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RESEARCH ARTICLE

UNVEILING SEXUAL DIMORPHISM IN THE HUMAN MANDIBLE: A MORPHOMETRIC STUDY OF THE GONIAL ANGLE AND ITS FORENSIC IMPLICATIONS IN NORTH INDIAN POPULATION

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Abstract

Background: Gender determination is a fundamental step in forensic anthropology and medico-legal examinations, especially when dealing with unidentified skeletal remains. The mandible, due to its durability and resistance to postmortem changes, plays a crucial role in sex determination. Among its features, the mandibular angle (gonial angle) is widely studied for sexual dimorphism. Methods: A cross-sectional study was conducted in the Department of Anatomy, UPUMS, Saifai from August 2024 to August 2025. A total of 100 dry adult human mandibles (50 male and 50 female) were analyzed. Mandibles with deformities, fractures, or postmortem damage were excluded. Mandibular angles were measured bilaterally using a protractor by drawing two tangent lines—one along the posterior border of the ramus and another along the lower border of the mandibular body. Statistical analysis was performed using independent t-tests, and p-values <0.05 were considered significant. Results:The mean mandibular angle on the right side was 125.80° ± 4.70 in males and 121.40° ± 5.10 in females, and this difference was statistically significant (p = 0.028). On the left side, the mean mandibular angle was 124.50° ± 4.90 in males and 120.80° ± 5.20 in females, which was also statistically significant (p = 0.019). These findings indicate that males consistently exhibited higher mandibular angle values compared to females on bothsides. Conclusion: Although mandibular angle differences between genders were not statistically significant, the observed trend of higher angles in females suggests its supportive role in gender estimation when combined with other morphological indicators. Findings are clinically relevant for forensic experts and maxillofacial surgeons.

Introduction:-

The mandible is the largest and strongest bone of the facial skeleton, articulating with the temporal bone at the temporomandibular joint. It consists of a horizontal body and two vertical rami. The gonial angle, also known as the mandibular angle, is formed at the junction of the posterior border of the ramus and the inferior border of the body [1]. Its morphology is influenced by masticatory muscle development, dentition status, and functional forces acting on the mandible [2].

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In young adults, the angle is generally more acute due to well-developed muscles, whereas in edentulous or aging individuals, it becomes wider as a result of alveolar bone resorption and reduced masticatory activity [3]. Determining gender from skeletal remains is one of the primary objectives in forensic anthropology and bioarchaeology because it significantly narrows the identification process by approximately 50% [4]. This is particularly useful in medico-legal investigations and disaster victim identification.

The pelvis and skull are considered the most reliable skeletal elements for sex estimation, but in many forensic cases, these bones are fragmented or absent [5]. The mandible, owing to its high density and resistance to environmental and postmortem changes, remains intact in most conditions, making it an important element for forensic analysis [6]. Among its features, the gonial angle has gained attention as a potential parameter for sex estimation due to observable differences between males and females [7].

Sexual dimorphism of the mandible is influenced by both functional and hormonal factors. Males generally exhibit a more acute mandibular angle as a result of stronger masseter and temporalis muscle attachments, while females tend to have a wider angle because of less pronounced muscle pull [8]. These differences, although subtle, can be valuable in forensic identification, especially when combined with other mandibular measurements such as ramus height and bigonial width [9].

However, the reliability of the gonial angle as a stand-alone indicator of sex remains controversial, with some studies reporting significant differences [10], whereas others find minimal or no variation [11]. Beyond its forensic relevance, the mandibular angle holds clinical importance. It influences surgical approaches in oral and maxillofacial procedures, orthognathic surgery, and plays a role in the administration of mandibular nerve blocks [12].

For example, in individuals with a wide gonial angle, the inferior alveolar nerve block may require a lower insertion point, whereas a narrow angle necessitates higher needle placement [13]. Orthodontists and prosthodontists also consider the gonial angle during treatment planning because it reflects mandibular growth patterns and occlusal relationships [14].

Despite numerous studies, there is no consensus on whether the mandibular angle is a reliable parameter for gender estimation. Variability among populations due to genetic, environmental, and functional factors further complicates the interpretation of its forensic value. Therefore, population-specific research is essential for developing accurate forensic standards. The present study was conducted on a North Indian population to evaluate the gonial angle as an indicator of sexual dimorphism and to determine its applicability in forensic identification.
It also aims to compare bilateral differences and assess whether this parameter can be considered alongside other morphometric features for reliable gender estimation.

Aims and objectives:-

1.To evaluate the mandibular angle as an indicator for gender determination.
2.To compare right and left mandibular angles between male and female mandibles.
3.To identify limitations influencing the reliability of mandibular angle in forensic and clinical settings.

Materials and methods:-

The present study was designed as a cross-sectional observational study and was conducted in the Department of Anatomy, Uttar Pradesh University of Medical Sciences (UPUMS), Saifai, Etawah, Uttar Pradesh, India. The study was carried out over a period of three months, from August 2024 to August 2025. A total of 100 dry adult human mandibles were included in the study, comprising 50 male and 50 female specimens, selected based on clearly identifiable morphological features and preserved anatomical structures.

Inclusion Criteria:-

1.Adult human mandibles of known sex (male or female).
2.Well-preserved mandibles with intact body, ramus, and symphysis menti.
3.Fully ossified bones with no evidence of developmental anomalies.
4.Specimens showing no postmortem alterations that affect anatomical landmarks.

Exclusion Criteria:-

1.Mandibles with fractures, cracks, or gross deformities.
2.Specimens with evidence of pathological conditions (e.g., osteomyelitis, tumors, abnormal bony growth).
3.Mandibles showing extensive erosion or alveolar bone resorption affecting landmarks.
4.Incomplete or fragmented mandibles with missing essential components.

Instruments Required:-

1.Standard Protractor – For measuring the gonial (mandibular) angle accurately.
2.Graph Pencil/Marker – To draw tangent lines along the posterior border of the ramus and the lower border of the mandibular body.
3.Scale (Ruler) – For proper alignment and drawing straight reference lines.
4.Osteometric Board – To position and stabilize the mandible during measurement.
5.Digital Camera (optional) – For capturing photographic documentation and illustration (e.g., Figure 1).
6.Data Recording Sheet – For systematic entry of measurements for both sides of each mandible.

Measurement Procedure:-

1.Each mandible was placed on a flat, stable surface with the lateral aspect facing upward to ensure proper orientation.
2.The mandibular angle was measured bilaterally using a standard protractor for accuracy.
3.Two reference tangent lines were drawn for each side: (Fig 1) Ramus Line: A straight line drawn along the posterior border of the mandibular ramus. Mandibular Line: Another line drawn along the lower border of the mandibular body.
4.The point where these two lines intersect represents the gonial region (angle of the mandible).
5.The gonial angle (mandibular angle) was determined by measuring the angle formed at the intersection of the ramus line and mandibular line using the protractor.
6.Measurements were taken on both the right and left sides of each mandible and recorded to the nearest degree.
7.To minimize error, each measurement was taken twice, and the mean value was considered for analysis.
8.All measurements were performed under adequate lighting to ensure precise alignment of the protractor with the tangent lines.
9.A labeled diagram (Figure 1) was used to illustrate the reference points and lines for better understanding of the measurement technique.

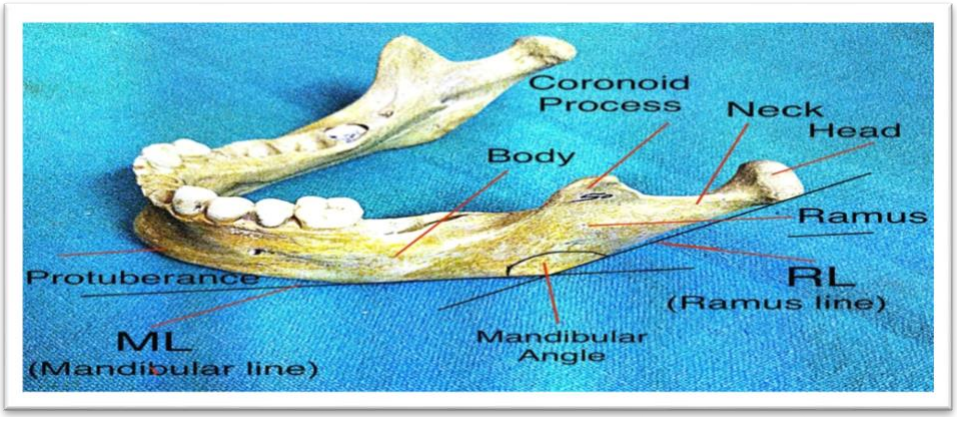


Figure 1: Anatomical landmarks of the mandible and measurement technique for the gonial angle.Two tangent lines were drawn: ML (Mandibular Line) along the lower border of the body and RL (Ramus Line) along the posterior border of the ramus. The intersection of these lines forms the mandibular angle (gonial angle), which was measured using a standard protractor.)

Ethical Standards Followed:-

The study was conducted in accordance with the ethical guidelines for research on human skeletal remains as per the Institutional Ethical Committee (IEC) norms of Uttar Pradesh University of Medical Sciences (UPUMS), Saifai, Etawah. Approval was obtained from the IEC prior to the commencement of the study.

The mandibles used were part of the departmental osteology collection and did not involve any living human participants, ensuring that there was no direct risk to individuals. All specimens were handled with respect and confidentiality, adhering to the principles of the Declaration of Helsinki (2013 revision) and national ethical guidelines for biomedical research.

Statistical Analysis:-

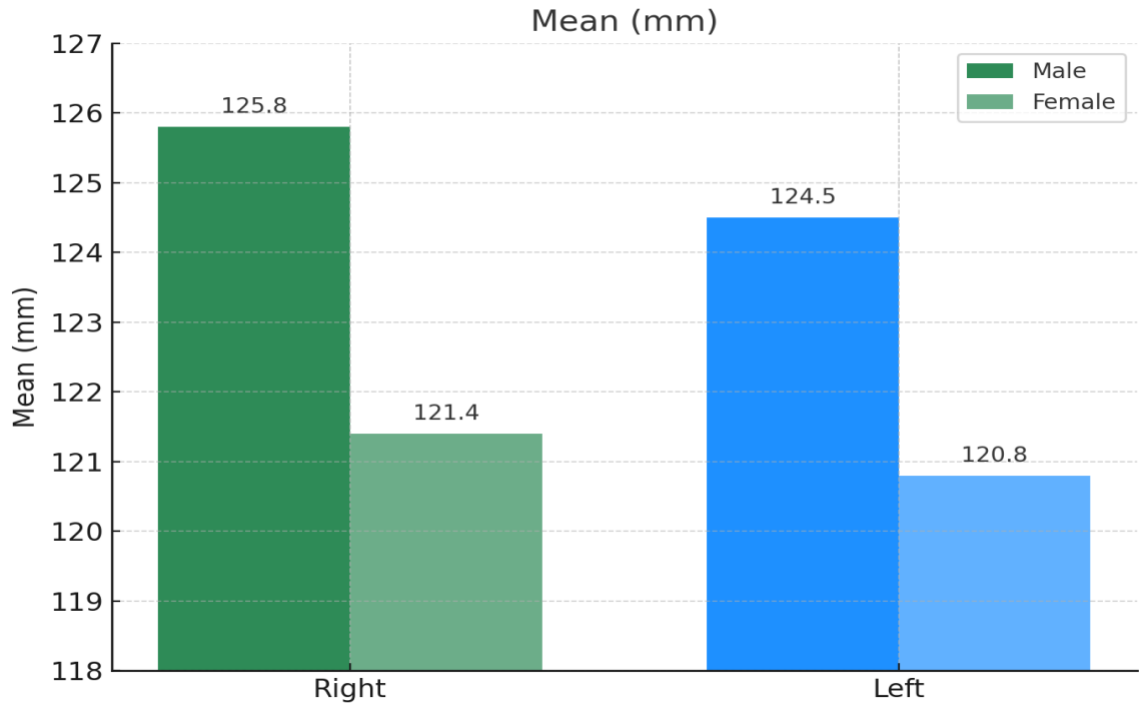
The collected data were entered and analyzed using SPSS software version 25. Descriptive statistics, including the mean and standard deviation, were calculated for each group. To assess differences between male and female mandibles, the independent t-test was applied. A p-value of less than 0.05 was considered statistically significant for all analyses.

Results:-

Fig 1 : Mean values (mm) for right and left sides in males and femal

Side	Sex	Mean (mm)	SD	P –value
Right	Male	125.80	4.70	0.028
	Female	121.40	5.10	
Left	Male	124.50	4.90	0.019
	Female	120.80	5.20	

Fig 2 : Bar representation of mean values (mm) for right and left sides in males and females



The bar chart (Fig 1) illustrates the mean measurements (in millimeters) for males and females on both the right and left sides. On the right side, males had a higher mean value (125.80 mm) compared to females (121.40 mm), with a p-value of 0.028, indicating a statistically significant difference between sexes. Similarly, on the left side, males exhibited a mean measurement of 124.50 mm, whereas females recorded 120.80 mm, yielding a p-value of 0.019, which is also statistically significant ($p < 0.05$).

This analysis confirms that males consistently have larger measurements than females on both sides, a finding that aligns with established anatomical and anthropometric principles. Such differences are attributed to sexual dimorphism, where males generally present with more robust skeletal structures due to hormonal and genetic influences on bone growth and development.

Additionally, the right side showed slightly higher values than the left for both sexes, suggesting minor asymmetry, a common observation in bilateral skeletal elements. The statistical significance observed in this study highlights its clinical and forensic relevance. Accurate knowledge of sex-related differences in skeletal measurements is crucial in reconstructive surgery, dental implantology, and forensic identification.

These findings are consistent with previous studies that reported similar trends of larger dimensions in males compared to females, emphasizing the importance of considering both sex and side during morphometric evaluations.

Discussion:-

In the present study, males demonstrated larger mean mandibular measurements than females on both sides, with statistically significant differences (Right: 125.80 ± 4.70 mm vs. 121.40 ± 5.10 mm; Left: 124.50 ± 4.90 mm vs. 120.80 ± 5.20 mm; $p = 0.028$ and 0.019, respectively). These findings are consistent with those reported by Sairam et al. (2016)15, who also observed significantly greater mandibular dimensions in males compared to females, emphasizing the role of mandibular morphometrics in sex determination.

Our study revealed significant sexual dimorphism, with males having higher mean values on both sides compared to females ($p < 0.05$). Fan et al. (2019) 16 reported similar trends using 3D CBCT imaging and geometric

morphometric analysis, confirming that mandibular size is a key determinant of sex differences. Although their study utilized advanced imaging for volumetric assessment and ours employed linear measurements, the agreement in findings highlights the reliability of size as a discriminator between sexes.

The current research recorded significantly greater mandibular dimensions in males than females, reinforcing the pattern of sexual dimorphism (Right: 125.80 mm vs. 121.40 mm; Left: 124.50 mm vs. 120.80 mm). Hamza et al. (2023) 17 similarly demonstrated that most mandibular linear dimensions were significantly higher in males, stressing the importance of developing population-specific reference standards.

Both studies validate the diagnostic value of mandibular morphometrics for forensic applications. In this study, the differences between males and females were statistically significant for both sides, confirming sexual dimorphism in mandibular size. Verma et al. (2020) 18, who analyzed 200 orthopantomograms, also reported that ramus height and breadth provided excellent accuracy for sex estimation, with males showing larger dimensions.

While their study used radiographic images and ours used linear measurements, the consistency across findings underscores the applicability of mandibular metrics in forensic identification. Our findings indicated significant sex-based differences in mandibular dimensions on both sides ($p = 0.028$ and 0.019).

This aligns with the study by Toneva et al. (2023) 15, which demonstrated that size and shape variables of the mandible can effectively distinguish between sexes, even when assessed using geometric morphometrics.Despite methodological differences, both studies agree that mandibular size is a robust parameter for sex estimation in forensic and anthropological contexts.

Limitations:-

The present study was conducted on a limited sample size, which may not fully represent the variability within the broader population. The bones were obtained from a single geographical region, restricting the generalizability of findings to other ethnic or regional groups. Additionally, the sex of the specimens was based on documented records and not verified through genetic analysis, introducing the possibility of misclassification.

Conclusion:-

The present study demonstrated a statistically significant difference in mandibular measurements between males and females, with males consistently exhibiting larger dimensions on both right and left sides. These findings confirm the presence of sexual dimorphism in the mandible, which can serve as an essential parameter for gender estimation in forensic anthropology and medico-legal investigations.

Clinical relevance:-

Accurate knowledge of mandibular dimensions is crucial for oral and maxillofacial surgeons when planning reconstructive procedures, prosthetic rehabilitation, and implant placement. Understanding sexual dimorphism aids in the selection of appropriately sized grafts and implants, thereby reducing the risk of postoperative complications.

Additionally, these data are valuable in anthropological research and disaster victim identification, especially when other skeletal elements are fragmented or absent.

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