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Gender determination using mandibular ramus on digital panoramic radiography: A retrospective study in Delhi NCR population

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Abstract
Background: The determination of gender of unknown person is of vital importance in forensic investigations. The most commonly studied bones in sex determination is the pelvis, skull, thorax, vertebrae, femur, and scapula. Skull is the most dimorphic and easily sexed portion of skeleton after pelvis, providing accuracy up to 92%. But 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.
Aim: The present study was undertaken to evaluate the accuracy and reliability of mandibular ramus and gonial angle in gender discrimination using morphometric measurements of National Capital Region population using digital panoramic radiographs. Apart from determining the gender, comparison with different age groups and bilateral side of mandible was also carried out.
Materials and Methods: Upper and Lower ramus breadth, Condylar and Coronoid ramus height and gonial angle was calculated in both males and females in age group ranging from 15-55 years.
Results: Out of the 5 parameters 3 were found to be significant. Gender assessment was established correctly with an accuracy of 78% for females and 80% for males with a mean of 79%.

Keywords: Gender determination, Mandibular morphometric analysis, Panoramic radiography

Introduction
The need for identification of an unknown person can be social, emotional and legal. Identification of an individual, living or dead is based on the theory that all individuals are unique. When an unidentified body is found, it is assumed that it could be anybody. By classifying the individuals into characteristic groups like age, sex, race, height, the possibilities are narrowed down. With the advent of forensics, adequate light is thrown on individual identification, when crime and disasters are at arise in today's scenario.[1]

Craniometric features are included among these characteristics which are closely related to forensic dentistry. The Techniques utilized can indicate sex, race, ancestry, and stature. Such studies play a vital role in investigating criminal and non-criminal legal matters.[2]

The most commonly studied bones in sex determination is the pelvis, skull, thorax, vertebrae, femur, and scapula. Skull is the most dimorphic and easily sexed portion of skeleton after pelvis, providing accuracy up to 92%. But 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.[3]

The present study was undertaken to evaluate the accuracy and reliability of mandibular ramus and gonial angle in gender discrimination using morphometric measurements with digital panoramic radiography. Apart from determining the gender, comparison with different age groups and bilateral side of mandible would also be carried out among the NCR population.

Materials and Methods
Previously exposed digital orthopantomogram of 500 subjects(Table-1) which satisfied the inclusion criteria were obtained from Department of Oral Medicine and Radiology, Divya Jyoti College of Dental Science & Research, Modinagar, Uttar Pradesh. The digital orthopantomogram were acquired by Kodak 8000C digital panoramic and cephalometric imaging system (Carestream Dental LLC, Atlanta, GA, USA). The occlusal plane was positioned horizontally to the scan plane. The mid-sagittal plane was centered. The images were obtained at 73 KVP, 12mA, and 13.9 s. For evaluation of the orthopantomogram images, a 19-inch LCD monitor (HP L1910, Hewlett-Packard Development Co., USA) with 1280×1024-pixel resolution and a 800:1 contrast ratio was used. The Kodak Dental Imaging Software 6.8 Windows edition (Carestream Health Inc., NY, USA) was used. The digital panoramic images were saved in a JPEG file format where linear and angular measurements were performed.

Measurement of ramus and gonial angle
After image calibration, the following Ramus and Gonial Angle measurements were carried out using mouse driven method (by moving the mouse and drawing lines using chosen points on the digital panoramic radiograph).

1. **Upper Ramus Breadth (a):** The horizontal distance between the most anterior to the most posterior point of ramus passing through the sigmoid notch along a line parallel to the transverse plane. **(Figure 1)**
2. **Lower Ramus Breadth (b):** The horizontal distance between the most anterior to the most posterior point of the ramus at the level of occlusal plane along a line parallel to the previous one. **(Figure 1)**

3. (An average ramus breadth value of (a) and (b) was calculated for each side and used for further analysis). For standardization, a horizontal orientation line (O) was digitally traced passing through the summit of the gonial angle and used for the following measurements.
4. **Condylar Ramus Height (c):** The distance from the condylion (A) to the intersection of the orientation line with the inferior border of ramus (B). **(Figure2)**
5. **Coronoid Ramus Height (d):** The distance between coronoid (C) and the intersection of the orientation line with the inferior border of ramus (B). **(Figure2)**
6. **Gonial Angle (e):** These were measured as the intersection between a digitally traced line tangential to the most inferior points at the angle and the lower border of the mandibular body and another line tangential to the posterior borders of the ramus and condyle. **(Figure3)**

Data collection and exporting to the software were done by a maxillofacial radiologist who did not participate in measurement taking. All the measurements were performed by two radiologists of similar experience in the field of Oral and Maxillofacial Radiology. The interobserver reliability was assessed by kappa coefficient (0.8). The mean values taken by the two observers was calculated.

The measured parameters, age and the subject's gender were entered in Microsoft Excel spread sheet. The data was obtained, tabulated and sent for statistical analysis.

Twenty percent of the samples (50 males and 50 females) were again evaluated after 3 months and the measurements were found to be similar to the previous measurements of the mandibular ramus parameters and gonial angle.

Results

The results of the present study revealed statistically significant differences in the morphometric measurements like condylar ramus height, coronoid ramus height and gonial angle among males and females. The dimensions are significantly higher in males for condylar ramus height (Table -2) and coronoid ramus height (Table -3) whereas dimension are slightly higher in females for gonial angle.(Table 4). On the other hand, difference in the mean upper ramus breadth and lower ramus breadth among males and females was statistically non-significant. The sex predictability was the highest for condylar ramus height, followed by coronoid ramus height and gonial angle. Sex assessment was established correctly with an accuracy of 78% for females and 80% for males with a mean of 79%. **(Figure 4).**

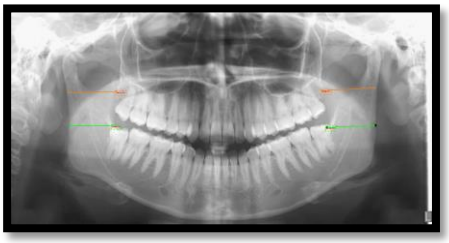

Fig 1: Upper and lower ramus breadth

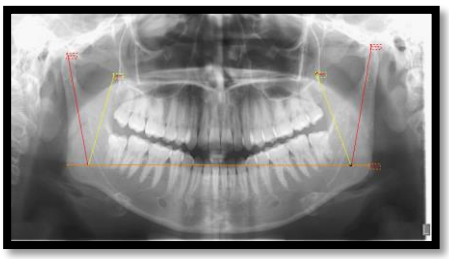

Fig 2: Condylar and coronoid height

Fig 3: Gonial angle

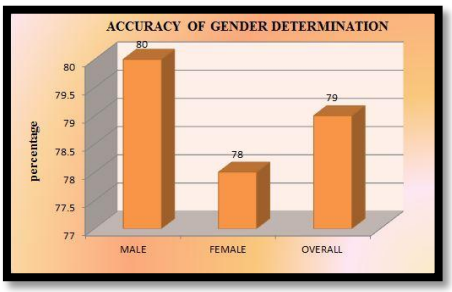

Fig 4: Accuracy of gender determination

Table 1: Age group and gender distribution

Age Groups	Male	Female	Total
25-35	83	90	173
36-45	89	87	176
46-55	78	73	151
Total	250	250	500

Table 2: Gender based comparison of condylar ramus height

Side	Mean ±SD (in mm)		Student's Unpaired 't' test value	P value	Significance
	Male	Female			
Right Side	66.51±5.78	62.45±4.79	5.924	P=0.001*	Significant
Left Side	63.77±6.05	59.51±4.94	6.246	P=0.001*	Significant

Table 3: Gender based comparison of coronoid ramus height

Side	Mean ±SD (in mm)		Student's Unpaired 't' test value	P value	Significance
	Male	Female			
Right Side	64.67±4.37	60.72±3.56	6.329	P=0.001*	Significant
Left Side	62.66±5.05	58.98±3.27	5.828	P=0.001*	Significant

Table 4: Gender based comparison of gonial angle

Side	Mean ±SD (in degree)		Student's Unpaired 't' test value	P value	Significance
	Male	Female			
Right Side	119.61±9.04	122.88±7.21	4.855	P=0.032*	Significant
Left Side	122.43±8.05	124.73±7.69	3.914	P=0.027*	Significant

Discussion

In the present study overall prediction accuracy rate using upper ramus breadth, lower ramus breadth, condylar ramus height, coronoid ramus height and gonial angle was 79%. This is comparable to the findings of **Indira et al.**[4] who concluded an accuracy rate of 76% and **Franklin et al.**[5] who got an accuracy rate of 77%. Earliest studies on mandible by **Morant et al.** [6]**(1986)** and **Martin (1996),** have established the usefulness of mandible for the determination of gender. They found that the gender differences were highest in height of the ramus, thus emphasizing that the differences are more pronounced in mandibular ramus than in body.

The results obtained in our study are in accordance with studies conducted **Vodanovic (2006)**[7] and **Behl et al. (2020)**[8] to these studies as coronoid ramus height, condylar ramus height and gonial angle reliably determined gender in these studies.

In the present study, Gonial angle values in males and females range from 109.5° to 143.7° with a mean value of 124.1°. Females had significantly greater gonial angle as compared to males. Our results were consistent with results obtained by **Kumar et al. (2013)**. [9]

A study by **Hettiarachchi PVK et al. (2021)** [10], measured condylar ramus height, coronoid ramus height, upper ramus width, and lower ramus width which were higher in males, while average values of gonial angle were higher in females. There were no significant differences between genders for average values for condylar ramus height, coronoid ramus height, upper and lower ramus widths, GA, and area with the present study with an overall accuracy of 79%

In other studies, carried out by **Saini et al.**[11] and **Neeru et al.**[12] on dry adult mandibles of the northern part of India and found that ramus expresses strong sexual dimorphism in this population. The overall prediction rate using five variables was 79.2%. results of our study were in accordance to the results obtained in their studies.

. We noticed that multiple factors when used together were more accurate than any single factor when used alone for gender determination using panoramic radiographs. This is also concluded by Leena James et al.[13] in their elaborate study.

Thus, it has been established that socio-environmental factors (e.g., malnutrition, climate, pathologies, occupation etc.) influences the development and the appearance of bones. Obviously, the highest probability of correct diagnosis of gender comes from a complete examination of all bones known to belong to a given individual-no single skeletal indicator should be relied upon exclusively if other proven dimorphic areas are available.

Limitation

The limitation includes the small sample size hence further studies are needed on a larger and different population to statistically determine the sample size. The other limitation of the present study was that the samples retrieved retrospectively and samples were randomly selected

Conclusion

The present study proposes the importance of sexual dimorphism of mandibular ramus morphometric measurements, in particular its condylar ramus height, coronoid ramus height and gonial angle are reliable discriminant significant parameters in gender assessment

when all the methods used in the field of forensics seem to be inconclusive.

This study also proposes that digital orthopantomogram imaging for morphometric measurements of ramus and gonial angle in the forensic field are reliable, reproducible and accurate in gender determination.

Hence digital orthopantomogram for morphometric analysis of ramus and gonial angle can be used as adjunct in forensic studies for gender determination. Further studies should be done with a large sample size to validate our results to the larger population. The use of three dimensional imaging technique like CBCT could also provide more accuracy with inclusion of more parameters.

Source of Funding
None.

Conflict of Interest
None.

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