 3: Mean measurements between males and females

Another study conducted by Indira *et al.* [16] on mandibular ramus measurements were subjected to discriminant function analysis. Each of the five variables measured on mandibular ramus using orthopantomogram. 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%. In our study, highest sexual dimorphism was seen with projective height of ramus and least with minimum ramus breadth. Coronoid height, condylar height, projective height of ramus was statistically significant ($P < 0.05$).The overall prediction rate was 87.5%.

Shivaprakash and Vijaykumar [17] conducted a study in diagnosing in the sex by observing the mandibular ramus posterior flexure. Sex was accurately determined in 44 cases out of 55 male mandibles with an accuracy rate of 80%, and sex was accurately determined in 35 cases out of 49 female mandibles with accuracy rate of 71%. In our study, sex was accurately determined in 32 cases out of forty male mandibular measurements with prediction accuracy rate of 80% and sex was accurately determined in 38 cases out of forty female mandibular measurements with accuracy rate of 95%.

Conclusion

The mandibular ramus height can be considered another valuable tool in gender determination in forensics with the help of OPG. However, further studies with larger sample and less magnification errors are needed to be taken up in future for better results.

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Conflicts of interest

There are no conflicts of interest

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