Original Article

# Sexual Dimorphism and Morphological Variations of the Human Mandible: A Cross-Sectional Morphometric Study

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## Abstract

**Background:** The mandible is a key component of the facial skeleton, essential for mastication, speech, and facial symmetry. Morphometric evaluation of the mandible is important in orthodontics, forensic anthropology, and maxillofacial surgery for understanding craniofacial growth patterns and skeletal variations. **Material and Methods:** This cross-sectional study analyzed290 human mandibles (166 males, 124 females; mean age 64.4 ± 10.46 years). Various parameters, including gonial angle, bigonial width, ramus breadth, bicondylar breadth, mandibular length, lower jaw length, mandibular index, body thickness, coronoid height, bimental breadth, symphyseal height, and body height, were measured. Morphological variations of the lingula, coronoid process, and genial tubercles were also examined. Statistical analysis was performed using independent t-tests and chi-square tests. **Results:** Most measurements showed significant sexual dimorphism, with larger values in males, while the gonial angle was significantly higher in females. The mandibular index showed no significant sex difference. Morphological analysis revealed that the triangular lingula and triangular coronoid process were the most frequent forms, and Type II genial tubercles were the most common pattern. **Conclusion:** Mandibular morphometry demonstrates clear sexual dimorphism and clinically relevant anatomical variations. These findings contribute valuable information for orthodontic diagnosis, forensic identification, and maxillofacial surgical planning.

**Keywords:** Mandible, morphometry, sexual dimorphism, orthodontics, craniofacial anatomy.

**Received: 02 May 2026** **Revised: 19 May 2026** **Accepted: 06 June 2026** **Published: 09 June 2026**

## Introduction

The mandible is the largest, strongest bone of the facial skeleton and contributes to the lower jaw, it plays an important role in mastication, articulation of speech and in maintaining the symmetry of the face.[1] It bears the lower teeth and attaches to some of the lower facial and chewing muscles. The complexity of the mandible's structure and its functional requirements result in significant intra- and inter-individual morphological and dimensional variability.[2]

The mandible is becoming increasingly important, especially in areas like orthodontics, forensic anthropology and maxillofacial surgery, as a subject for morphometric evaluation.[3] The detailed measurements of the mandibular structures gives the dentist insight into the pattern of craniofacial development and evaluates the presence of any differences in the skeletons. Several factors including genetic, environmental, muscle loading and developmental factors can contribute to variations in the morphology of the mandible.[4]

A correct knowledge of the mandibular morphometry is essential in the diagnosis, treatment planning and surgical reconstruction in orthodontics.[5] Moreover, the mandibular parameters have been extensively employed in forensic sciences for sex determination and anthropological studies to recognize the population difference.[6] Hence, the study of the morphometric parameters of the mandible is importance in clinical and research aspects.

## Materials and Methods

This observational cross-sectional study included 290 mandibles obtained for anatomical analysis. Among these, 166 specimens (57.24%) were male and 124 (42.76%) were female. The mean age of the individuals was 64.4 ± 10.46 years.

The largest proportion of subjects belonged to the age group above 70 years (37.59%), followed by the 60–70 years group (31.03%). Participants aged 51–60 years accounted for 19.31%, while 10.34% were in the 41–50 years group. The smallest proportion was observed in the 31–40 years group (1.72%).

Various morphometric parameters of the mandible were measured, including:

- Gonial angle
- Bigonial width
- Ramus breadth
- Bicondylar breadth

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**DOI:**
10.21276/amit.2026.v13.i2.726

**How to cite this article:** Pawde PP, Gupta M, Singh R. Sexual Dimorphism and Morphological Variations of the Human Mandible: A Cross-Sectional Morphometric Study. Acta Med Int. 2026;13(2):578-582.

- Mandibular length
- Lower jaw length
- Mandibular index
- Body thickness
- Coronoid height
- Bimental breadth
- Symphyseal height
- Body height of mandible

In addition to these measurements, morphological variations in the lingula, coronoid process, and genial tubercles were also evaluated. Such anatomical landmarks are important in maxillofacial surgery and dental anaesthesia procedures.[7]

Statistical analysis was performed using the independent t-test and chi-square test, and $p < 0.05$ was considered statistically significant.

## Results

In this study, a total of 290 specimens were analyzed. Among them, 166 were males, and 124 were females. Statistical analysis showed no significant association between age group and gender distribution ($\chi^2 = 0.84$, $p > 0.05$).

**Morphometric Measurements**

The gonial angle ranged from 115.79° to 143.47° in males and 125.42° to 150.57° in females. The mean gonial angle was 129.63 ± 6.92° in males and 137.99 ± 6.29° in females. Females showed a significantly higher gonial angle ($p < 0.001$). Similar variations in gonial angle between sexes have been reported in previous morphometric studies.[8]

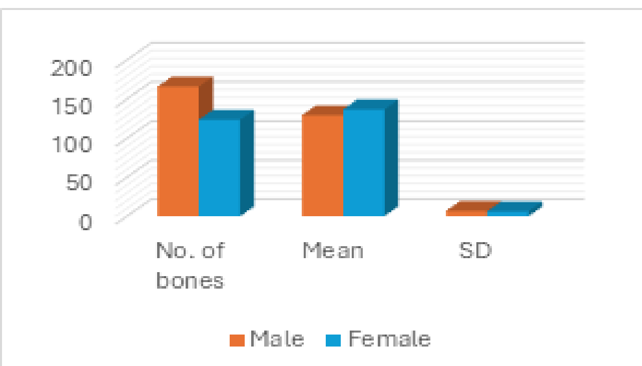


**Figure 1: The gonial angle recorded in the study specimens**

In this study, the bigonial width ranged from 84.58–105.32 mm in males and 77.96–103.53 mm in females. The mean values were 94.95 ± 5.19 mm in males and 90.75 ± 6.39 mm in females, with males showing significantly greater width ($p < 0.001$). Bigonial width is widely considered a reliable parameter for sex determination and craniofacial analysis.[9]

**Ramus Breadth**

Ramus breadth ranged from 36.75–58.31 mm in males and 31.35–52.86 mm in females. The mean values were 47.53 ± 5.39 mm in males and 42.11 ± 5.38 mm in females, demonstrating significant sexual dimorphism ($p < 0.001$). The mandibular ramus plays an important role in the attachment of masticatory muscles and mandibular biomechanics.[10]

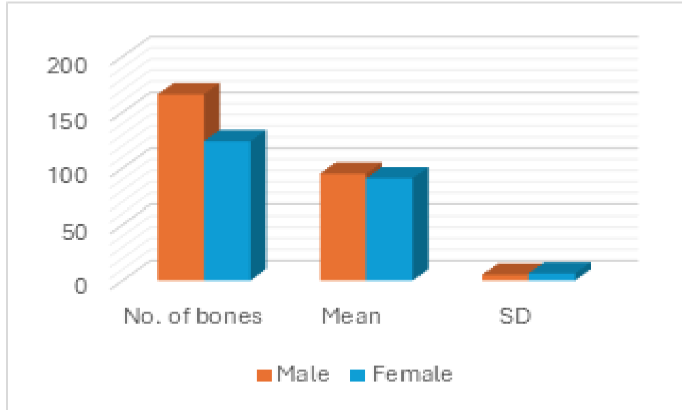


**Figure 2: The bigonial width observed in the study specimens.**

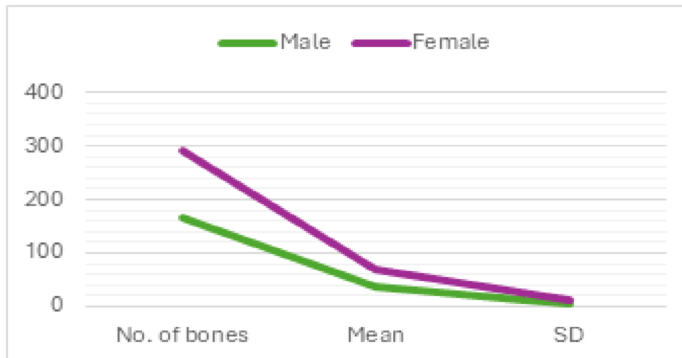


**Figure 3: The ramus breath observed in the study speimens**

**Mandibular Dimensions:** In the present study, the bicondylar breadth ranged from 102.54–121.31 mm in males and 86.25–116.83 mm in females, with mean values of 111.93 ± 4.69 mm in males and 101.54 ± 7.65 mm in females, demonstrating significantly greater measurements in males ($p < 0.001$). These findings are consistent with previous studies that have identified bicondylar breadth as a reliable parameter exhibiting marked sexual dimorphism in mandibular morphometry.[11]

Similarly, the mandibular length ranged from 65.64–80.57 mm in males and 61.25–80.72 mm in females, with mean values of 73.11 ± 3.73 mm and 70.99 ± 4.87 mm, respectively, showing a statistically significant difference ($p < 0.001$). The lower jaw length also demonstrated higher measurements in males, ranging from 51.45–66.57 mm, compared with 45.25–66.12 mm in females, with mean values of 59.01 ± 3.78 mm and 55.69 ± 5.22 mm, respectively.

However, the mandibular index showed mean values of 52.39 ± 4.04 in males and 51.77 ± 5.82 in females, and the difference between the sexes was not statistically significant ($p > 0.05$), suggesting that proportional relationships between certain mandibular dimensions may remain relatively consistent across genders.

In addition, the body thickness ranged from 13.43–20.24 mm in males and 11.31–16.53 mm in females, with mean values of 16.84 ± 1.70 mm and 13.92 ± 1.31 mm, respectively, indicating comparatively greater mandibular robustness in males. These observations support the concept that male mandibles generally exhibit larger and more robust dimensions, reflecting differences in skeletal development and functional loading of masticatory

muscles.
In our study, we recorded that the coronoid height ranged from 53.67–73.47 mm in males and 43.78–62.56 mm in females. The mean values were 63.57 ± 4.95 mm in males and 53.17 ± 4.70 mm in females, and the bimental breadth ranged from 40.35–47.79 mm in males and 35.36–43.86 mm in females, with mean values of 44.07 ± 1.86 mm and 39.61 ± 2.13 mm, respectively.

**Symphyseal and Body Height Measurements**

In the present study, the symphyseal height ranged from 23.52–37.86 mm in males and 15.97–28.68 mm in females, with mean values of 30.69 ± 2.39 mm and 22.33 ± 2.12 mm, respectively [Figure 4]. These findings indicate that males exhibit greater symphyseal height compared with females.
Similarly, the body height of the mandible ranged from 23.85–34.63 mm in males and 16.57–28.31 mm in females, with mean values of 29.24 ± 1.80 mm and 22.44 ± 1.96 mm, respectively [Table 1]. The higher measurements observed in males suggest a greater mandibular robustness and structural development.

Overall, these parameters demonstrate marked sexual dimorphism, with males showing significantly larger mandibular dimensions than females. These findings are consistent with previous morphometric studies of the mandible, which have reported similar patterns of sex-related differences in mandibular morphology.[12]

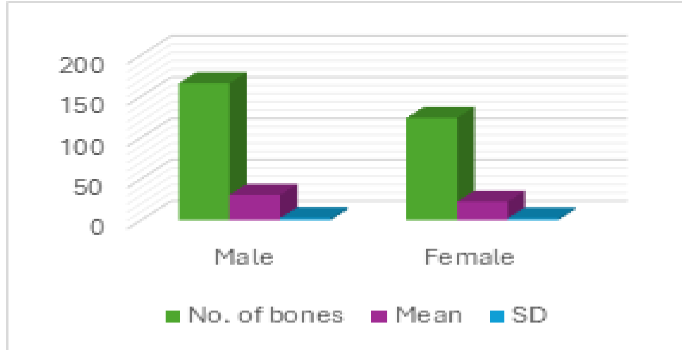


**Figure 4: Measurement of Symphyseal Height in the Present Study Specimens.**

**Table 1: Measurement of Body Height in the Present Study Specimens**

| Measurement | Male | Female |
|---|---|---|
| No. of bones | 166 | 124 |
| Range | 23.85 –34.63 | 16.57-28.31 |
| Mean ± SD | 29.24 ± 1.80 | 22.44 ± 1.96 |

**Morphological Variations**

**Lingula:** The triangular type of lingula was the most frequently observed morphology in the present study, followed by the nodular and truncated types, while the assimilated type was the least common. The lingula serves as an important anatomical landmark for locating the mandibular foramen during inferior alveolar nerve block and other maxillofacial surgical procedures.

**Coronoid Process:** The triangular type of coronoid process was the most prevalent variant, observed in 374 sides, followed by the hook-shaped type in 164 sides and the rounded type in 42 sides. Variations in the morphology of the coronoid process may be associated with differences in functional activity of the temporalis muscle, which inserts at this site.

**Genial Tubercles:** Four morphological patterns of genial tubercles were identified. Type II was the most common pattern (140 cases), followed by Type III (92 cases) and Type I (48 cases), whereas Type IV was the least frequent (10 cases). These tubercles provide attachment for the genioglossus and geniohyoid muscles and are important anatomical landmarks in surgical procedures involving the mandibular symphysis.

## Discussion

**Age and Gender Distribution:** In the present study, 290 mandible specimens were examined, including 166 males and 124 females. Statistical analysis revealed no significant association between age group and gender distribution ($\chi^2 = 0.84$, $p > 0.05$). This suggests that the observed differences in mandibular measurements are primarily attributable to sexual dimorphism rather than age-related variation. Similar observations were reported by Krogman and Iscan,[6] who emphasized that mandibular morphometry remains a reliable indicator of sex when age-related bias is minimized. Likewise, Franklin et al,[13] noted that mandibular dimensions are relatively independent of age in adult skeletal populations.

**Morphometric Measurements:** The present study demonstrated significant differences in several mandibular parameters between males and females. The gonial angle ranged from 115.79°–143.47° in males and 125.42°–150.57° in females, with females exhibiting significantly larger values ($p < 0.001$). This finding is consistent with Indira et al,[8] who reported that females generally present a more obtuse gonial angle due to comparatively lower masticatory muscle strength. Humphrey et al,[4] further suggested that the functional activity of the masseter and temporalis muscles influences mandibular remodelling, resulting in a more acute angle in males.
The bigonial width was significantly greater in males (94.95 ± 5.19 mm) than in females (90.75 ± 6.39 mm) ($p < 0.001$). Similar findings were reported by Steyn and Iscan,[14] who demonstrated that male mandibles tend to be broader and more robust, particularly in the gonial region. Franklin et al,[13] also identified bigonial width as a reliable parameter for sex determination in forensic anthropology.
The ramus breadth showed significantly higher values in males (47.53 ± 5.39 mm) compared with females (42.11 ± 5.38 mm) ($p < 0.001$). Comparable findings were reported by Saini et al,[9] who observed larger ramus dimensions in males. According to Enlow,[15] increased ramus breadth may result from greater biomechanical loading generated by stronger masticatory muscles.
Similarly, the bicondylar breadth was significantly greater in

males (111.93 ± 4.69 mm) than in females (101.54 ± 7.65 mm) ($p < 0.001$). These results align with the findings of Dayal et al,[16] who identified bicondylar breadth as an important parameter that demonstrates sexual dimorphism. Vodanovic et al,[17] also reported that males generally exhibit larger transverse mandibular dimensions.

The mandibular length was significantly greater in males (73.11 ± 3.73 mm) compared with females (70.99 ± 4.87 mm) ($p < 0.001$). Similar results were reported by Rai et al,[18] who identified mandibular length as a useful parameter for sex determination. Kranioti et al,[19] further emphasized the value of mandibular measurements in forensic identification and craniofacial reconstruction.

Although the lower jaw length was greater in males (59.01 ± 3.78 mm) than in females (55.69 ± 5.22 mm), the mandibular index showed no statistically significant difference between sexes ($p > 0.05$). This observation is consistent with Babu et al,[20] who reported that proportional mandibular indices may show minimal variation despite differences in absolute dimensions.

The body thickness was greater in males (16.84 ± 1.70 mm) compared with females (13.92 ± 1.31 mm). According to Enlow,[15] increased mandibular body thickness may reflect adaptive bone remodelling resulting from greater functional loading during mastication.

Similarly, the coronoid height was higher in males (63.57 ± 4.95 mm) than in females (53.17 ± 4.70 mm). Comparable findings were reported by Shah et al,[21] who attributed greater coronoid process height in males to stronger attachment of the temporalis muscle.

The bimental breadth was also greater in males (44.07 ± 1.86 mm) compared with females (39.61 ± 2.13 mm). Franklin,[22] reported similar findings, suggesting that broader mental regions contribute to the characteristic square chin morphology commonly observed in male mandibles.

Furthermore, symphyseal height and body height were significantly greater in males than in females. These findings correspond with those of Iscan and Steyn,[23] and Kranioti et al,[19] who highlighted the importance of these parameters in forensic sex estimation.

**Morphological Variations:** The present study also evaluated morphological variations in specific mandibular landmarks. The triangular type of lingula was the most common morphology, followed by nodular and truncated forms, while the assimilated type was the least frequent. Similar findings were reported by Tuli et al,[24] and Shrestha et al,[25] who emphasized the clinical importance of lingula morphology in locating the mandibular foramen during inferior alveolar nerve block procedures.

The triangular coronoid process was the most prevalent variant, followed by hook-shaped and rounded forms. Comparable results were reported by Shah et al,[21] who noted that the morphology of the coronoid process is influenced by the functional activity of the temporalis muscle.

Regarding genial tubercles, four patterns were identified, with Type II being the most common, followed by Type III and Type I, while Type IV was the least frequent. Similar distribution patterns were reported by Singh et al,[27] who highlighted the importance of these structures as attachment sites for the genioglossus and geniohyoid muscles.

Overall, the present study's findings demonstrate significant sexual dimorphism in most mandibular parameters, with males generally exhibiting larger dimensions than females. These results are consistent with previous studies by Franklin et al. (2007), Dayal et al. (2008), and Saini et al. (2011), which highlighted the importance of mandibular morphometry in forensic identification, anthropological research, and orthodontic diagnosis.[6,9,16]

## Conclusion

The present investigation is an extensive morphometric study of the mandible of humans, which shows that there is sexual dimorphism in most of the mandibular parameters. The bigonial width, bimalar distance, ramus breadth, mandibular length, body thickness, coronoal height, bimental breadth, height of symphyseal area, and body height were significantly larger in males; the gonial angle was significantly higher in females. The mandibular index on the other hand, did not present any statistically significant difference in sex, indicating that some proportional relationships of the structures of the mandible are relatively constant.

The study also pointed out that there are significant morphological differences between the different types of lingula and coronoid process, with the most common being the triangular type, and the predominant type in the genial tubercles was Type II. These anatomic variations also are clinically relevant, as they are used as landmarks for dental anesthesia, orthognathic surgery, and other maxillofacial surgery.

The overall results reveal the clinical and forensic importance of the morphometry of the mandible. Thorough knowledge of the morphological variations and the dimensions of mandible could be useful in the process of proper diagnosis in orthodontics, treatment planning, craniofacial analysis and sexing in forensic investigations. Larger and more diverse populations are needed for further study to gain additional information on population-specific mandibular characteristics.


### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.


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