

Mandibular Ramus: An Indicator of Gender and Chronological Age - A Digital Radiographic Study

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Abstract

Background: The determination of sex and age of individual is important in forensic practice and medico legal purposes. Mandible may play a vital role in sex estimation as it is the most dimorphic bone of skull that often is recovered intact. The present study was conducted to evaluate the reliability of mandibular measurements in gender determination and age estimation as seen on digital panoramic radiographs. **Aims and Objectives:** The aim of the study was to evaluate and compare seven parameters of the mandibular ramus obtained from digital orthopantomographs, and to assess the usefulness of these parameters as aids in gender and age estimation. The objectives were: 1. To assess:-Maximum ramus breadth in mm, Minimum ramus width in mm, Projective height of ramus in mm, Maximum height of the ramus in mm, Maximum coronoid height in mm, Gonial width in mm and Bigonial angle in degrees, 2. To correlate each of these seven variables with the age of the patient, and 3. To compare these seven parameters between males and females. **Materials and Methods:** OPGs of 500 patients satisfying inclusion and exclusion criteria selected from the Dept. of Oral Medicine and Radiology, Govt. Dental College, Kottayam, were being studied. Permission from the concerned departments was taken. The measurements were made on this radiograph using GIMP 2.8 Software. **Results:** All the parameters were found to show statistically significant difference between males and females. After performing logistic regression, an equation was formulated to determine gender from the parameters that were statistically significant in regression analysis. The cut off was set at 0.5. Values above the cut off value were interpreted as males and values below the cut off were interpreted as females. The overall accuracy of sex determination at this cut off value from this method was 73.9%. Significant correlation was not noted between the mandibular parameters and age of the individual. **Conclusion:** It can be concluded that the mandibular ramus can be considered as a valuable tool in gender estimation since it possesses resistance to damage and disintegration processes. Nevertheless, the age of the individual cannot be determined using this method.

Keywords: Digital Radiographs, Mandibular Ramus, Medico-legal Cases, Orthopantomograms

Introduction

One of the important aspects of forensic practice and medico legal purposes is the determination of sex of the individual. This is because the methods of age and

stature estimation depend on correct sex determination. The discriminant function derived from one specific population cannot be applied to another since magnitude of sex-related differences such as body size, robustness etc., are different for different populations¹. Thus, each

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population requires the development of population – specific standards for accurate sex determination for that population.

The mandible can be used to distinguish among ethnic groups and between sexes. This is because the stages of mandibular development, growth rates, and duration are distinctly different in both sexes². The function and shape of the muscles of mastication contributes a lot to the shape of the mandibular base, especially the gonial angle³. The masticatory muscles also change in function and structure, as age progresses. There is decreased contractile activity and lower muscle density with age. Very few studies have been carried out to correlate the changes in the mandibular angle with age, sex and dental status. Aside from age and loss of teeth, other factors may influence change in gonial angle⁴.

When there are plentiful antemortem orthopantomograms available, it may be of great value in studying and developing population specific standards for accurate sex and age estimation. The present study was conducted to evaluate the reliability of mandibular measurements in gender determination and age estimation by evaluating and comparing measurements of mandibular ramus seen on digital panoramic radiographs.

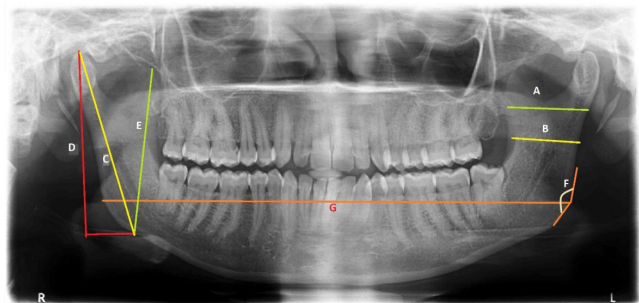
Materials and Methods

A cross-sectional study was conducted at the Department of Oral Pathology and Microbiology, and Department of Oral Medicine and Radiology, Govt. Dental College, Kottayam, Kerala. After obtaining ethical clearance from institutional review board, 500 digital panoramic radiographs (250 males and 250 females) from the records library of patients within the age group 18–50 years were selected for the study. Inclusion criteria comprised OPGs of patients aged between 18-50 years and those with good contrast and free of distortion. Any developmental problems, fractured, deformed and edentulous mandible 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. Mandibular ramus measurements were carried out using GIMP 2.8 software.

The parameters used in this study were (Figure 1):

- Maximum ramus breadth: Largest anterior-posterior diameter of the ramus--A

- Minimum ramus width: Smallest anterior-posterior diameter of the ramus--B
- Maximum height of the ramus: Perpendicular distance from the point of line of intersection from the highest projection point of the condyle to the lower margin of the bone--C
- Projective height of ramus: From the most superior point on the mandibular condyle to the most inferior point of the mandible--D
- Maximum coronoid height: Projective distance between coronoid and the most inferior point of the bone--E
- Gonial angle: A line traced tangentially to the most inferior point on ramus 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 gonias --G.



A-Maximum ramus breadth, B-Minimum ramus width, C-Maximum height of ramus, D-Projective height of the ramus, E-Maximum coronoid height, F-Gonial angle, G-Bigonial width.

Figure 1. Various mandibular parameters that was included in the study.

Statistical Analysis

Statistical analysis was done using SPSS software. Student's t-test was used to compare between males and females. Pearson's correlation coefficient (r) was used to determine the correlation between the independent variables and the dependent variable. Step-wise logistic regression was applied to derive a formula to predict the sex from the seven mandibular measurements. Multiple linear regressions was used to formulate regression

equation to predict age (Dependent variable) from the ramus breadth, projective ramus height, condylar ramus height, coronoid ramus height, bi-gonial width as well as gonial angle (independent variables).

Results

Student's t-test was performed to compare between males and females. The mean values of all the parameters were found to be greater in males compared to females (Table 1). All the parameters were found to show statistically significant difference between males and females (with p-value <0.05) (Table 2).

Table 1. Gender differences in different parameters between males and females

Parameter	Mean (in mm)		Standard deviation	
	Females	Males	Females	Males
Maximum ramus breadth	29.97	31.01	.11	.12
Minimum ramus breadth	25.75	26.47	.16	.18
Maximum ramus height	52.73	55.78	.31	.33
Projective height of ramus	53.67	56.85	.35	.37
Coronoid height	50.72	54.36	.29	.33
Gonial angle	156.33	159.19	.45	.46
Bigonial width	165.81	175.02	.79	.77

Table 2. Students't-test for comparison between males and females

Parameters	Mean difference	Sig.	95% Confidence interval	
			Lower	Upper
Maximum ramus breadth	-1.0472	.000	-1.37	-.72
Minimum ramus breadth	-.72637	.003	-1.20	-.26
Maximum ramus height	-3.05028	.000	-3.94	-2.16
Projective height of ramus	-3.17396	.000	-4.18	-2.17
Coronoid height	-3.63920	.000	-4.51	-2.77
Gonial angle	-2.86092	.000	-4.12	-1.60
Bigonial width	-9.21044	.000	-11.38	-7.04

Gender Determination

Next, step-wise logistic regression was done to formulate the equation to predict the gender from the seven variables. The parameters that were found to show statistically significant result in predicting gender were maximum ramus height, coronoid height, bi-gonial width and gonial angle. The equation obtained was $-26.539 + 0.17 \times \text{Maximum ramus breadth} + 0.11 \times \text{Coronoid height} + 0.05 \times \text{Gonial angle} + 0.05 \times \text{Bi-gonial width}$.

The cut off value was set at 0.5 by system. A discriminant value is obtained by using this formula. A discriminant's core greater than sectioning point indicates male and less than sectioning point indicates female.

At this cut off value, the accuracy of males to be identified was 72.7% (181 out of 250) and females to be correctly identified as females was 75.2% (188 out of 250). The overall accuracy was found to be 72.9%. The sensitivity and specificity at that cut off was 72 and 75 respectively. The sensitivity and specificity at that cut off was 72 and 75 respectively.

Age estimation

Pearson's correlation coefficient was calculated to correlate the age of the individual with the seven parameters from the mandibular ramus. No significant correlation was noted between the age of the individual and the given parameters. So the age of the individual could not be estimated from the mandibular ramus in the given population sample.

Discussion

Gender Determination

Estimation of gender from fragmented jaws and dentition is an important aspect of forensic science. The major drawback of sex determination using morphological marks is that this method is subjective and likely to be inaccurate. On the other hand, methods based on measurements and morphometry are accurate and can be used in the estimation of gender from the skull. Mandibular condyle and ramus were considered in the study as they are the sites associated with remodeling. It is also understood that any site of mandibular bone deposition or desorption has a potential for becoming sexually dimorphic⁵. In the modern human mandible,

sexual dimorphism has been interpreted in the literature as being related to differences between male and female growth trajectories and musculoskeletal development⁶. The muscles of mastication affect facial growth and partly determine the final facial dimensions⁷.

In this study, all the existing important parameters (viz. maximum ramus breadth, minimum ramus breadth, maximum ramus height, projective height of ramus, coronoid height, and gonial angle and bi-gonial width) were included for determining the gender of the individual from morphometry of mandibular ramus.

The mean maximum ramus width in our study in males and females are 31.07mm and 29.97mm respectively, which was significant ($P = 0.000$). This result is similar to the findings of Saini *et al.*⁸ and Pokhrel and Bhatnagar⁹ on intact 92 mandibles of North Indian population. But our result was contrary to the retrospective study conducted by Damera *et al.*¹⁰ in 2016 using 80 digital orthopantomographs of population from Visakhapatnam (South India) in the age group between 20–50 years. The seemingly smaller difference between the male and female values may be due to the fact that their sample size was too small. So the results of our study cannot be extrapolated from the results of Damera *et al.*¹⁰

The mean value of minimum ramus width in males and females were 26.47mm and 25.75mm, respectively, with a statistical significance ($P = 0.003$) in the present study. This was similar to the study conducted by Saini *et al.*⁸ in 2011 and Pokhrel and Bhatnagar⁹ in 2013. But according to Damera *et al.*¹⁰ the mean difference of minimum ramus breadth between males and females were statistically insignificant ($p = 0.847$). The possible reason for the contradictory results has been described above.

The mean maximum ramus height in our study was 55.78 for males and 52.73 for females. The current study has shown the maximum height of the ramus in males and females to be significant ($P = 0.000$), which is in accordance with the findings of Indira *et al.*¹¹ on OPGs of 50 males and 50 females from population of Bangalore (South India). This result was contrary to the results of Kharoshah *et al.*¹² on Egyptian population, where p value was greater than 0.05. The insignificant p value in their study could be either due to the smaller sample size or could be a specific population characteristic.

Measurements of the height of mandibular ramus tend to show higher sexual dimorphism than measurements of body height and breadth, thus emphasizing that

sex differences are more pronounced in mandibular ramus than body. Loth and Henneberg¹³ proved that the mandibular ramus flexure is very useful in the determination of sex up to an accuracy of 94–99% in combined African and Americans samples. A number of metric studies performed by different authors on mandible also have confirmed that the ramus of mandible is most dimorphic¹⁴.

The mean projective height of the ramus in males and females in this study were 56.85mm and 53.67mm, respectively, which indicated significant sexual dimorphism. The mean value of coronoid height in males and females in the present study were 54.36mm and 50.72mm, respectively (p value=0.000). This study was in agreement with Indira *et al.*¹¹ and Damera *et al.*¹⁰.

The present study also shows the mean value of gonial angle to be statistically significant between males and females. The mean gonial angle for males was 159.19mm, while for females was 156.33mm. Similar findings were noted by Damera *et al.*¹⁰ on Vishakhapatnam population. But the results of this study cannot be considered reliable to compare with our study due to the small sample size. The results of our study were in contrast to the study by Shamout⁴ in 2012 on population of Jordan, which included 209 subjects (103 men and 106 women). This finding again indicates the population specificity of gonial angle. Another study of Sambhana *et al.*¹⁴ on 384 OPGs from population of Vishakhapatnam in 2016 showed that the mean gonial angle of females were greater compared to males. Even though this difference was not statistically significant, this could be related to the sampling errors of the latter study.

The mean value of bi-gonial width for males was 175.02 and for females were 165.81. The variable bi-gonial width also showed significant difference between males and females, which was similar to the findings by Shamout⁴ ($p = 0.00$). On the contrary, Damera *et al.*¹⁰ got an insignificant p value of 0.083.

Each of the seven variables measured on the mandibular ramus using orthopantomographs showed statistically significant differences between sexes, indicating that mandibular ramus expresses strong sexual dimorphism in terms of maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus, coronoid height, gonial angle and bi-gonial width in this population. Previous studies on different population showed varying results for all the above seven variables. The reason for the

difference of results for different parameters strongly points to the fact that the levels of sexual dimorphism are population - specific, due to a combination of genetic and environmental factors¹⁵. Also, inherited hormonal or endocrine growth factors and socioeconomic factors may contribute to a lower degree of sexual dimorphism¹⁴. Being a retrospective study, the above mentioned factors could not be controlled in the present study. The above factors also should be taken into account while considering the variation of results in different populations.

Mandibular ramus measurements were subjected to logistic regression to formulate equation for identification of gender from the seven parameters. Based on logistic regression, the variables that were found to be statistically significant in determining the gender were the maximum ramus breadth, coronoid height, and gonial angle and bi-gonial width.

The prediction rate using the four variables was 75.2% for females, 72.7% for males, while the overall accuracy was 73.9%. In a study conducted by Giles¹⁶ it was 85%, while Dayal *et al.*¹⁷ showed an accuracy of 75.8%. In most of the studies that have been conducted in the past, the important variables that were considered and included for sex determination were mandibular height, mandibular ramus projection, mandibular width, or mandibular gonial angle. Steyn and Iscan¹⁸ achieved an accuracy of 81.5% with five mandibular parameters (i.e., gonial breadth, total mandibular length, bicondylar breadth, minimum ramus breadth, and gonion-gnathion) in South African whites. The present study also supports the findings of previous studies that mandibular ramus measurements can be used to determine the gender of an individual, although the overall accuracy we got was lower compared to the results of previous studies i.e; 73.9%. Logistic regression was performed to obtain ROC curve (Figure 2). From the ROC curve, cut off values at different sensitivity and specificity values may be obtained for screening or confirmatory purposes. In this study, at a cut off value of 0.5% the specificity was 75%, while the sensitivity was found to be 72%. For screening a large population, a cut off set at high sensitivity may be selected from the ROC curve. While choosing a cut-off with high sensitivity, it is likely that there may be more false positive cases. So for confirmatory purposes we have selected a cut off value at a high specificity.

As magnitude of sex-related differences varies significantly among regional populations, the discriminant

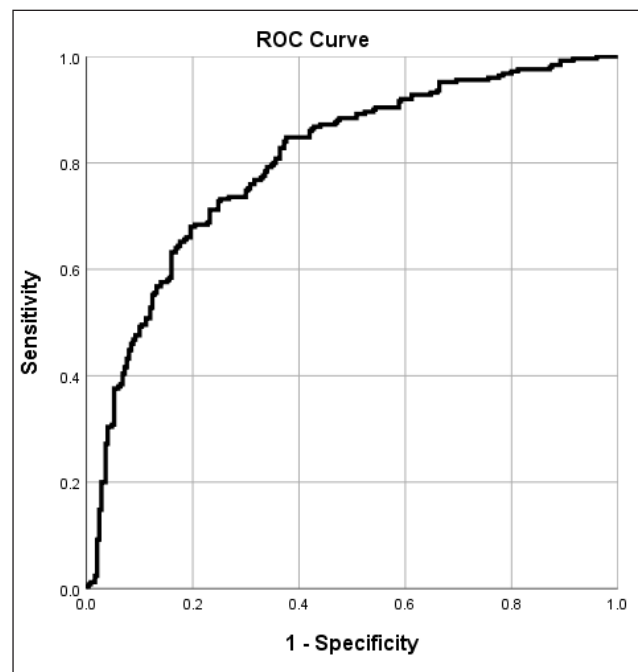


Figure 2. ROC curve obtained with different specificity and sensitivity.

function derived from one specific population cannot be applied to another¹. So, there is always a need to develop population-specific standards for accurate sex determination from a skeleton derived from that population. Hence, standards have been developed for different populations worldwide. In the previous studies, the mandibular parameters were subjected to stepwise discriminant analysis to get the equation to predict gender. This is the first study where stepwise logistic regression, followed by statistical modelling was used to formulate an equation to predict gender.

In the present study, mandibular measurements and age did not show a statistically significant positive (direct) correlation in the whole sample studied. This was contrary to the results of Taleb NSA and Beshlawy ME¹⁹, which showed a significant correlation between gonial angle and the age in Egyptian population sample. May be study including a wider age range could have resulted in a positive correlation between mandibular measurements and age. But according to the present scenario in Kerala it is difficult to get dentate patients above 50 years of age. However, Raustia and Salonen²⁰ found no correlation between age and ramus height in their study on complete denture wearers (12 males, 18 females, age range 42-74 years mean 61 years). In a study by Oksayan *et al.*²¹ on completely edentulous (n=24, mean age 69.7), old dentate

(n=24, mean age 62.2 years) and young dentate (n=24, mean age 18.8 years) subjects the results revealed that ramus height increased with age but decreased with edentulous status. The different results of the correlation between mandibular parameters and age observed among various studies may be attributed to the different age ranges and different dental status selected among those studies.

The result of the present study support previous research on other populations that the mandibular ramus shows high sexual dimorphism and proves to be beneficial in sex determination, but could not assist in age estimation.

Limitations

1. In the present study, no significant correlation was noted between the age of the individual and the given parameters. The reason may be because the sample size for each age group was different. The number of panoramic radiographs is less after 30 years of age, considering the trend in the institution.
2. The comparison between different age groups also could not be done as the sample size for each age group was different.

However, the use of mandibular ramus is recommended as an aid for sex determination in forensic analysis. Further studies using wider age range of dentate population and different imaging modalities are recommended to set our population standards for age estimation.

Conclusion

In the present study, a total of 500 individuals consisting of 250 males and 250 females were analysed. Variables like maximum ramus breadth, minimum ramus breadth, maximum ramus height, projective height of ramus, coronoid height, gonial angle and bigonial width were assessed on OPG's and compared between males and females. All the seven parameters showed statistically significant differences of mean between males and females (p -value <0.05). The parameters that were found to show statistical significance in predicting gender were maximum ramus height, coronoid height, bigonial width and gonial angle.

At the cut of value of 0.5 the specificity was 75%, and sensitivity was 72% for the study. The accuracy of gender prediction for males was 72.7%; females was 75.2%, while the overall accuracy was 73.9%. Mandibular measurements and age did not show a significant positive (direct) correlation in the study. In the present study, no significant correlation was noted between the age of the individual and the given parameters. The reason may be because the sample size for each age group was different.

There were differences between the results of the present study and the previously published studies. This may be because the morphometric differences of mandible between males and females may be based on environmental and genetic factors. Hence, it is necessary to validate these results on different ethnic and racial populations. Further studies on more diverse populations with a wide age group and including the environmental and genetic factors are recommended to assess the significance of these parameters. Also, population specific sex determination in the sub-adult range and gender identification in edentulous cases are possible avenues to be explored.

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