Original Article

Radiographic evaluation of mandibular ramus for gender estimation: Retrospective study

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Abstract

Background and Aims: Gender estimation is a very important part of a study in the field of anthropology and forensic sciences. In the skeleton, gender estimation is the first step of the identification process as subsequent methods for age and stature estimation are sex-dependent. Skeletal components such as the pelvis and skull are investigated for gender estimation and the mandible is a practical element to analyze sexual dimorphism in fragmented bones. The aim of the present study is to measure, compare, and evaluate various measurements of the mandibular ramus, observed in digital orthopantomographs and also to assess the usefulness of the mandibular ramus as an aid in gender estimation. **Materials and Methods:** A radiographic retrospective study was conducted using 80 digital orthopantomographs to measure, compare, and evaluate the measurements of the mandibular ramus such as maximum ramus breadth, maximum ramus height, and coronoid heightusing Planmeca ProMax® digital machine to assess the usefulness of mandibular measurements in gender estimation. **Results:** Descriptive statistics of various measurements and associated univariate F ratios for both the sexes were determined. Four variables were significant predictor in classifying a given sample ($P < 0.001$). The F-statistic values indicated that measurements expressing the greatest sexual dimorphism were noticed in the maximum ramus height. **Conclusion:** Mandibular ramus can be considered as a valuable tool in gender estimation and the most reliable measurements were obtained of linear objects in the horizontal plane by digital panoramic imaging.

Key words: Anthropometry, bigonial breadth, forensic dentistry, gender identification, gonial angle, mandible, mandibular ramus, sex characteristics, sexual dimorphism

Introduction

Gender estimation of the bone is a very important part of a study in the field of anthropology and forensic sciences as further interpretations and analysis are based on it. Normally, morphological and metric analyses are used to determine the sex of the bone.[1,2] The sex of an unknown individual can be determined based on the data

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from the morphology and metric features of the skull and the mandible, soft tissues, dental records as well as by DNA analysis of teeth.[3]

As evident from the earlier studies, the skull is the most dimorphic and easily sexed portion of the skeleton after the pelvis, providing an accuracy of up to 92%. But in cases where an intact skull is not found, the mandible may play a vital role in gender estimation as it is the most dimorphic, largest, and strongest bone of the skull. The presence of a dense layer of compact bone makes it very durable and hence, it remains well-preserved than many other bones. It is the hardest facial bone and retains its shape better than 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.[1,2]

It is the strongest and movable part of the skull. 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. 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 the trait should be recognizable through time and across paleospecies.[3,4]

Morphological changes of the mandible are thought to be influenced by the occlusal status and age of the subject.[3] Longitudinal studies have shown that remodeling of the mandibular bone occurs with age. The shape of the mandibular base, especially the gonial angle, correlates with the function and shape of the muscles of mastication. With age, the masticatory muscles change in function and structure, as seen in decreased contractile activity and lower muscle density.

Hence, this paper aims to evaluate the usefulness of various mandibular parameters for gender estimation.

Aims and objectives

- To measure, compare, and evaluate the various measurements of the mandibular ramus as observed in digital orthopantomographs
- To assess the usefulness of the mandibular ramus as an aid in gender estimation.

Materials and Methods

The sample size was calculated and validated as follows: Proportional power calculation was used to determine the sample size and according to the analysis, a minimum of 36 subjects was needed to detect a sensitivity of 2 mm between two radiographs when the power of the test was 0.80 at a significance level of 0.05. A retrospective study was conducted using 80 digital orthopantomographs of Visakhapatnam's population in the age group of 20–50 years. Digital radiographs were taken by Planmeca ProMax® digital machine Helsinki, Finland (66kVp, 9mA,16s). The study was conducted on the radiographs stored in the system; however, consent to use theses radiographs was obtained from the patients for our study. Ethical clearance was obtained from the institutional review board. Mandibular ramus measurements were performed using Planmeca Romexis software 2.81 R version Helsinki, Finland.

The inclusion criterion was ideal orthopantomographs of completely dentate patients.

The exclusion criteria were pathological fractures, developmental disturbances of the mandible, and deformed and edentulous mandible.

The following parameters were measured using mouse-driven method by two individuals; one of them being the faculty and they were recorded, tabulated, and sent for statistical analysis to eliminate the intraobserver errors [Figure 1]. The investigators demonstrated good intrarater percentage of agreement and kappa statistics, which were 93% and 0.81, respectively.

- Maximum ramus breadth: Largest anterior-posterior diameter of the ramus—A
- Minimum ramus width: Smallest anterior-posterior diameter of the ramus—B
- Maximum condylar height: From the most superior point on the mandibular condyle to the most inferior point of the mandible—C
- Maximum height of the ramus: The point of line of intersection from the highest projection point of the condyle to the lower margin of the bone—D
- Maximum coronoid height: Projective distance between coronoid and the most inferior point of the bone—E
- Gonial angle: A line traced tangential to the most inferior points at the gonial angle and the lower border of the mandibular body and another line tangential to the posterior borders of the ramus and the condyle. The intersection of these lines formed the gonial angle—F
- Bigonial width: It is the distance between two gonia. It is measured horizontally from the right to left gonia—G.

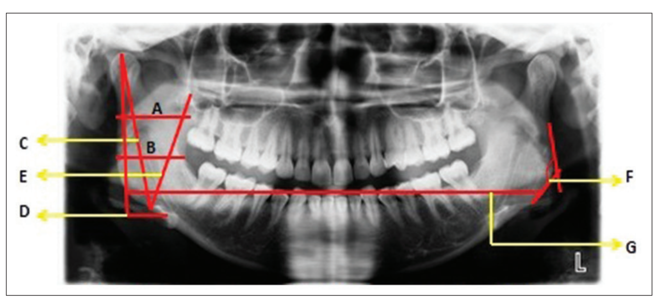

Figure 1: Various mandibular parameters that were included in the study

Results

Descriptive statistics of various mandibular ramus measurements and associated F ratios for both sexes are shown in Tables 1 and 2. It shows the various means of all the variables/parameters, i.e., maximum ramus width, minimum ramus width, maximum ramus height, projection height of ramus, coronoid height, and bigonial angle and bigonial width of both the male and female populations with their significant value. The mean value of maximum ramus width in males was 31.0275 with a standard deviation of 3.54567; in females, it was 30.5625 and their standard deviation was 2.92309, which was insignificant ($P = 0.524$). The mean value of minimum ramus width in males and females was 29.4225 and 29.5525, respectively, with standard deviations of 3.146 and 2.83241, respectively. The maximum height of the ramus mean was determined as 66.9475 with a standard deviation of 4.556 in males and 60.5075 with a standard deviation of 4.09561 in females, which was significant ($P = 0.00$). The mean value of projection height of the ramus in males and females was 66.1950 and 60.08, respectively, and their standard deviations were 4.75779 and 4.30068, respectively, which was significant ($P = 0.00$).

The parameter coronoid height mean value was 55.98 in males and 51.32 in females and the standard deviations in males and females were 6.5411 and 4.66, respectively, which was found to be significant ($P = 0.00$). The mean value of bigonial angle in males was 172.9455 with a standard deviation of 31.89837 and the mean value in females was 152.7142 with a standard deviation of 14.69607 with a significance of ($P = 0.00$). The mean value of bigonial width in males was 182.1325 and in females it was 177.9600 and the standard deviations in males and females were 11.61159 and 9.57721 respectively, which was found to be insignificant ($P = 0.083$).

We have noticed that four variables were significant predictors in classifying a given sample ($P < 0.001$) except the maximum ramus width and minimum ramus width. The mean values showed that all dimensions were higher for males compared to females. . The F-statistic values indicated that mandibular measurements expressing the greatest sexual dimorphism were (in descending order) maximum ramus height, projection height of ramus, coronoid height, bigonial angle, bigonial width, maximum ramus width, and minimum ramus width.

The gender could be estimated from calculations using the equations given below:

D_{Male}: –258.432 + 4.306 (maximum ramus breadth) – 3.334 (minimum ramus breadth) +7.139 (maximumramus height) – 3.856 (projective height of ramus) – 1.328 (coronoid height) + 0.326 (bigonial angle) + 1.511 (bigonial width)

D_{Female}: –228.555 + 3.743 (maximum ramus breadth) – 2.689 (minimum ramus breadth) + 6.618 (maximumramus height) – 3.759 (projective height of ramus) – 1.239 (coronoid height) + 0.298 (bigonial angle) + 1.485 (bigonial width).

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, Table 3 shows the prediction group stating that out of 40 males taken in the study group, 33 were predicted as males and 7 were predicted as females, whereas in 40 female individuals 34 were predicted as females and 6 were predicted as males, giving an accuracy of 83.8%. In this study, the sectioning point was found to be -0.917. Values greater than this sectioning point indicate male and values lesser than this point indicate female.

Discussion

One of the important aspects of forensics is to estimate gender from fragmented jaws and dentition.[5] 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 the estimation of gender from the skull. Mandibles were used for the analysis for two simple reasons: First, there appears to be a paucity of standards utilizing this element and second, this bone is often recovered largely intact.[1,6]

The accuracy of panoramic radiography in providing anatomic measurements has been established. Orthopantomograph

Table 1: The various means of all the variables/parameters of both and females with their respective standard deviations, along with their significance values

Variable	Male		Female		Wilks's lambda	F	*P*
	Mean	SD†	Mean	SD			
Maximum ramus width	31.0275	3.54567	30.5625	2.92309	0.995	0.410	0.524
Minimum ramus width	29.4225	3.14663	29.5525	2.83241	1.000	0.038	0.847
Maximum ramus height	66.9475	4.55648	60.5075	4.09561	0.638	44.197	0.000
Projective height of ramus	66.1950	4.75179	60.0825	4.30068	0.682	36.385	0.000
Coronoid height	55.9800	6.54116	51.3225	4.66869	0.853	13.435	0.000
Bigonial angle	172.9455	31.89837	152.7142	14.69607	0.855	13.273	0.000
Bigonial width	182.1325	11.61159	177.9600	9.57721	0.962	3.074	0.083

†SD: Standard deviation

Table 2: Linear discriminant function for males and females in the study group included

Variable	Male	Female
Constant	−258.432	−225.555
Maximum ramus width	4.306	3.743
Minimum ramus width	−3.334	−2.689
Maximum ramus height	7.139	6.618
Projective height of ramus	−3.856	−3.759
Coronoid height	−1.328	−1.239
Bigonial angle	0.326	0.298
Bigonial width	1.511	1.485

Table 3: Mean measurements between males and females in the study group with their respective prediction values and their accuracy levels in percentage

True group	Predicted group		Total	Accuracy (%)
	Male	Female		
Male	33	7	40	83.8
Female	6	34	40	

has been advocated routinely, and is widely used by the clinicians as an appropriate screening tool for the diagnosis of oral diseases. The advantages of panoramic images are its broad coverage, low patient radiation dose, and the short time required for image acquisition.[7] The other advantages are that interference of superimposed images are not encountered, whereas the contrast, brightness enhancement, and enlargement of images provide an accurate and reproducible method of measuring the chosen points.[8] The disadvantages are magnification and geometric distortion, the vertical dimension in contrast to the horizontal dimension is a little altered, and this technique is quite sensitive to positioning errors because of a relatively narrow image layer.[7] The study performed by Kambylafkas *et al*.[9] states that panaromic radiographs are used to evaluate the mandibular asymmetry but some amount of under diagnosis is always present. In a study conducted by Schulz *et al*.,[10] it was shown that linear objects found reliability in an horizontal plane measurement. Mandibular condyle and ramus were considered in the present study as they are the sites associated with remodeling as emphasized by Humphrey *et al*.,[6] which states that almost any site of mandibular bone deposition or resorption has a potential for becoming sexually dimorphic. In our study the parameter ramus, flexure was not included as this parameter did not give any conclusive evidence ofsexual dimorphism in the past studies reported by Shiva Prakash, Aparna *et al*., and Galdames.[11-14]

The present study showed greatest sexual dimorphism, with an accuracy of 83.8% in consideration to the maximum ramus height, the mean of which was 66.94; similar contributions by Morant, Martin, and Hrdlicka[6] have shown a mean of 63.5 in maximum ramus height depicting the highest sexual dimorphism, which is in accordance with the studies conducted by Kambylafkas[9] and Schulz[10] *et al*., which stated that differences between the sexes are marked in the mandibular ramus than in the mandibular body.[6]

The present study shows the mean value of maximum ramus width in males and females as 31.0275 and 30.5625, respectively, which was insignificant (P = 0.524). Similar findings were observed in studies conductedby Indira *et al*.,[1] Pokhrel, Bhatnagar,[15] and Saini *et al*.[16] The mean value of minimum ramus width in males and females was 29.4225 and 29.5525, respectively, with an insignificance (P = 0.84) in the present study and studies conducted by Indira *et al*., Pokhrel and Bhatnagar, and Saini *et al*. have shown similar findings.

The current study has shown the maximum height of the ramus mean in males and females to be significant (P = 0.00), whereas Indira *et al*., have shown similar values in both the genders with a significance ($P \leq 0.001$). Similar findings were also recorded in a study by Shamount *et al*., and Pokhrel and Bhatnagar. The mean value of projection height of the ramus in males and females was 66.1950 and 60.0825, respectively, which indicated significant sexual dimorphism.

The mean value of coronoid height in males and females in the present study was 55.98 and 51.32, respectively, and a study by Indira *et al*. have shown the coronoid height to be significant (P = 0.00, < 0.001). The present study also shows the mean value of bigonial angle to be significant, the same as that in Shamount's study (P = 0.00). The mean value of bigonial width in the present study was insignificant, where as Shamount's study had shown it to be significant (P = 0.00), which contradicts the present study.

In the present study, mandibular ramus measurements were subjected to discriminant function analysis. Each of the seven variables measured on the mandibular ramus using orthopantomographs showed statistically significant sex differences between sexes, indicating that ramus height expresses strong sexual dimorphism in terms of minimum ramus breadth, condylar height, projective height of ramus, and bigonial angle followed by bigonial width. Overall, the prediction rate using all five variables was 83.8%.

A similar study by Giles has shown an accuracy of 85%, Steyn and Iscanin their study achieved an accuracy of 81.5% with five mandibular parameters, Dayal *et al*. showed 75.8% accuracy,[1,16,17] and Saini *et al*. showed an accuracy of 80.2%.[18] With respect to the studies that have been conducted in the past, the most important variables that were considered and included were mandibular height, mandibular ramus projection, mandibular width, or mandibular gonial angle on an individual basis. Some even considered them on a collective basis with a maximum of five parameters. But this study as such involves all the existing important parameters put together for determining the usefulness of the ramus. And thus, this study is more accurate, giving a specificity of 83.3%. The present study, found out that the sexual differences were highest in the height of the ramus >maximum condylar height >coronoid height >bigonial angle.

Conclusion

The mandibular ramus can be considered as a valuable tool in gender estimation since it possesses resistance to damage and disintegration processes. Given methodology used and the significant results obtained, it can be concluded that mandibular ramus measurements using orthopantomographs can be used as a reliable parameter for gender estimation. In view of these findings, further studies on more diverse populations to assess the significance of these parameters are recommended.

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Conflicts of interest

There are no conflicts of interest.

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