Mandibular ramus: An indicator for gender determination: A retrospective digital radiographic study

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**Abstract**---The results of present study proved that the mandibular ramus plays an important role in sex determination due to its unique high sexual dimorphism, so does the gonial angle, which is linear to studies done previously with a smaller sample size. [8, 9, 13] The mandible also possesses resistance to damage and
disintegration process. Hence, we conclude that the use of mandibular ramus and gonial angle is recommended as an aid for gender determination in forensic anthropology.

Keywords—mandibular ramus, indicator gender determination, retrospective digital radiographic study.

Introduction

Extra-oral digital dental radiography is becoming more popular in routine dental practice.[1] The ease of storing the digital radiographic images and to be able to reproduce them when required has made digital radiography an important tool in forensic anthropology. Orthopantomographs (OPGs) are the most common extra-oral radiographs made for viewing the maxillo-mandibular structures completely in dentistry.[2] Gender determination is necessary in forensic science, in cases of mass fatality incidents where bodies are damaged beyond recognition and it depends largely on the available parts of the skeleton. The mandible is considered as one of the strongest bone in the human skeleton that can survive in a well-conserved state much longer than any other bones.[3] Hence, it is imperative to study the mandibular ramus for scope of gender determination.

Materials & Methods

This study was a digital retrospective study. 600 digital OPGs of patients with age ranging between 21 to 50 years of either gender, fulfilling the exclusion and inclusion criteria were randomly selected from the archives of Department of Oral Medicine and Radiology for this study.

Inclusion criteria

The study included the scans of:

1. Scans of completely dentulous mandible
2. High quality radiographs with correct positioning.

Exclusion Criteria

The study did not include the scans of:

1. Presence of any visible gross deformity of the maxilla-mandibular structures on the OPG.
2. Presence of any artefacts on the radiograph.
3. Presence of any radiolucent or radio-opaque lesions in the mandibular arch.
4. Missing premolars
5. Mixed dentition
6. History of trauma and/or ongoing / completed treatment for the same.

A total of 7 measurements (in mm) were performed on the digital radiographic image. Method of analysis of various parameters were as follows (refer to Figure 1)

**Figure 1: Image showing OPG measurements**

1. Maximum Ramus width: Largest Anterior-Posterior diameter of the ramus - A.
2. Minimum Ramus width: Smallest Anterior-posterior diameter of the ramus - B.
3. Maximum Condylar Height: from the most superior point on the mandibular condyle to the most inferior point of the mandible - C.
4. Maximum height of the ramus: The point of line of intersection from the highest projection point of the mandibular condyle and lower margin of the bone - D.
5. Maximum coronoid height: Projective distance between the coronoid and most inferior point of the bone - E.
6. Gonial Angle: A line traced tangentially to the most inferior points at the gonial angle and the lower border of mandibular body and another line tangential to the posterior borders of the ramus and the condyle. The intersection of these two lines formed the gonial angle - F.
7. Bigonial width: It is the distance between two gonia. It is measured horizontally from the right to the left gonia - G.

These parameters are most stable and easy to identify on the mandible. Hence they were chosen for current study with a larger sample size of 600 OPGs on consulting the biostatistician, based on previous studies. These parameters were also considered in a previous study by Ajit Demera et al which was of a lower sample size (less than 100). The measurements were noted down in a tabular form. Each gender group was further subdivided into three age-wise categories, to determine age-related changes in these parameters of the mandible.

The data on categorical variables is shown as (n % of cases) and data on continuous variables is presented as mean and standard deviation (SD). The
inter-group statistical comparison of distribution of means of continuous variables is tested independent sample 't' test or unpaired 't' test. The inter-group statistical comparison of distribution of means of continuous variables is also tested using analysis of variance (ANOVA) procedure. For paired comparisons of means of continuous variables, paired 't' test is used. The linear discriminant function analysis is carried out to obtain the linear combination of various measurements that characterizes the two classes of gender. The underlying normality assumption was tested before subjecting the study variables to 't' test and ANOVA. All results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly. In the entire study, the p-values less than 0.05 are considered to be statistically significant. The entire data is statistically analyzed using Statistical Package for Social Sciences (SPSS version 24.0, IBM Corporation, USA) for MS Windows for gender determination.

**Results**

The descriptive statistics of various mandibular ramus measurements on digital OPGs according to age in males and females is shown in Figure 2 (a) and (b).

Figure 2 (a): The descriptive statistics of various mandibular ramus measurements according to age and laterality in males; combined (right and left)

2(b): The descriptive statistics of various mandibular ramus measurements according to age and laterality in females; combined (right and left)

This shows various means of all the parameters of the left and the right side as well their combined means within the age category as illustrated in Table 1 (a) and (b) and Table 2.
Table 1: (a) The linear discriminant function based on various mandibular ramus measurements for each sex [all age groups combined]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Right Side</th>
<th>Left Side</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Constant</td>
<td>-9214.64</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Max. Ramus Width</td>
<td>57.24</td>
<td>54.65</td>
<td>9.96</td>
</tr>
<tr>
<td>Max. Condylar Height</td>
<td>29.37</td>
<td>26.69</td>
<td>30.28</td>
</tr>
<tr>
<td>Max. Ramus Height</td>
<td>40.03</td>
<td>34.82</td>
<td>43.95</td>
</tr>
<tr>
<td>Max. Coronoid Height</td>
<td>34.97</td>
<td>38.14</td>
<td>24.92</td>
</tr>
<tr>
<td>Angle</td>
<td>58.49</td>
<td>66.29</td>
<td>65.73</td>
</tr>
<tr>
<td>Bigonial width</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Values are Classification function coefficients (Fisher’s linear discriminant function).

(b) The sex could be determined from the calculations of discriminant analysis using the equations given below

<table>
<thead>
<tr>
<th>Measurement Side</th>
<th>Equation based on discriminant analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>DMale = -9214.64 + 57.24 (Max. Ramus Width) – 37.37 (Min. Ramus Width) + 29.37 (Max. Condylar Height) + 40.03 (Max. Ramus Height) + 34.97 (Max. Coronoid Height) + 58.49 (Angle).</td>
</tr>
<tr>
<td></td>
<td>DFemale = -7656.54 + 54.65 (Max. Ramus Width) – 34.19 (Min. Ramus Width) + 26.69 (Max. Condylar Height) + 34.82 (Max. Ramus Height) + 38.14 (Max. Coronoid Height) + 66.29 (Angle).</td>
</tr>
<tr>
<td>Left</td>
<td>DMale = -8878.17 + 9.96 (Max. Ramus Width) – 27.30 (Min. Ramus Width) + 30.28 (Max. Condylar Height) + 43.95 (Max. Ramus Height) + 24.92 (Max. Coronoid Height) + 65.73 (Angle).</td>
</tr>
<tr>
<td></td>
<td>DFemale = -7285.49 + 11.81 (Max. Ramus Width) – 24.54 (Min. Ramus Width) + 27.58 (Max. Condylar Height) + 37.04 (Max. Ramus Height) + 27.61 (Max. Coronoid Height) + 70.65 (Angle).</td>
</tr>
<tr>
<td>Combined</td>
<td>DMale = -16408.50 + 16.35 (Max. Ramus Width) – 30.53 (Min. Ramus Width) + 57.29 (Max. Condylar Height) + 19.19 (Max. Ramus Height) + 36.93 (Max. Coronoid Height) + 64.84 (Angle) + 84.44 (Bigonial width).</td>
</tr>
<tr>
<td></td>
<td>DFemale = -14437.30 + 16.80 (Max. Ramus Width) – 26.13 (Min. Ramus Width) + 52.93 (Max. Condylar Height) + 12.31 (Max. Ramus Height) + 40.32 (Max. Coronoid Height) + 54.72 (Angle) + 84.56 (Bigonial width).</td>
</tr>
</tbody>
</table>

Table 2: The distribution of accuracy of prediction of sex based on various mandibular ramus measurements (combined measurements)

<table>
<thead>
<tr>
<th>True Group</th>
<th>Predicted Group Membership</th>
<th>Total</th>
<th>% Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>268</td>
<td>32</td>
<td>300</td>
</tr>
<tr>
<td>Female</td>
<td>30</td>
<td>270</td>
<td>300</td>
</tr>
<tr>
<td>Total</td>
<td>298</td>
<td>302</td>
<td>600</td>
</tr>
</tbody>
</table>
We found that all the 7 parameters show statistically significant difference between the two genders. The mean bigonial width in males is found to be 182.5mm, while it is 176.79mm in females. The mean bigonial angle in males is 154.73, while in females it is 172.45. Males showed greater mean value of maximum ramus width (31.09 ± 0.67), minimum ramus width (29.30 ± 0.75), maximum condylar height (57.38 ± 1.69), maximum ramus height (66.46 ± 0.49) and maximum coronoid height (56.66 ± 0.78), while females showed lower value of maximum ramus width (30.45 ± 1.08), minimum ramus width (28.73 ± 1.59), maximum condylar height (52.12 ± 2.12), maximum ramus height (60.25 ± 1.22) and maximum coronoid height (55.90 ± 1.28). Although, age group did not show statistically significant difference in values of chosen parameters.

Table 3: The comparison of various mandibular ramus right sided measurements between male and female subjects studied (Overall age group)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Male (n = 300)</th>
<th>Female (n = 300)</th>
<th>T-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Ramus Width</td>
<td>31.20 ± 0.72</td>
<td>30.34 ± 0.94</td>
<td>12.57</td>
<td>0.001***</td>
</tr>
<tr>
<td>Min. Ramus Width</td>
<td>29.66 ± 0.79</td>
<td>28.68 ± 1.47</td>
<td>10.18</td>
<td>0.001***</td>
</tr>
<tr>
<td>Max. Condylar Height</td>
<td>57.41 ± 2.18</td>
<td>51.55 ± 1.82</td>
<td>35.73</td>
<td>0.001***</td>
</tr>
<tr>
<td>Max. Ramus Height</td>
<td>66.47 ± 0.55</td>
<td>60.31 ± 1.22</td>
<td>79.89</td>
<td>0.001***</td>
</tr>
<tr>
<td>Max. Coronoid Height</td>
<td>56.63 ± 0.77</td>
<td>55.96 ± 1.04</td>
<td>8.99</td>
<td>0.001***</td>
</tr>
<tr>
<td>Angle</td>
<td>154.28 ± 2.17</td>
<td>172.32 ± 0.47</td>
<td>140.71</td>
<td>0.001***</td>
</tr>
</tbody>
</table>

P-value by unpaired t test, p-value<0.05 is considered to be statistically significant. ***P-value<0.001.

A discriminant analysis was performed to predict sex. The Results are as given in Table 1(b). This shows that the mandible shows high degree of sexual dimorphism and that these parameters can be used to determine gender of an individual as required in forensic medicine using digital OPG.

Discussion

The mandible is considered as one of the strongest bone in the human skeleton that can survive in well conserved state much longer than any other bones. Among various anatomical landmarks in the mandible, the mandibular ramus and gonial angle are regarded as stable landmarks. Mandibular ramus is believed to differentiate between genders, because of the differences in the stage of development, growth duration and growth rates. The gonial angle is located at the posterior border of the junction of the lower border of the ramus of the mandible. In all racial groups, the mean angle in females is 16 to 18 degrees higher than in males. Similar results were found in this study.

In forensic anthropology, comparison of ante-mortem and post-mortem radiographs is one of the cornerstones in positive identification of human skeletal remains. Antemortem orthopantomomograms may be of great value in identification since they are commonly accessible and are used in daily
clinical practice to assess mandibular vital structures bilaterally. Thus the presence of plenty of digital panoramic radiographs provide a great opportunity to study sexual dimorphism as it images the mandible very well. Skeletal characteristics differ in each population emphasizing the need for population specific osteometric standards for gender determination. Also, many studies have been carried out in India on gender determination using mandibular ramus but most of them had a sample size of less than 100 OPGs. Therefore the current study was planned using a sample size of 600, and it produced reliable results.

The methodology used was useful for gender determination. It was possible to create a logistic regression model using these parameters, that presented 89.67% accuracy (Table 6) for gender estimation in this large sample size of 600, thus can be useful in forensic sciences. However, the model cannot be used for age estimation (Figure 3 a and b) which is consensus with other similar studies by Mehta et al and Shah PH et al in 2020.

Figure 3: The comparison of various mandibular ramus combined (right and left sided) measurements between male and female subjects studied (Overall age group)

Conclusion

The results of present study proved that the mandibular ramus plays an important role in sex determination due to its unique high sexual dimorphism, so does the gonial angle, which is linear to studies done previously with a smaller sample size. The mandible also possesses resistance to damage and disintegration process. Hence, we conclude that the
use of mandibular ramus and gonial angle is recommended as an aid for gender determination in forensic anthropology.

Acknowledgements

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Consent for publication

Not applicable. There is no individual person’s data in any form in the manuscript (No individual details, pictures, images or videos)

Conflict of interest

There are no conflicts of interests.

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