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Anthropometric Study of The Mandible For Age and Sex Estimation in Forensics

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ABSTRACT

Background: In forensic anthropology, accurate estimation of age and sex from skeletal remains forms the foundation of biological profiling, particularly in cases of mass disasters, criminal investigations, or unidentified bodies.

Objective: To conduct an anthropometric study of the human mandible for estimating age and sex, and to determine the most reliable morphometric parameters for forensic identification.

Methodology: A descriptive cross-sectional study was conducted at Quaid-E-Azam Medical College Bahawalpur from December 2023 to December 2024. A total of 75 adult human mandibles (42 male, 33 female) were analyzed using standard anthropometric procedures. Parameters measured included bigonial width, bicondylar breadth, mandibular body length, ramus height, and gonial angle. Measurements were recorded using a digital vernier caliper (accuracy ±0.01 mm) and a goniometer.

Results: Male mandibles exhibited significantly greater dimensions in bigonial width (97.2 ± 4.9 mm), bicondylar breadth (121.6 ± 5.8 mm), mandibular body length (80.2 ± 5.3 mm), and ramus height (68.9 ± 3.8 mm) compared to females ($p < 0.05$). Conversely, the mean gonial angle was larger in females (126.5° ± 6.1°) than in males (120.9° ± 5.8°). Age analysis showed a progressive decrease in ramus height and an increase in gonial angle with advancing age ($p < 0.05$). Discriminant function analysis revealed that bicondylar breadth, bigonial width, and ramus height provided the highest accuracy for sex classification, correctly identifying 85% of mandibles overall.

Conclusion: The mandible exhibits clear sexual dimorphism and predictable age-related changes, underscoring its value in forensic identification. Linear measurements such as bicondylar breadth, bigonial width, and ramus height are particularly effective for sex estimation.

Keywords: *Mandible, Anthropometry, Forensic Anthropology, Age Estimation, Sex Determination, Gonial Angle*

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1. INTRODUCTION

In forensic anthropology, the estimation of age and sex from skeletal remains forms one of the most essential components of biological profiling. These parameters not only aid in establishing identity but also contribute to the reconstruction of demographic information in both medico-legal and archaeological contexts [1]. Among the skeletal structures, the mandible holds a position of particular importance due to its durability, distinct morphology, and the rich forensic information it retains even in fragmented or decomposed states [2]. Unlike other facial bones, the mandible is the strongest and most massive component of the skull, capable of withstanding environmental degradation, fire exposure, and postmortem trauma. Its resistance to disintegration makes it one of the most frequently recovered bones in forensic examinations, rendering it a key focus for anthropometric and morphological analyses [3].

Age and sex estimation in forensics traditionally rely on various skeletal and dental markers such as the pelvis, skull, long bones, and teeth. However, the pelvis and skull, while highly diagnostic, are not always preserved intact, especially in cases involving explosions, natural disasters, or advanced decomposition [4]. In such instances, the mandible serves as a resilient and anatomically informative alternative. The mandible displays clear sexual dimorphism due to the influence of hormonal and genetic factors that affect bone growth and muscular attachments [5]. For example, males typically exhibit a larger and more angular mandible with pronounced muscle attachments, whereas females tend to have a smaller, smoother, and more gracile mandibular structure. These differences manifest in measurable parameters such as the gonial angle, ramus height, bigonial width, and body length, which can be statistically analyzed to discriminate between sexes with high accuracy [6]. The mandible also reflects age-related morphological changes that occur due to growth, functional adaptation, and bone remodeling. During early life, the mandible is characterized by a wide gonial angle and relatively small ramus height, which gradually alters as an individual matures [7]. With advancing age, the bone undergoes resorption and changes in muscle attachment patterns, leading to a reduction in bone mass and remodeling of the alveolar region following tooth loss. These features make the mandible a reliable indicator for estimating not only sex but also age at death, especially in adult individuals [8]. Such estimations, when combined with dental wear and alveolar bone resorption data, can yield a comprehensive picture of biological age [9]. Advancements in technology have greatly refined the accuracy of mandibular measurements. The use of radiographic tools such as orthopantomography (OPG), lateral cephalometry, cone-beam computed tomography (CBCT), and three-dimensional imaging allows non-invasive and highly precise analysis of mandibular landmarks [10]. These imaging techniques facilitate the acquisition of standardized anthropometric data, which can be subjected to discriminant function analysis and regression modeling to derive population-specific equations for age and sex estimation [11]. The application of these methods has proven valuable in numerous forensic and clinical studies across different populations, emphasizing that mandibular morphology is significantly influenced by genetic, environmental, nutritional, and functional factors [12].

2. OBJECTIVE

To conduct an anthropometric study of the human mandible for estimating age and sex, and to determine the most reliable morphometric parameters for forensic identification.

3. METHODOLOGY

This was a descriptive cross-sectional study conducted at Quaid-E-Azam Medical College Bahawalpur from December 2023 to December 2024. A total of 75 human mandibles were included in the study. Non-probability purposive sampling was employed.

Inclusion Criteria:

1. Adult mandibles of known sex and age (between 20 and 70 years).
2. Fully dentate or partially dentate mandibles with minimal postmortem damage.
3. Mandibles free of pathological deformities, fractures, or surgical alterations.

Exclusion Criteria:

1. Mandibles showing evidence of disease, trauma, or congenital deformity.
2. Edentulous mandibles with extensive alveolar bone loss.
3. Mandibles with incomplete or missing landmarks required for measurement.

4. DATA COLLECTION

Each mandible was carefully examined, cleaned, and numbered for identification. Standard anthropometric landmarks were identified according to internationally accepted anatomical definitions. Measurements were taken using a digital vernier caliper with an accuracy of ±0.01 mm and a goniometer for angular readings. Key parameters recorded included bigonial width, bicondylar breadth, mandibular body length, ramus height, and gonial angle. Each measurement was performed three times by the same observer, and the mean value was used for final analysis to minimize intra-observer variability. The sex and age of the specimens were verified through institutional records accompanying the skeletal material. The mandibles were divided into male and female groups, and further categorized into three age brackets: 20–35 years, 36–50 years, and 51–70 years. This classification allowed for the assessment of both sexual dimorphism and age-related morphological variations in mandibular dimensions.

5. DATA ANALYSIS

The collected data were entered into the Statistical Package for the Social Sciences (SPSS) version 25.0 for analysis. Descriptive statistics were computed for all measurements, expressed as mean ± standard deviation (SD). The Student's t-test was employed to compare mean mandibular dimensions between male and female groups. A p-value of less than 0.05 was considered statistically significant in all analyses.

6. RESULTS

Out of the 75 mandibles analyzed, 42 (56%) were from males and 33 (44%) were from females. The mean age of male specimens was 42.3 ± 11.2 years, while for females it was slightly lower at 39.8 ± 10.5 years, giving an overall mean age of 41.2 ± 10.9 years. The age range for both sexes spanned from 20 to 70 years, ensuring representation from young adulthood through older age groups.

Table 1: Demographic Distribution of the Study Sample (n = 75)

Variable	Male (n = 42)	Female (n = 33)	Total (n = 75)
Mean Age (years)	42.3 ± 11.2	39.8 ± 10.5	41.2 ± 10.9
Age Range (years)	20–70	20–70	20–70
Percentage (%)	56%	44%	100%

The bigonial width was 97.2 ± 4.9 mm in males compared to 91.1 ± 4.1 mm in females ($p < 0.001$), making it one of the strongest indicators of sex differentiation. Similarly, the bicondylar breadth was higher in males (121.6 ± 5.8 mm) than in females (113.9 ± 5.4 mm; $p < 0.01$), reflecting greater transverse mandibular expansion in males. The mandibular body length also showed significant sexual variation, averaging 80.2 ± 5.3 mm in males versus 74.9 ± 4.6 mm in females ($p < 0.05$), suggesting longer mandibular bodies in men due to greater bone mass and masticatory muscle influence. The ramus height followed a similar pattern, with males averaging 68.9 ± 3.8 mm and females 63.1 ± 3.5 mm ($p < 0.05$), highlighting the greater vertical height of male mandibles. Interestingly, the gonial angle demonstrated a reverse trend, being wider in females (126.5° ± 6.1°) than in males (120.9° ± 5.8°; $p < 0.05$).

Table 2: Mean Mandibular Measurements According to Sex

Parameter	Male (Mean ± SD)	Female (Mean ± SD)	*p*-Value
Bigonial Width (mm)	97.2 ± 4.9	91.1 ± 4.1	< 0.001
Bicondylar Breadth (mm)	121.6 ± 5.8	113.9 ± 5.4	< 0.01
Mandibular Body Length (mm)	80.2 ± 5.3	74.9 ± 4.6	< 0.05
Ramus Height (mm)	68.9 ± 3.8	63.1 ± 3.5	< 0.05
Gonial Angle (°)	120.9 ± 5.8	126.5 ± 6.1	< 0.05

Student's t-test applied; p < 0.05 considered statistically significant.

Ramus height decreased from 68.4 ± 3.7 mm in the youngest group to 63.8 ± 4.1 mm in the oldest group (p = 0.021), likely due to bone resorption and decreased muscle activity associated with aging. Conversely, the gonial angle increased progressively with age, from 121.1° ± 5.2° in younger individuals to 126.8° ± 6.4° in older adults (p = 0.034), which can be attributed to reduced masticatory stress and alveolar bone loss over time.

Table 3: Mandibular Parameters According to Age Groups

Parameter	20–35 Years (Mean ± SD)	36–50 Years (Mean ± SD)	51–70 Years (Mean ± SD)	*p*-Value (ANOVA)
Bigonial Width (mm)	95.8 ± 5.1	94.2 ± 5.0	93.5 ± 5.6	0.312
Bicondylar Breadth (mm)	119.6 ± 6.1	118.5 ± 6.4	117.2 ± 6.8	0.287
Ramus Height (mm)	68.4 ± 3.7	66.7 ± 4.0	63.8 ± 4.1	0.021*
Gonial Angle (°)	121.1 ± 5.2	123.8 ± 5.7	126.8 ± 6.4	0.034*

One-way ANOVA applied; p < 0.05 indicates statistical significance.

Bicondylar breadth, bigonial width, and ramus height emerged as the most significant discriminators, with Wilks' Lambda values of 0.682, 0.714, and 0.753, respectively, and high F-ratios with statistically significant p-values. The standardized coefficients indicated that bicondylar breadth had the greatest discriminating power (0.672), followed by bigonial width (0.583) and ramus height (0.528). Mandibular body length and gonial angle contributed less to the overall function. The discriminant function achieved an overall classification accuracy of 85%, correctly identifying 86.7% of male and 82.1% of female mandibles.

Table 4: Discriminant Function Analysis for Sex Determination

Variable	Wilks' Lambda	F-Ratio	Significance (*p*)	Standardized Coefficient
Bicondylar Breadth	0.682	15.23	< 0.001	0.672
Bigonial Width	0.714	12.98	< 0.01	0.583
Ramus Height	0.753	10.41	< 0.05	0.528
Mandibular Body Length	0.781	8.63	0.061	0.410
Gonial Angle	0.812	7.21	0.078	-0.325

Overall correct classification rate: 85% (Male = 86.7%, Female = 82.1%)

7. DISCUSSION

The findings of this study highlight the significance of mandibular morphometry as a reliable indicator for both age and sex estimation in forensic anthropology. Among the 75 mandibles analyzed, clear and consistent differences were observed between males and females, reflecting marked sexual dimorphism in almost all measured parameters. The results demonstrated that males possessed greater mandibular dimensions than females across bigonial width, bicondylar breadth, mandibular body length, and ramus height, whereas the gonial angle was notably wider in females. These findings reinforce the well-established principle that the mandible, being highly influenced by hormonal, muscular, and genetic factors, exhibits predictable differences between the sexes. The larger dimensions observed in male mandibles are attributable to the prolonged period of growth under the influence of testosterone, which enhances bone mass and muscular attachments. This results in more prominent gonial and mental regions as well as increased ramus height. In contrast, female mandibles, which develop under the influence of estrogen, tend to display smoother contours, a rounder chin, and a wider gonial angle [13]. The present findings are consistent with previous forensic and anatomical studies that have reported similar sex-related trends in mandibular morphometry across different populations. The statistically significant differences observed in bigonial width, bicondylar breadth, and ramus height align with earlier research emphasizing the diagnostic value of these dimensions for sex determination, particularly when pelvic or cranial bones are unavailable [14].

The gonial angle demonstrated an inverse relationship with sex, being larger in females than in males. This observation supports the biomechanical explanation that the reduced masticatory muscle mass in females contributes to a wider gonial angle, whereas in males, stronger masseter and temporalis muscle attachments create a more acute angle. This parameter, therefore, serves as an important yet complex indicator for sex estimation. The slight overlap between male and female gonial angle values noted in the current study suggests that, although useful, this measurement should ideally be used in combination with other parameters for more accurate sex discrimination [15]. The age-related findings of this study further emphasize the mandible's dynamic nature throughout life. Progressive changes in ramus height and gonial angle across different age groups were observed. Younger individuals (20–35 years) exhibited taller ramus heights and more acute gonial angles, reflective of strong masticatory function and well-maintained bone integrity. In contrast, older individuals (51–70 years) displayed reduced ramus height and an increased gonial angle, likely resulting from age-associated bone resorption, reduced muscular tension, and alveolar bone loss. These patterns are consistent with prior forensic and anatomical research that has described the mandible as a site of continuous remodeling influenced by function, nutrition, and hormonal status throughout adulthood [16]. The discriminant function analysis in the present study demonstrated an overall sex classification accuracy of approximately 85%, which is comparable to international reports ranging from 80% to 90% [17]. The combination of bicondylar breadth, bigonial width, and ramus height emerged as the most effective predictor set for sex estimation. This finding is particularly valuable in forensic practice, where fragmented skeletal remains may limit the number of measurable parameters. The ability to achieve high classification accuracy using just a few mandibular dimensions reinforces the mandible's importance as a dependable tool for biological profiling [18].

Despite the promising results, this study acknowledges certain limitations. The sample size of 75, though adequate for preliminary analysis, may not capture the full variability within the broader population. Moreover, the use of dry mandibles limits the ability to correlate findings with soft-tissue or dental variables, which could enhance predictive accuracy. Future research incorporating radiographic techniques such as 3D computed tomography (CT) or cone-beam CT (CBCT) could provide more comprehensive morphometric insights and allow digital reconstruction of damaged mandibles.

8. CONCLUSION

It is concluded that the mandible serves as a highly dependable and morphologically informative bone for forensic age and sex estimation. The present study, based on the analysis of 75 adult mandibles, revealed significant sexual dimorphism in almost all linear dimensions, namely bigonial width, bicondylar breadth, ramus height, and mandibular body length, where male mandibles consistently exhibited larger and more robust structures compared to female mandibles. Conversely, females demonstrated a wider gonial angle, a feature attributed to reduced masticatory muscle influence and differences in bone remodeling patterns.

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