Assessment of Sexual Dimorphism in Mandibular Ramus: An Orthopanoramic Study

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ABSTRACT

Background

Mandible is the largest and strongest bone of the face, is very durable, and hence remains well preserved than many other bones. In cases of mass disasters where an intact skull is not found, the mandible may play a vital role in sex determination as it is the most dimorphic bone of the skull. Morphometric analysis of mandibular ramus provides highly accurate data to discriminate sex. This can be accomplished by the use of panoramic radiography which is widely available and is used routinely to assess the mandibular structures.

Objective

To evaluate and compare the various parameters of the mandibular ramus and to determine the usefulness of the mandibular ramus as an aid in sex determination.

Method

Orthopantomograms of 140 samples (70 males and 70 females) were collected from the archives and traced manually on matte acetate tracing paper. Various parameters of mandibular ramus were measured on the right and left sides. The obtained measurements were subjected to discriminant function analysis.

Result

Mandibular measurements on the right side were greater than on the left side. However, only the ramus breath (minimum and maximum) and projective height of ramus were statistically significant ($p < 0.05$). All the measurements were higher for males than females. F-statistic values indicated that the highest sexual dimorphism was seen with the projective height of ramus and least with minimum ramus breath.

Conclusion

Mandibular ramus measurements can be a useful tool for gender determination and can be an essential tool in forensic science especially when there is damaged or partially preserved mandibles and may be helpful for medico-legal purpose in Nepal.

KEY WORDS

Dimorphism, Discriminant analysis, Gender, Mandible, Panoramic, Ramus

INTRODUCTION

Forensic age estimation has been a conventional feature of the field.[1] However, sex determination of the skeletal remains is considered a preliminary step in its identification. Gender identity is often crucial in mass fatality situations where the bodies may have been damaged beyond recognition.[2] In the present forensic scenario, dismemberment or mutilation of the body has become the frequent method of concealing the victims' identity. When the entire adult skeleton is available for examination, sex can be determined with high precision, but this is not possible in mass disasters, as it is highly dependent on the parts of the skeleton that are available.[3] In such cases, the mandible can play a vital role next to the pelvis in determining age as well as identifying an individual.[4]

Sexual dimorphisms occur in almost every bone of the human skeleton.[3] Since the mandible is the most dimorphic bone in the skull, it can be used to determine gender when an intact skull is not present.[5] Variations in the maturation rate and growth pattern also exist among males and females as skeletal maturity occurs earlier in females.[3]

To date, no such studies have been carried out in Nepal. So, this study was undertaken to evaluate and compare the various parameters of the mandibular ramus for assessing sexual dimorphism and its applicability for gender identification in forensic science.

METHODS

A descriptive cross-sectional study was conducted in Kantipur Dental College Teaching Hospital and Research Center (KDCH) after obtaining ethical clearance from the Institutional Review Committee (Ref. No. 32/020). The study was conducted for a period of six months in the Department of Oral Pathology. The study was conducted on orthopantomograms (OPGs) of the patient greater than 20 years of age. Good quality standard OPGs with presence of normal anatomical structures, adequate resolution and contrast were collected from the archives of the Department of Orthodontics, Kantipur Dental College Teaching Hospital and Research Center. Patients with the full complement of teeth taken as part of pretreatment planning for orthodontic treatments were included in the study. Radiographs showing evidence of extraction, trauma, fracture involving the mandibular ramus, and any other severe developmental disturbances leading to variation in the size of the mandible, radiogrpahs with double or ghost images, artifacts, distortions were excluded. All radiographs were taken by Carestream (CS9300, Kodak) with standard parameters of 74KvP, 12 mA for 14.3 seconds exposure time, magnification of 1.22 (± 10%). The patient positioning was done based on the manufacturer's instructions.

The sample size was calculated by using the following formula: Sample size (n) = $2(Z\alpha+Z\beta)^2 s^2/d^2$

$Z\alpha$ = z deviate corresponding to the α error rate =1.96 for 95% reliability

$Z\beta$ = z deviate corresponding to the β error rate =1.28 at 90% power

s = mean of the standard deviation6 = (4.8+9.06)/2 = 6.93

d = mean difference between two groups6 = 62.61-58.82 = 3.79

n = sample size required per group = 70.195 per group

N = 70.195 X 2= 140.384

OPG fulfilling the inclusion criteria were selected through convenience sampling and were viewed in a view box using trans-illuminated light. The magnification factor for each radiograph was calculated with the help of the printed scale on the radiographic film and comparing with the stainless steel scale. Each radiograph was traced manually on matte acetate tracing paper with a 2B sharp pencil on a view box. (Figure 1a,b) All the measurements were taken by a single observer who was blinded for the age and gender of the patient. Additionally to minimize intra-observer error, all the measurements were taken with a stainless steel ruler (1 mm precision) twice for both the right and left sides and the average value was utilized for the analysis.

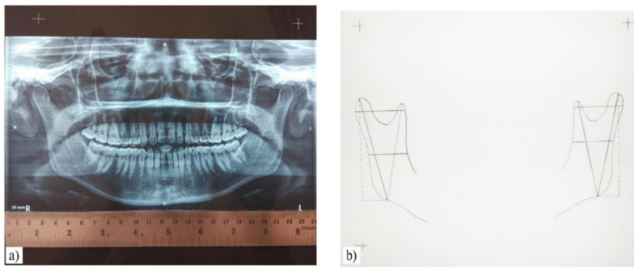

Figure 1. a) Orthopantomogram, b) Mandibular ramus tracing on matte acetate tracing paper.

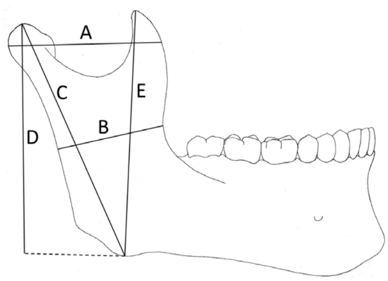

Figure 2. Variables measured in the mandibular ramus. (A) Maximum ramus breadth. (B) Minimum ramus breadth. (C) Condylar height ⁄ maximum ramus height. (D) Projective height of ramus. (E) Coronoid height.

The following measurements were taken.[3] (Figure 2);

- Maximum Ramus Breadth: The distance between the most anterior point on the mandibular ramus and a line connecting the most posterior point on the condyle and the angle of the jaw.
- Minimum Ramus Breadth: Smallest anterior-posterior diameter of the ramus.

• Condylar Height/Maximum Ramus Height: Height of the ramus of the mandible from the most superior point on the mandibular condyle to the tubercle, or the most protruding portion of the inferior border of the ramus.

• Projective Height of Ramus: Projective height of ramus between the highest point of the mandibular capitulum and lower margin of the bone

• Coronoid Height: Projective distance between coronion and lower wall of the bone.

Data were entered in the Microsoft (Ms)-Excel datasheet and analysis was done using Statistical Package for the Social Sciences (SPSS) 20.0 version. Comparison between the right and left side measurements of the mandible were done using Paired t-test while for comparison between the genders, an Independent t-test was used. Discriminant function analysis was used to determine variables that discriminate between males and females and a discriminant function was derived.

RESULTS

The study included 140 OPGs (70 males and 70 females). The patient ranged from 21-45 (22.75 ± 3.607) years of age. The mandibular parameters on the right were greater than on the left. The Paired t-test showed a statistically significant difference between the maximum ramus breadth, minimum ramus breadth, and the projective height of the ramus ($p < 0.05$) (Table 1).

Table 1. Comparison between right and left measurements using paired t-test

Variables		Mean (mm)	Std. Deviation	t	Sig. (2-tailed)	95% Confidence Interval of the Difference	
						Lower	Upper
Maximum ramus breadth	Right	36.4329	.35541	4.861	0.000	0.80767	1.91518
	Left	35.0714	.35230				
Minimum ramus breadth	Right	30.3429	.31062	2.718	0.007	0.15957	1.01185
	Left	29.7571	.28904				
Condylar height	Right	70.7714	.71076	0.176	0.860	-0.65709	0.78566
	Left	70.7071	.65751				
Projective height of ramus	Right	69.4143	.63489	2.142	0.034	0.04409	1.09876
	Left	68.8429	.64813				
Coronoid height	Right	63.5643	.61409	1.646	0.102	-0.10923	1.19495
	Left	63.0214	.65068				

The measurements in males were greater than in females on both sides (right and left). Independent t-test showed a statistically significant difference between the mandibular parameters among the genders on both sides ($p < 0.05$) (Table 2, 3).

A discriminant analysis was conducted to predict gender. The five mandibular parameters recorded were the predictor variables. Each parameter showed a statistically significant difference ($p < 0.05$) and hence each variable could be considered as a significant predictor in determining gender. F-statistic values indicate that mandibular measurements expressing the greatest dimorphism are the projective height of ramus and the least with minimum ramus breadth (Table 4).

Box's M statistics was applied to verify the applicability of mandibular ramus in predicting gender. Our study confirmed that the male and female sex can be differentiated using mandibular ramus (Table 5). The standardized and unstandardized discriminant function coefficients, structure matrix, and group centroids are shown in table 6. The unstandardized canonical discriminant function coefficients are used to create the discriminant function (equation). The discriminant function (equation):

Table 2. Comparison of measurements between gender (right side) using Independent t-test

Variables	Gender	Mean (mm)	Std. Deviation	t	Sig. (2-tailed)	95% Confidence Interval of the Difference	
						Lower	Upper
Maximum ramus breadth	Female	35.2429	3.99433	-3.479	0.001	-3.73251	-1.02749
	Male	37.6229	4.09843				
Minimum ramus breadth	Female	29.5571	3.35199	-2.581	0.011	-2.77553	-0.36733
	Male	31.1286	3.83697				
Condylar height	Female	68.3857	8.76140	-3.489	0.001	-7.47561	-2.06724
	Male	73.1571	7.35958				
Projective height of ramus	Female	67.1857	7.39034	-3.664	0.000	-6.86268	-2.05161
	Male	71.6429	6.99904				
Coronoid height	Female	61.8571	6.93716	-2.850	0.005	-5.78282	-1.04575
	Male	65.2714	7.23302				

Table 3. Comparison of measurements between gender (left side) using Independent t-test

Variables	Gender	Mean (mm)	Std. Deviation	t	Sig. (2-tailed)	95% Confidence Interval of the Difference	
Maximum ramus breadth	Female	34.0571	3.61112	-2.958	0.004	-3.38449	-0.67265
	Male	36.0857	4.45832	-3.053			
Minimum ramus breadth	Female	28.9000	3.23545		0.003	-2.82457	-0.60400
	Male	30.6143	3.40627	-4.041			
Condylar height	Female	68.1857	7.13492		0.000	-7.51056	-2.57515
	Male	73.2286	7.62371	-4.277			
Projective height of ramus	Female	66.2286	7.09188		0.000	-7.64570	-2.81144
	Male	71.4571	7.36951	-3.258			
Coronoid height	Female	60.9714	7.23713		0.001	-6.58855	-1.61145
	Male	65.0714	7.64866				

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D = (0.150*max. ramus breadth) + (-0.003*min ramus breadth) + (-0.037*condylar height) + (0.187*projective height of ramus) + (-0.073*coronoid height) - 10.916.

Table 4. Descriptive statistics and sexual dimorphism of the mandible

Variables	Female		Male		Wilks' Lamb-da	F	p-value
	Mean (mm)	SD	Mean (mm)	SD			
Maximum ramus breadth	34.6500	3.38512	36.8543	3.98249	0.917	12.450	0.001
Minimum ramus breadth	29.2286	3.00083	30.8714	3.42591	0.938	9.109	0.003
Condylar height	68.2857	7.56832	73.1929	7.30212	0.901	15.240	0.000
Projective height of ramus	66.7071	7.02660	71.5500	7.05627	0.893	16.556	0.000
Coronoid height	61.4143	6.85405	65.1714	7.14644	0.932	10.078	0.002

Table 5. Box's M test

Box's M	F Approx.	df1	df2	Sig
23.712	1.519	15	76677.158	0.089

Table 6. Unstandardized, Standardized Canonical discriminant function coefficients, structure matrix, and centroids

	Unstandard-ized Canonical Discriminant Function Coef-ficients	Standardized Canonical Discriminant Function Coefficients	Structure matrix	Centroids
Maximum ramus breadth	0.150	0.555	0.772	Female=-0.386 Male=0.386
Minimum ramus breadth	-0.003	-0.010	0.660	
Condylar height	-0.037	-0.278	0.854	
Projective height of ramus	0.187	1.316	0.890	
Coronoid height	-0.073	-0.513	0.695	
(Constant)	-10.916			

Table 7. Prediction accuracy

Group	Predicted Group	Total	Accuracy (%)
	Female	Male	
Female	49	28	70
Male	21	42	70

Overall Accuracy = 65.0%

Cases with scores near to a centroid are predicted as belonging to that group.

By considering all these variables, out of 70 males, 42 (60.0%) were correctly predicted as male, whereas out of 70 females, 49 (70.0%) were correctly predicted as female. The overall accuracy for predicting gender from mandibular ramus was 65.0% (Table 7).

DISCUSSION

The largest and the strongest bone in the face is mandible, and remains well preserved than many other bones.[3,7] As mandible is the last skull bone to cease growth, it is sensitive to adolescent growth spurt.[8,9] Both the genders have a distinct mandibular ramus, growth rate, and duration. Studies show that mandibular growth in females was found to be significant for the age periods of 14 to 16 years and 16 to 20 years and; 16 to 18 years and 18 to 20 years in males.[11,12] Hence, the present study included patient with age greater than 20.

The difference in the masticatory forces among genders also influences the shape of the mandibular ramus.[12] This could be a reason for mandibular parameters analyzed in our study to be significantly greater in males than females. This was inconsistent with the findings of other studies.[2,3,6,13,14] Palinkas et al. found that males have a greater masticatory force as compared with the female.[15] Humphrey et al. suggested that the larger values in males may be due to higher rates of bone deposition, lower rates of resorption, or even a decrease in overall bone remodeling activity at certain locations.[16]

All the parameters in this study showed a significant predictor in determining a given sample based on gender. This supports the finding of previous studies which were done on digital OPGs.[14,17] Similar study conducted by Samatha et al. on digital OPGs found that the coronoid height and minimum ramus breadth were not statistically significant.[6] Chalkoo et al. found both the maximum and minimum ramus breadth were not statistically significant.[2]

Discriminant analysis showed that the projective height of the ramus was found to be the most dimorphic in this study. This was similar to other studies.[2,6] However other studies have also reported different parameters to be dimorphic such as; condylar height, coronoid height, minimum ramus breadth.[3,13,14,17-19] Humphrey et al. pointed out that the mandibular ramus and condyle are the sites that undergo the most morphological changes in size and remodeling during development, making them the most dimorphic.[16] In our study, the variable that can be of the least use for the discrimination was found to be minimum ramus breadth.

Sexual dimorphism of the mandible is primarily characterized by size, which is population-specific.[20] Its morphology is greatly influenced by external factors.[21] Genetic factors, environment, gender, diet, hormonal and endocrine growth regulators could influence the form and degree of sexual dimorphism in mandibular morphology.[20] Since the magnitude of sex-related differences differs significantly across regional populations, it is well known that a discriminant feature derived from one population cannot be applied to another.[22] As a result, developing a population-specific standard for accurate sex determination from a skeleton derived from that population is often essential. Hence, discriminant function analysis was done to determine variables that discriminate between males and females.

The study estimated that the gender for females with an accuracy of 70.0% and 60.0% for males. The overall accuracy rate of the discriminant function was found to be 65.0%. Other studies have reported the accuracy rate to be 60.3 to 80.2% and 56.5%.[3,6] Greater accuracy has also been reported with an accuracy rate of 84.0%, 87.5%, and 90.0%.[2,14,18]

Several studies have been conducted to test the efficiency of the mandible as a tool for sexual dimorphism worldwide.[7,12,16] The mandible was chosen for the study for two reasons: first, it appears that few standards use this feature, and second, this bone is often recovered largely intact.[23] In addition to descriptive characteristics, morphometric analysis of the skeleton for sex determination is considered more reliable due to its objectivity, precision, reproducibility, and lower degree of inter-and intra-observer errors.[24,25]

A study based on Multidetector Computed Tomography (MDCT) images showed parallel results among the ramus breadth and height.[26] The MDCT is subjected to more amount of radiation and is more expensive than our method. However, panoramic imaging is also subjected to limitations such as distortion as a result of unequal magnification, lower resolution images, superimposition of real, double, and ghost images. It also requires accurate patient positioning. The vertical dimension in contrast to the horizontal dimension is altered less.[24] It is also quite sensitive to positioning errors because of the relatively narrow image layer.[27]

CONCLUSION

The mandible can be considered as a valuable tool in gender determination since it possesses resistance to damage and disintegration process The present study showed that the various parameters of mandibular ramus have the satisfactory potential for the determination of sex. The projective height of the ramus was found to be the most dimorphic variable and the minimum ramus breadth to be least dimorphic to predict gender. The study also indicates that the ramus can be an essential tool in forensic science for determining gender especially when there is a damaged or partially preserved mandible and will be helpful for medico-legal purposes in Nepal.

However, further studies with a large scale, fewer magnification errors, and populations from more diverse geographic regions of Nepal are needed to be taken up in the future to enhance the effectiveness of these parameters in gender determination. In addition, similar studies in large age groups and edentulous patients with different imaging modalities as well as clinical studies are recommended.

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