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ORIGINAL ARTICLE

Determination of Sexual Dimorphism using Panoramic Radiograph –A Cross Sectional Study from Kerala, India

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Abstract:

Morphological features of mandible have a vital role in forensic anthropology. The objective of the study was to determine whether morphometric mandibular ramus measurements like minimum ramus width, maximum ramus width and condylar height from digital radiography can be used for the assessment of sexual dimorphism. Cross-sectional study from the 300 clear panoramic radiographs without any artefacts with the permanent dentition of adults between the age group 21 to 60 were included. Mandibular measurements were carried out using the standard inbuilt imaging Ez dent imaging software using anatomical points in the radiograph. Discriminant function analysis (DFA) was used to build a predictive model group based on gender. Receiver Operating Characteristics (ROC) curve was used to classify the gender with all three mandibular measurements. Males have higher values for all three measurements compared to female sex. Maximum ramus height coefficient (0.962) with large absolute values corresponds to variables with greater discriminating ability; while minimum ramus width (0.232) and maximum ramus width coefficient (-0.110) had lesser discriminatory function. ROC curve failed to discriminate gender for all three mandibular variables. Mandibular maximum ramus height was the most important predictor to assess sexual dimorphism in the present study. Morphometric measurements were accurate and in present study, DFA correctly classified 73.7% cases from Kerala population.

Keywords: Forensic odontology; Morphometric mandibular measurements; Discriminant function analysis.

Introduction:

Identification of characteristics of an individual involves estimation of age, sex and ethnicity. In forensics, gender estimation is crucial since only people of the estimated sex need to be considered in the further investigations. Forensic skeletal remains are investigated to determine the gender of an individual based on anthropological metric and nonmetric analysis or biochemical analysis.

The whole body or skeleton when available for the study gender estimation becomes easy based on the physiologic and morphologic dimorphism exhibited by the human body. Forensic odontology forms a part of forensic anthropology. Various methods have been employed time to time to estimate age, sex and race of an individual. Morphometric analyses plays a major role in assessment of gender and male bone have found to be bigger and robust than female bones.[1,2] Mandible has been often recovered intact in the degenerated or burned skeletal remains due to the dense layer of cortical bone surrounding it. Morphological features of mandible have a vital role in sex determination. Numerous mandibular parameters have been put into study like minimum ramal width, maximum ramal width, gonial flexure, ramal height, coronoid height and position of mental foramen. The study in primates show that mandibular ramus exhibit marked sexual dimorphism since active bone remodelling takes place in ramus due to the different levels of masticatory forces and also due to varying growth trajectories in males and females.[3]

Digital panoramic radiography has been used as a routine investigation for diagnosis as well as treatment of various hard tissue and soft tissue related pathologies. The present study puts in use of the digital radiographic data of adults obtained as a part of routine dental evaluation and treatment for morphometric mandibular ramus measurements like minimum ramus width, maximum ramus width and condylar height for the assessment of sexual dimorphism.

Materials and methods:

A cross-sectional study from the 300 digital panoramic radiographs was taken from the database of the department of Oral Medicine and Radiology from a tertiary care centre in Kerala after getting ethical clearance.

Inclusion criteria: Clear panoramic radiographs without any artefacts with the permanent dentition of adults between the age group 21 to 60 were included.

Exclusion criteria: Panoramic radiographs of the edentulous

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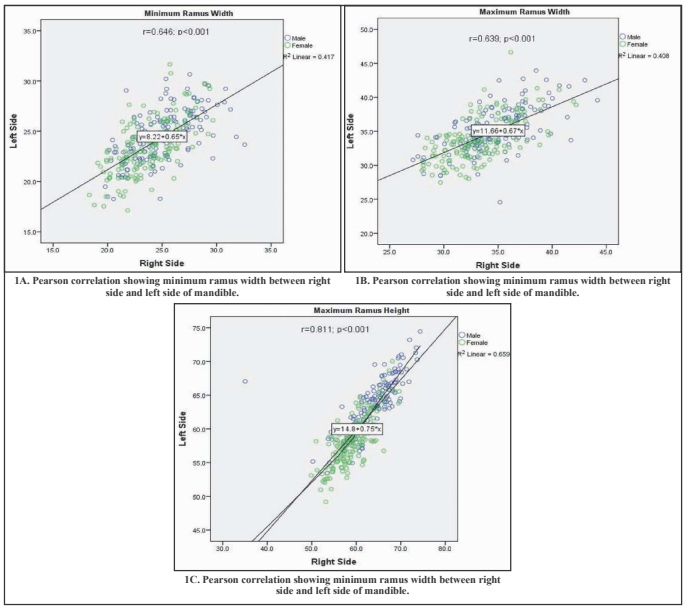

1A. Pearson correlation showing minimum ramus width between right side and left side of mandible.

1B. Pearson correlation showing minimum ramus width between right side and left side of mandible.

1C. Pearson correlation showing minimum ramus width between right side and left side of mandible.

Figure 1. Pearson correlation showing relationship of height and width of mandible between right and left sides.

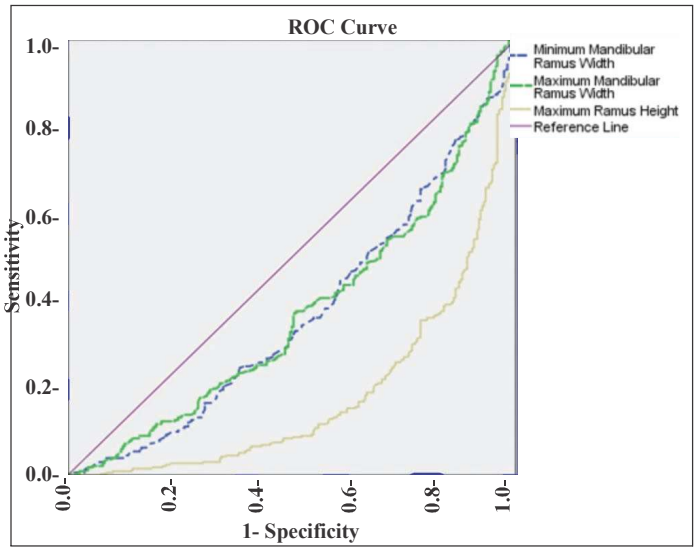

Figure 2. Receiver operating characteristics (ROC) curve showing Discriminatory threshold of morphometric mandibular ramus measurements with gender.

mandible, fractured mandibles of those having gross facial asymmetry, those with a history of orthodontic treatment or maxillofacial surgery were excluded from the study.

All digital radiographs were obtained using PaX-I digital panoramic and cephalometric machine of Villa tech (73kVp, 12mA, 13.9s). Measurements were carried out using the standard inbuilt imaging Ez dent imaging software using anatomical points in the radiograph. The following measurements were carried out

1. Minimum mandibular ramus width- the smallest anteroposterior breadth of the ramus[4]
2. Maximum mandibular ramus width-measured from anterior most point of the ramus and line connecting the most posterior point on the condyle and the angle of the jaw.[4]
3. 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.[5]

Statistical Analysis: Descriptive statistics for categorical data was represented in frequencies and for continuous data in mean (SD). Independent t test was used to study the age differences in males and females. Pearson correlation was used to study relationship between right and left side measurements. Discriminant function analysis (DFA) was used to build a predictive model group based on gender. The independent variables such as mandibular ramus measurements were used as predictors for determining gender. DFA assess how well the predictors separate the gender in mandibular measurements. Receiver operating characteristics (ROC) curve was used to classify the gender with all three mandibular measurements.

Results:

Out of 300 panoramic radiographs, 134 (45%) were selected from males and 166 (55%) were females, with mean age of 38± 11.6 years for males and 37 ± 11.6 years for females. The age distribution between the sexes were comparable (p= .702).

Figure 1 displays the correlation value which explains the relationship between right and left side measurements of mandible. There was a moderate correlation between the sides for minimum ramus width (Figure 1A; r=0.646; p<0.001). Moderate correlation was also seen for maximum ramus width between the sides (Figure 1B, r=0.639; p<0.001). Maximum ramus height displayed a strong correlation between the sides (Figure 1C, r=0.811; p<0.001).

Table 1 compares the mandibular measurements between the gender using DFA. Overall males have higher values for all three measurements compared to female sex. The Wilks lambda for Maximum ramus height was the lowest among three predictors (Lambda=0.704), with F =124.4, which can be considered as strong predictor among the mandibular measurements by DFA.

Table 2 explains whether any relationship present among the predictor variables selected. There was a moderate correlation between minimum ramus width and maximum ramus width (r=0.645), mild correlation was present between maximum ramus width and maximum ramus height (r=0.333). And no correlation was seen between minimum ramus width and maximum ramus height (r=0.251).

The canonical correlation value which measures the relation between discriminant score and gender was 0.551. The variance was 30%, estimated by square of the canonical correlation. 30% variance in dependent variable was explained by the predictors in the study. Standardized discriminant function coefficients allow comparing variables measured on different scales. Maximum ramus height coefficient (0.962) with large absolute values corresponds to variables with greater discriminating ability; while minimum ramus width (0.232) and maximum ramus width coefficient (-0.110) had lesser discriminatory function.

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Table 1. Discriminant function analysis- mandibular measurements for males and females.

	Male		Female		Wilk's lambda	F	P value
Variable	Mean	SD	Mean	SD			
Min. ramus width	24.8	2.4	23.5	2.3	0.934	20.9	<0.001
Max. ramus width	35.0	2.9	33.6	2.7	0.947	16.7	<0.001
Max. ramus height	63.9	4.3	58.8	3.6	0.704	124.4	<0.001

Table 2. Correlation coefficient between the predictor variables.

	Min. ramus width	Max. ramus width	Max. ramus height
Min. ramus width	1.000	.645*	.251$
Max. ramus width	.645*	1.000	.333#
Max. ramus height	.251$	.333#	1.000

*- Moderate; #- Mild; $- No.

Table 3. Unstandardized coefficient of mandibular measurements to Construct prediction equation for classifying males and females.

	Male	Female
Min. ramus width	1.396	1.267
Max. ramus width	2.045	2.097
Max. ramus height	3.417	3.094
Constant	-163.121	-141.964

Table 4. Classification statistics - mandibular measurements for males and females.

True Group	Predicted Group		Total	% Accuracy
	Male	Female		
Male	95 (71%)	39 (29%)	134	73.7
Female	40 (24%)	126 (76%)	166	

Table 3 shows un-standardized coefficients for the predictors, which was used to construct the actual prediction equation for classifying new cases. Overall 73.7% cases with 71% Male and 76% Female were correctly classified by DFA in the present study (Table 4). Morphometric mandibular ramus measurements in ROC curve failed to discriminate gender for all three variables (Figure 2). The area under curve was least for maximum ramus height (0.184), while the minimum and maximum mandibular ramus width had 0.369 and 0.372 respectively.

Discussion:

Overall males had higher mean values for all three (minimum ramus width, maximum ramus width and maximum ramus height) variables which can be used to construct the prediction equation for classifying new cases in Kerala. Overall 73.7% cases (71% Male and 76% Female) were correctly classified by DFA in the present study.

The age, sex and race form defining characteristics of an individual. The sex determination is carried out for identification in medicolegal cases and to identify the accident or natural disaster victims. Sex determination is considered to be the primary step since age and stature of an individual are dependent on it.[6] In situations where the whole body or skeleton is available sex determination can be done with the pelvic examination almost with 100% accuracy. For sex estimation, odontological and anthropological methodologies are utilised, both of which include different metric and nonmetric characteristics as well as biochemical studies. Odontological methods are based on sexual dimorphism in morphological and metrical features of teeth and adjacent structures (lips, mandible, palate, sinuses). It also involves biochemical structure of various tooth materials. Bitemark analysis, Palatal rugoscopy, cheiloscopy, tongue prints, digital imaging and dental records, DNA analysis, facial reconstruction profiling are a few among the odontological methods[7]. Anthropological methods are using morphological features and measurements of skeletal bones(skull, hip, sacrum, scapula, clavicle, sternum, humerus and femur mainly) as well as biochemical analyses of different skeletal materials.[8-10]

The role of Cranium in assessing sexual dimorphism is already known but an intact skull when not recovered, mandible is put to use. Because of the dense layer of cortical bone that covers it, mandibular bone is frequently recovered intact. Sexual dimorphism in mandible is evident since the bone is large in volume and robust in males compared to females. The different masticatory forces exerted by the males and females tend to influence the size, shape and mandibular flexure.[11] Mandibular ramal width, ramal height, condylar height, gonial flexure, inclination of synovial fossa, position of mental foramen were the few parameters studied to assess sexual dimorphism. In the recent study by Hazari et al the most prominent parameter showing the significant sex dimorphism was the mandibular ramus. Out of twenty morphometric studies of dry mandible 75% of studies showed a positive correlation between sex dimorphism and mandibular parameters. Mandibular ramal width and ramal height exhibited significant differences in both sexes.[12]

The craniofacial measurements which would likely contribute to sex differentiation were described by Stewart et al.[13] Hanihara et al assessed the sex difference in mandibles of Japanese population and found the parameters like mandibular symphysis height, mandibular ramus height, bigonial diameter, mandibular ramus minimum breadth contributing to the assessment.[14] The morphometric analysis of mandibular ramus width in American whites and Negroes had a remarkable sexual dimorphism compared to the mandibular body according to the study by Giles et al. The study also emphasize the fact that the assessment in a population cannot be extrapolated to another population.[15] In Korean population the anthropometric analysis done by Lin et al yielded results that favour the use of mandibular ramus measurements in sexing the individuals with 85.0% accuracy.[16]

The difference in the bigonial breadth and minimum ramus breadth exhibited by the male and female mandible were found significant by the study of Steyn et al in South African Whites.[1] Another study in South African population by Franklin et al highlighted the use of mandibular ramus to assess the sexual dimorphism. Mandibular coronoid height, ramal height and maximum mandibular length were found to be significantly different in males and females.[11] The study by Saini et al in Indian population used the parameters like minimum and maximum ramal breadth, height of ramus, condylar and coronoid height which reflected the significant role of mandibular coronoid height and mandibular ramal breadth. The study had a limited sample size and author's assumption of the effect of malnutrition which prevail commonly in Northern part of India affecting the study have been ruled out in our setting.[6] Another study done in Indians residing in South Africa by Ishwar Kumar et al reflected that males and females differed in the height of mandibular ramus to a significant level.[18] The significance of mandibular ramus

showing gender discrimination hence prompted us to do the study in our population.

The digital panoramic radiography has become a primary investigation to diagnose and treat common oral conditions. Schuller is being credited with the first to suggest the use of radiographs in human identification. He had studied the morphological variations exhibited by the sinuses in skull radiographs. Culbert and Law and Law have performed positive identification with measurements of mastoid sinuses obtained on skull radiograph and comparing with the antemortem data. Sassouni et al have discussed regarding the validity of use of different radiographs in obtaining the anthropometric measurements and highlighted the use of panoramic radiography as it ensures a high degree of standardization.[19] The principal advantage of digital panoramic radiograph involves broad coverage, low radiation dose, brightness and contrast enhancement, reproducibility, storage and computer aided metric analysis with the help of inbuilt Ez Dent imaging software. The technique is sensitive to patient positioning errors which could result in image distortion and magnification hence images obtained with standard positioning technique were only included in this study. Schulze et al had found that the Digital Panoramic radiographs are reliable in obtaining horizontal measurements and can be put to clinical use.[1] Kambylafkas et al. concluded that the use of the panoramic radiograph for evaluation of total ramal height is reliable and an asymmetry of more than 6% is an indication of a true asymmetry on the basis of study done by Kambylafkas et al.[20] Panoramic radiography has the advantage of cost effectiveness for gender and age estimation compared to the biological analyses and could be employed with ease even in fragmented skeletal remains.

An anthropological study done by Kumar MP et al in South India described significant differences in mandibular ramus breadth and height between males and females but the study warrants use of a combination of parameters rather than one alone.[21] Another study in South Indian population showed that bicondylar breadth, bigonial breadth and mandibular height measurements showed statistically significant difference in both the sexes and could form a baseline parameter in gender estimation.[22] A morphometric study on dry mandibles conducted in Pune, North India by Pokhrel and Bhatnagar depicted minimum and maximum ramus breadth showed very promising results and can be used for sexing from ramus of mandible.[23] Sex determination using digital panoramic radiographs were done in various cities of south India but not many studies have been done in the people of Kerala.

A retrospective study done in the population of Bangalore and Karnataka on the digital panoramic radiographs of complete dentate patients assessed five parameters like minimum ramus breadth, maximum ramus breadth, condylar height, projective height of ramus and coronoid height. This study by Indira et al highlighted the strong sexual dimorphism exhibited by mandibular ramus again. 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%.[6]

The research done by Sairam et al on the panoramic radiographs in Andhra Pradesh measured five mandibular parameters and found male mandibles bigger than females and projective height of ramus exhibited greater sexual dimorphism.[24] Based on studies by Mathew et al in Mangalore, Karnataka comparing two parameters; gonial flexure and Minimum ramal breadth, minimum ramal breadth was found to be more useful to predict sex.[25] Poongodi et al described differences in both angular and linear dimensions of mandibular ramus in Chennai population and stated both measurements were significantly higher in males compared to females.[26] The above studies were consistent with the results of the present study.

Conclusion:

Mandibular maximum ramus height was the most important predictor to assess sexual dimorphism in the present study. Morphometric measurements were accurate and in present study, DFA correctly classified 73.7% cases from Kerala population.

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