Assessment of Sexual Dimorphism in Mandibular Ramus: An Orthopanoramic Study
Koju S,¹ Maharjan N,¹ Rajak RRK,² Yadav DK,¹ Bajracharya D,¹ Ojha B¹

¹Department of Oral Pathology
²Department of Orthodontics
Kantipur Dental College Teaching Hospital and Research Center (KDCH), Basundhara, Kathmandu, Nepal.

Corresponding Author
Dipshikha Bajracharya
Department of Oral Pathology, Kantipur Dental College Teaching Hospital and Research Center (KDCH), Basundhara, Kathmandu, Nepal.
E-mail: drdipshikhabaj@gmail.com

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. 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. 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. In such cases, the mandible can play a vital role next to the pelvis in determining age as well as identifying an individual.

Sexual dimorphisms occur in almost every bone of the human skeleton. 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. Variations in the maturation rate and growth pattern also exist among males and females as skeletal maturity occurs earlier in females.

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, radiographs 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 \( (n) = \frac{2(Z\alpha+Z\beta)^2s^2}{d^2} \)

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

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

\( s = \) mean of the standard deviation

\( d = \) mean difference between two groups

\( n = \) sample size required per group = 70.195 per group

\( N = 70.195 \times 2 = 140.384 \)

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: (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 |
|-------------------------|-----------|----------------|---|----------------|------------------------------------------|
| 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      | 68.8249        | .64813                     |                                    |
| Coronoid height         | Right     | 63.5643        | .61409 | 1.646 | 0.102 | -0.10923 | 1.19495 |
|                         | Left      | 63.0214        | .60688                     |                                    |

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 |
|----------------------|--------------|-----------|----------------|----|----------------|------------------------------------------|
| Maximum ramus breadth| Female       | 35.2429   | 3.99433        | -3.479 | 0.005 | -5.78282 | -7.51056 |
|                      | 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 | -3.88449 | -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        |                |                |                                         |
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' Lambda | F     | p-value |
|------------------------------------|--------------|--------------|---------------|-------|---------|
| Mean (mm)                          | SD           | Mean (mm)    | SD            |       |         |
| Maximum ramus breadth              | 34.6500      | 3.38512      | 36.8543       | 3.98249 | 0.017   | 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

| Unstandardized Canonical Discriminant Function Coefficients | 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   | 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. As mandible is the last skull bone to cease growth, it is sensitive to adolescent growth spurt. 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. 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. 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. Palinkas et al. found that males have a greater masticatory force as compared with the female. 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.

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. Similar study conducted by Samatha et al. on digital OPGs found that the coronoid height and minimum ramus breadth were not statistically significant. Chalkoo et al. found both the maximum and minimum ramus breadth were not statistically significant.

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. However other studies have also reported different parameters to be dimorphic such as; condylar height, coronoid height, minimum ramus breadth. 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.

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. Its morphology is greatly influenced by external factors. Genetic factors, environment, gender, diet, hormonal and endocrine growth regulators could influence the form and degree of sexual dimorphism in mandibular morphology. 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.\textsuperscript{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%.\textsuperscript{3,6} Greater accuracy has also been reported with an accuracy rate of 84.0%, 87.5%, and 90.0%.\textsuperscript{2,14,18}

Several studies have been conducted to test the efficiency of the mandible as a tool for sexual dimorphism worldwide.\textsuperscript{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.\textsuperscript{21} 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.\textsuperscript{24,25}

A study based on Multidetector Computed Tomography (MDCT) images showed parallel results among the ramus breadth and height.\textsuperscript{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.\textsuperscript{24} It is also quite sensitive to positioning errors because of the relatively narrow image layer.\textsuperscript{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.

**ACKNOWLEDGEMENT**

We would like to express our sincere gratitude to Prof. Dr. Rabindra Man Shrestha, Department of Orthodontics for his guidance throughout the study; and Dr. Sujita Shrestha, Department of Community and Public Health Dentistry for her support in statistical analysis.

**REFERENCES**

1. Karaarslan B, Karaarslan ES, Ozsevik AS, Ertas E. Age estimation for dental patients using orthopantomographs. Eur J Dent. 2010;4(4):389-94.

2. Chalkoo AH, Maqbool S, Wani BA. Radiographic evaluation of sexual dimorphism in mandibular ramus: a digital orthopantomography study. Int J Appl Dent Sci. 2019;5(1):163-6.

3. Saini V, Srivastava R, Rai RK, Shalal SN, Singh TB, Tripathi SK. Mandibular ramus: an indicator for sex in fragmentary mandible. J Forensic Sci. 2011;56 Suppl 1:S13-16.

4. Jambunath U, Govindraju P, Balaji P, Poornima C, Latha S, Former. Mandibular ramus: an indicator for sex in fragmentary mandible. J Forensic Sci Int. 2011;56 Suppl 1:S13-16.

5. Durić M, Rakоćević Z, Donić D. The reliability of sex determination of skeletons from forensic context in the Balkans. Forensic Sci Int. 2005;147(2-3):159-64.

6. Samatha K, Bhyattti SM, Ammanagi RA, Tantradi P, Sarang CK, Shivpaje P. Sex determination by mandibular ramus: a digital orthopantomographic study. J Forensic Dent Sci. 2016;8(2):95.

7. Hu KS, Koh KS, Han SH, Shin KJ, Kim HJ. Sex determination using nonmetric characteristics of the mandible in Koreans. J Forensic Sci. 2006;51(6):1376-82.

8. Rogers TL. Determining the sex of human remains through cranial morphology. J Forensic Sci. 2005;50(3):493-500.

9. Rosas A, Bastrí M, Martínez-Maza C, Bermúdez de Castro JM. Sexual dimorphism in the Atapuerca-SH hominids: the evidence from the mandibles. J Hum Evol. 2002;42(4):451-74.

10. Foley TF, Mamandras AH. Facial growth in females 14 to 20 years of age. Am J Orthod Dentofacial Orthop. 1990;107(3):248-54.

11. Love RJ, Murray JM, Mamandras AH. Facial growth in males 16 to 20 years of age. Am J Orthod Dentofacial Orthop. 1990;107(3):200-6.

12. Loth SR, Henneberg M. Mandibular ramus flexure: a new morphologic indicator of sexual dimorphism in the human skeleton. Am J Phys Anthropol. 1996;99(3):473-85.

13. Indira AP, Markande A, David MP. Mandibular ramus: an indicator for sex determination - a digital radiographic study. J Forensic Sci. 2012;4(2):58-62.

14. Pongotra N, Chalkoo AH, Dar N. Mandibular Ramus: an indicator for gender determination - a digital radiographic study. Int J Sci Stud. 2018;6(7):42-5.

15. Palnikas M, Nasser MSF, Cecilio FA, Siéssere S, Semprini M, Machado-de-Sousa JP, et al. Age and gender influence on maximal bite force and masticatory muscles thickness. Arch Oral Biol. 2010;55(10):797-802.
16. Humphrey LT, Dean MC, Stringer CB. Morphological variation in great ape and modern human mandibles. *J Anat.* 1999;195(Pt 4):491-513.

17. Ranaweera WGPE, Chandrasekara CMCTK, Hraputhanthiri HDS, De Silva P, Herath UHMIM. Sex determination by mandibular ramus – a digital panoramic study. *Sri Lanka J Forensic Med Sci Law.* 2020;11(1):10-9.

18. Bhagwatkar T, Thakur M, Palve D, Bhondey A, Dhengar Y, Chaturvedi S. Sex determination by using mandibular ramus-a forensic study. *J Adv Med Dent Sci Res.* 2016;4(2):1-6.

19. Tejavathi Nagaraj LJ, Gogula S, Ghouse N, Nigam H, Sumana CK. Sex determination by using mandibular ramus: A digital radiographic study. *J Med Radiol Pathol Surg.* 2017;4:5-8.

20. Bejdová S, Krajíček V, Velemínská J, Horák M, Velemínský P. Changes in the sexual dimorphism of the human mandible during the last 1200 years in Central Europe. *Homo.* 2013;64(6):437-53.

21. Smith HF. Which cranial regions reflect molecular distances reliably in humans? Evidence from three-dimensional morphology. *Am J Hum Biol.* 2009;21(1):36-47.

22. Rösing FW, Graw M, Marré B, Ritz-Timme S, Rothschild MA, Rötzscher K, et al. Recommendations for the forensic diagnosis of sex and age from skeletons. *Homo.* 2007;58(1):75-89.

23. Mehta H, Bhuveshwarri S, Singh MP, Nahar P, Mehta K, Sharma T. Gender determination using mandibular ramus and gonial angle on OPG. *J Indian Acad Oral Med Radiol.* 2020;32(2):154-8.

24. Patil KR, Mody RN. Determination of sex by discriminant function analysis and stature by regression analysis: a lateral cephalometric study. *Forensic Sci Int.* 2005;147(2-3):175-80.

25. Kemkes A, Göbel T. Metric assessment of the “mastoid triangle” for sex determination: a validation study. *J Forensic Sci.* 2006;51(5):985-9.

26. Inci E, Ekizoglu O, Turkay R, Aksoy S, Can IQ, Solmaz D, et al. Virtual Assessment of Sex: Linear and Angular Traits of the Mandibular Ramus Using Three-Dimensional Computed Tomography. *J Craniofac Surg.* 2016;27(7): 627-32.

27. Larheim TA, Svanaes DB. Reproducibility of rotational panoramic radiography: mandibular linear dimensions and angles. *Am J Orthod Dentofacial Orthop.* 1986;90(1):45-51.