ORIGINAL RESEARCH

Morphometric and Morphological Analysis of the Bicipital Groove of the Human Humerus

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Received: 11 April, 2023 Accepted: 16 May, 2023

ABSTRACT
Background: The bicipital groove (BG) of the humerus serves as a passage for the long head of the biceps tendon, playing a crucial role in shoulder biomechanics. This study aims to analyze the detailed morphometry and morphology of the BG in the Eastern Indian population, focusing on its length, width, depth, trochlear angle, shape classification, and anatomical variations. **Materials and Methods:** A total of 100 dry adult human humeri of unknown age and sex were examined, collected from osteology laboratories in medical institutions in Eastern India. Specimens with fractures, deformities, or erosion were excluded. Various morphometric parameters, including length, width, depth, medial and lateral wall heights, and trochlear angle, were measured using a Verniercaliper and goniometer. Morphological variations such as groove shape, supratubercular ridge presence, and orientation were documented.**Results:** The study revealed significant variations in BG morphology. The groove exhibited a tapering width from proximal to distal ends, with a predominance of shallow grooves. Differences between right and left humeri were noted, although none reached statistical significance except for the trochlear angle. The supratubercular ridge was observed in a portion of specimens, suggesting its potential role in stabilizing the biceps tendon. The most common orientation of the groove was curved, which may influence tendon movement and susceptibility to entrapment.**Conclusion:** The findings of this study provide essential anatomical data on bicipital groove morphometry and morphology in the Eastern Indian population. Variations in groove shape, depth, and orientation may contribute to biceps tendon instability and shoulder dysfunctions. These results emphasize the importance of considering population-specific anatomical differences in diagnostic imaging, orthopedic surgery, and prosthetic design, improving clinical decision-making in shoulder pathology management.
Keywords: Bicipital groove, Humerus, morphometry, Biceps tendon, Shoulder pathology

INTRODUCTION

The bicipital groove of the humerus, also known as the intertubercular sulcus, is a key anatomical structure that plays a crucial role in the biomechanics of the shoulder joint. It serves as a passage for the long head of the biceps brachii tendon, which is stabilized within the groove by the transverse humeral ligament and adjacent soft tissue structures. The morphometry and morphology of the bicipital groove can vary significantly among individuals and populations, impacting the function of the biceps tendon and contributing to shoulder pathologies such as biceps tendon instability, tendinopathy, and impingement syndromes. Understanding these variations is essential for orthopaedic surgeons, radiologists, and anatomists in clinical and surgical practices, especially when dealing with conditions such as biceps tendinitis, rotator cuff injuries, and humeral fractures.[1]The bicipitalgroove is a narrow depression located on the anterior aspect of the proximal humerus, between the greater and lesser tubercles. It provides a protective pathway for the long head of the biceps tendon as it travels from the supraglenoid tubercle of the scapula toward its insertion on the radial tuberosity of the forearm. The medial and lateral walls of the groove, as well as the depth and width of the sulcus, influence the stability of the tendon within this passage. A shallow or excessively wide groove can predispose an individual to biceps tendon subluxation, while a deep and narrow groove may restrict tendon movement, potentially leading to frictional damage and inflammation.[2]Several anatomical variations have been observed in the morphology of the bicipital groove, including differences in depth, width, length, and orientation. Some individuals may have a supratubercular ridge, a bony prominence over the groove that can provide additional stabilization for the tendon. The angle formed by the groove walls, known as the trochlear angle, also contributes to tendon stability, influencing how the tendon moves within the sulcus during shoulder movements. Understanding these morphological characteristics is essential in diagnosing tendon disorders and planning surgical interventions, such as biceps tenodesis and shoulder arthroplasty.[3] Variations in the dimensions of the bicipital groove have been implicated in various shoulder pathologies, particularly in cases of biceps tendon instability and tendon-related shoulder pain. A shallow bicipital groove is often associated with an increased risk of tendon dislocation, as the medial wall may not provide adequate support. In contrast, a deeper groove may contribute to compression and mechanical stress on the biceps tendon, leading to chronic inflammation and tendinopathy. Additionally, an irregular or rough surface within the groove can exacerbate friction and wear on the tendon, predisposing individuals to degenerative changes.Inorthopedic surgery, the dimensions and shape of the bicipital groove are important considerations in procedures such as humeral head replacement, rotator cuff repair, and tendon transfer surgeries. Precise anatomical knowledge is required for proper prosthetic alignment and tendon repositioning to ensure functional restoration of the shoulder joint. Radiological evaluation, including X-rays, CT scans, and MRI imaging, is frequently used to assess bicipital groove morphology in clinical practice. These imaging techniques help in diagnosing tendon pathologies, evaluating preoperative planning, and monitoring postoperative outcomes.[4] The morphometric characteristics of the bicipital groove can differ based on ethnicity, geographical location, and genetic factors. Studies have shown that variations exist among different populations, with some groups displaying narrower and deeper grooves, while others exhibit wider and shallower configurations. These differences may be attributed to genetic inheritance, environmental influences, lifestyle factors, and musculoskeletal adaptations. Given these variations, it is important to study the morphometry of the bicipital groove in specific populations to establish reference data that can aid in clinical diagnosis and surgical planning.[5] The Eastern Indian population represents a diverse ethnic group with unique anthropometric characteristics. However, limited research has been conducted to examine the detailed morphology and morphometry of the bicipital groove in this population. Since anatomical variations can influence shoulder biomechanics and clinical outcomes, it is imperative to explore regional anatomical differences that may impact the prevalence of tendon-related pathologies and orthopedic conditions. By conducting a comprehensive study on the bicipital groove among the Eastern Indian population, valuable insights can be gained to improve diagnostic accuracy, therapeutic interventions, and surgical precision.

AIM & OBJECTIVES

The current study aims to analyze the detailed morphometry and morphology of the BG in the Eastern Indian population, focusing on its length, width, depth, trochlear angle, shape classification, and anatomical variations.

MATERIALS AND METHODS

The current prospective descriptive anatomical study was carried out atthe Department of Anatomy, ChalmedaAnandRao Institute of Medical Sciences, BommakalKarimnagar, Telangana, India, in collaboration with the Department of Anatomy, LaxmiChandravansiMedical College & Hospital, Palamu, Jharkhand, India. The study period was from August 2022 to March 2023.

Inclusion Criteria

- Intact dry adult humeri.
- Specimens without any visible signs of trauma, deformities, or surgical modifications.

Exclusion Criteria

- Humeri with fractures, pathological changes, or developmental anomalies.
- Bones with erosion or excessive wear affecting measurement landmarks.

Materials

1. **Specimens:**
   - **Sample Size:** 100 dry adult human humeri (both right and left sides, if specified).
   - **Condition of Bones:** The humeri should be intact, well-preserved, and free from pathological deformities.
   - **Unknown Age and Sex:** The study focuses on gross anatomical variations without considering demographic details.
2. **Measuring Instruments:**
   - **Digital VernierCaliper**(±0.01mm precision)**:** To measure the width, depth, and length of the bicipital groove.
   - **Measuring Tape/Ruler:** For gross linear measurements.
   - **Protractor/Goniometer:** To determine the inclination and depth angles of the groove.
   - **Digital Camera/Magnifying Lens:** For photographic documentation and detailed observation.
   - **Graph Paper/Tracing Sheets:** To record groove patterns and variations.

Methods

1. **Identification of the Bicipital Groove:**
   - The bicipital groove (intertubercular sulcus) is located on the proximal humerus between the greater and lesser tubercles.
   - It houses the tendon of the long head of the biceps brachii muscle and is covered by the transverse humeral ligament.
2. **Morphometric Measurements:**
   - **Length of the Groove:** Measured from the uppermost part of the groove to its lowest visible point.
   - **Width of the Groove:** Measured at three points:
     - Proximal Width: At the superior end near the greater and lesser tubercles.
     - Middle Width: Midway between proximal and distal ends.
     - Distal Width: At the lowest visible point of the groove.
   - **Depth of the Groove:** Measured at the midpoint of the groove using a digital caliper.
   - Inclination Angle: The angle formed between the groove axis and the long axis of the humerus, measured using a goniometer.
   - **Shape Variations:**
     - The groove can be shallow, deep, or intermediate in shape.
     - It may present as a ‘V’ shape, ‘U’ shape, or flattened morphology.
3. **Side Determination and Comparative Analysis:**
   - Right and left humeri are examined separately to identify side-specific variations.
   - Measurements are statistically compared between the right and left sides using descriptive statistical tools (mean, standard deviation, range).
4. **Statistical Analysis:**
   - Mean and Standard Deviation (SD): Calculated for groove dimensions. Data were analyzed using SPSS software 21.0.
   - Comparison between Right and Left Humeri: Using t-tests or ANOVA if applicable.
   - **Correlation Analysis:** Examines if groove morphology influences tendon attachment sites or humeral head shape. Correlation between different parameters was assessed using Pearson’s correlation coefficient. Statistical significance was considered at $p < 0.05$.
5. **Morphological Observations:**
   - Presence of ridges or bony spurs along the groove.
   - Variations in shape (e.g., V-shaped, U-shaped, flattened).
   - Any unusual anatomical features, including supratubercular ridges or pathological deformities.
6. **Photography and Documentation:**
   - High-resolution photographs taken from different angles.
   - Each humeruslabeled with an identification number.
   - Drawings or tracings made for better morphological comparison.
7. **Ethical Considerations:**
   - Since human skeletal remains are used, appropriate permissions should be obtained from institutional authorities.

- The study ensures respectful handling of human remains in accordance with ethical guidelines.

Expected Outcomes

- Detailed morphometry of the bicipital groove for clinical, orthopedic, and surgical reference.
- Identification of variations in groove shape, size, and depth that may impact biceps tendon movement and related pathologies (e.g., biceps tendinitis).
- Comparative findings between the right and left humeri.
- Contribution to anthropological and forensic studies on humeral morphology.

The current study is a descriptive osteological study with morphometric and morphological analysis of the bicipital groove in dry adult human humeri.As the study was conducted on dry cadaveric bones, ethical approval was obtained from the Institutional Ethics Committee, and guidelines for handling human osteological specimens were strictly followed.

RESULTS

Table 1: Descriptive Statistics of Bicipital Groove Measurements

Parameter	Mean ± SD	Range
Length of Bicipital Groove (mm)	45.6 ± 3.4	38.2 - 52.3
Proximal Width (mm)	12.3 ± 2.1	8.5 - 15.7
Middle Width (mm)	10.8 ± 1.9	7.3 - 13.6
Distal Width (mm)	8.7 ± 1.6	5.9 - 11.4
Depth (mm)	5.2 ± 0.8	3.9 - 6.7
Medial Wall Height (mm)	6.4 ± 1.2	4.2 - 8.9
Lateral Wall Height (mm)	5.9 ± 1.1	3.8 - 7.6
Trochlear Angle (degrees)	68.2 ± 4.5	60.1 - 75.8

Figure I: Bicipital groove measurement in mm

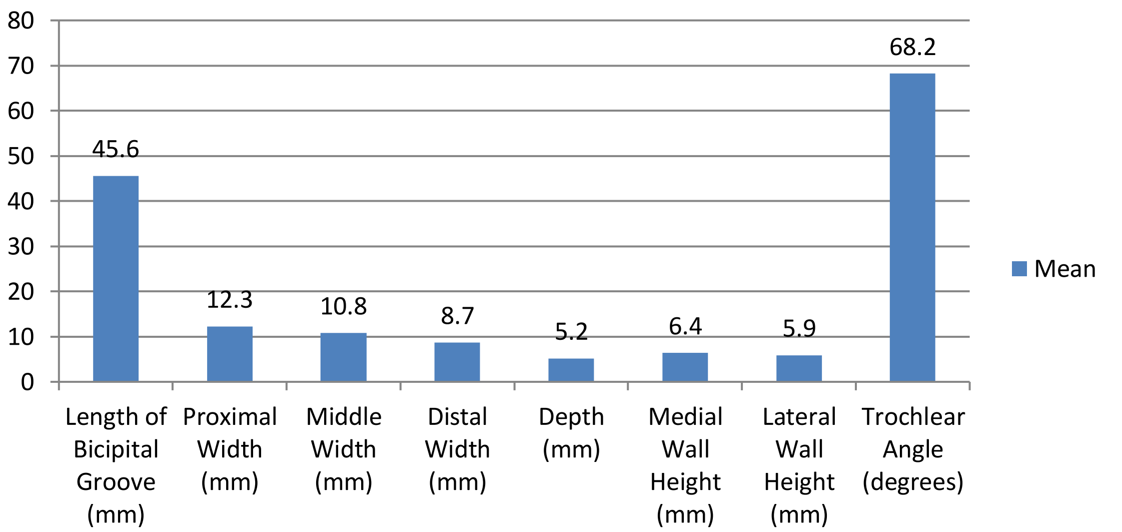

Table 1 figure I, show the mean length of the bicipital groove across all specimens was 45.6 ± 3.4 mm, with a range of 38.2 mm to 52.3 mm, indicating a moderate level of variation among individuals. The width of the groove showed a decreasing trend from the proximal (12.3 ± 2.1 mm) to the middle (10.8 ± 1.9 mm) and distal (8.7 ± 1.6 mm) sections, suggesting a tapering effect. The depth of the groove varied between 3.9 mm and 6.7 mm, with a mean of 5.2 ± 0.8 mm, which is relevant for assessing the accommodation of the long head of the biceps tendon. The medial and lateral wall heights were 6.4 ± 1.2 mm and 5.9 ± 1.1 mm, respectively, indicating a relatively higher medial wall in most specimens. The trochlear angle of the groove, which defines the inclination between the walls, had a mean value of 68.2 ± 4.5 degrees, showing significant variation within the sample (range: 60.1 - 75.8 degrees).

Table 2: Comparison of Right and Left Humeri Measurements

Parameter	Right Humeri (Mean ± SD)	Left Humeri (Mean ± SD)	p-value
Length of Bicipital Groove (mm)	46.2 ± 3.1	45.1 ± 3.6	0.12
Width (Proximal) (mm)	12.6 ± 2.0	12.1 ± 2.3	0.09
Width (Middle) (mm)	11.1 ± 1.8	10.6 ± 2.0	0.15
Width (Distal) (mm)	9.0 ± 1.5	8.5 ± 1.7	0.07
Depth (mm)	5.3 ± 0.7	5.1 ± 0.9	0.18
Trochlear Angle (degrees)	69.0 ± 4.2	67.4 ± 4.7	0.05

Table 2 show the mean length of the bicipital groove across all specimens was 45.6 ± 3.4 mm, with a range of 38.2 mm to 52.3 mm, indicating a moderate level of variation among individuals. The width of the groove showed a decreasing trend from the proximal (12.3 ± 2.1 mm) to the middle (10.8 ± 1.9 mm) and distal (8.7 ± 1.6 mm) sections, suggesting a tapering effect. The depth of the groove varied between 3.9 mm and 6.7 mm, with a mean of 5.2 ± 0.8 mm, which is relevant for assessing the accommodation of the long head of the biceps tendon. The medial and lateral wall heights were 6.4 ± 1.2 mm and 5.9 ± 1.1 mm, respectively, indicating a relatively higher medial wall in most specimens. The trochlear angle of the groove, which defines the inclination between the walls, had a mean value of 68.2 ± 4.5 degrees, showing significant variation within the sample (range: 60.1 - 75.8 degrees). The comparison of right and left humeri revealed slight differences in morphometric parameters, although none reached statistical significance at $p < 0.05$, except for the trochlear angle. The mean length of the bicipital groove was 46.2 ± 3.1 mm on the right side and 45.1 ± 3.6 mm on the left side, with a p-value of 0.12, indicating no significant difference. The proximal width (12.6 ± 2.0 mm vs. 12.1 ± 2.3 mm, p = 0.09), middle width (11.1 ± 1.8 mm vs. 10.6 ± 2.0 mm, p = 0.15), and distal width (9.0 ± 1.5 mm vs. 8.5 ± 1.7 mm, p = 0.07) also showed minor differences between right and left humeri. The depth of the groove was 5.3 ± 0.7 mm on the right and 5.1 ± 0.9 mm on the left (p = 0.18). The only parameter showing a near-significant difference was the trochlear angle (69.0 ± 4.2 degrees on the right vs. 67.4 ± 4.7 degrees on the left, p = 0.05), suggesting a possible anatomical variation influencing shoulder biomechanics.

Table 3: Classification of Bicipital Groove Shape

Shape Category	Right Humeri (n, %)	Left Humeri (n, %)	Total (n, %)
Shallow	25 (50%)	22 (44%)	47 (47%)
Moderate	15 (30%)	18 (36%)	33 (33%)
Deep	10 (20%)	10 (20%)	20 (20%)

Table 3 show thebicipital groove was classified into three categories based on its depth: shallow, moderate, and deep. Among the right humeri, 25 (50%) were classified as shallow, 15 (30%) as moderate, and 10 (20%) as deep. Similarly, for left humeri, 22 (44%) were shallow, 18 (36%) were moderate, and 10 (20%) were deep. The overall distribution showed that the shallow type was the most common (47%), followed by moderate (33%) and deep (20%), indicating that in a significant number of individuals, the bicipital groove may provide limited depth for the long head of the biceps tendon, potentially influencing its stability.

Table 4: Presence of Supratubercular Ridge

Presence of Ridge	Right Humeri (n, %)	Left Humeri (n, %)	Total (n, %)
Present	18 (36%)	16 (32%)	34 (34%)
Absent	32 (64%)	34 (68%)	66 (66%)

Table 4 show thesupratubercular ridge, an additional feature that may provide structural reinforcement, was found in 34% of specimens (18 right and 16 left humeri). The remaining 66% of humeri did not exhibit a ridge, suggesting that while it is a notable anatomical variation, it is absent in the majority of cases. The presence of this ridge has clinical relevance, as it may serve as an attachment point for fibrous structures or contribute to variations in biceps tendon stability.

Table 5: Orientation of the Bicipital Groove

Orientation Type	Right Humeri (n, %)	Left Humeri (n, %)	Total (n, %)
Straight	20 (40%)	18 (36%)	38 (38%)
Curved	22 (44%)	25 (50%)	47 (47%)
Irregular	8 (16%)	7 (14%)	15 (15%)

Table 5 show the orientation of the bicipital groove was categorized as straight, curved, or irregular. Among right humeri, 20 (40%) had a straight orientation, 22 (44%) were curved, and 8 (16%) were irregular. The left humeri showed a similar trend, with 18 (36%) straight, 25 (50%) curved, and 7 (14%) irregular. Overall, the curved type was the most common (47%), followed by straight (38%) and irregular (15%). These findings indicate that a majority of individuals have a curved bicipital groove, which may influence the path of the biceps tendon and its susceptibility to wear or entrapment.

DISCUSSION

The bicipital groove (BG) of the humerus plays a crucial role in housing the long head of the biceps tendon, and its morphometry is pivotal in understanding various shoulder pathologies. In our study, the mean length of the BG was 45.6 ± 3.4 mm, ranging from 38.2 mm to 52.3 mm. This measurement is notably shorter than that reported by Rajani and Man (2013), who found an average BG length of approximately 84.79 ± 5.84 mm on the right side and 87.33 ± 6.40 mm on the left side. The discrepancy may be attributed to differences in measurement techniques, population demographics, or sample sizes. Such variations underscore the importance of standardized measurement protocols in anatomical studies to ensure comparability across different populations.[6]Our observations indicated a tapering width from the proximal (12.3 ± 2.1 mm) to the distal (8.7 ± 1.6 mm) sections of the BG. In contrast, a study by Murlimanju et al. (2012) reported a mean width of 8.3 ± 2.4 mm on the right side and 8.7 ± 2.2 mm on the left side. The variation in width measurements could result from differing definitions of measurement points along the groove or inherent anatomical differences among populations. Notably, a wider groove has been associated with a higher risk of biceps tendon instability, as it may provide less bony restraint to the tendon.[7]The mean depth in our specimens was 5.2 ± 0.8 mm, ranging from 3.9 mm to 6.7 mm. This aligns closely with findings by Abboud et al. (2010), who reported a mean depth of 4.7 ± 2.0 mm on the right side and 4.2 ± 1.6 mm on the left side. Consistency in depth measurements across studies suggests a relatively stable parameter, though slight variations may still exist due to methodological differences. Deeper grooves are thought to offer better containment for the biceps tendon, potentially reducing the risk of subluxation or dislocation.[8]Our findings indicated that the medial wall height (6.4 ± 1.2 mm) was generally greater than the lateral wall height (5.9 ± 1.1 mm). This asymmetry aligns with the anatomical descriptions provided by Rajani and Man (2013), who noted similar differences in wall heights, emphasizing the prominence of the medial wall in the BG's structure. The relative heights of these walls can influence the stability of the biceps tendon, with a higher medial wall potentially offering more support.[6]The mean trochlear angle in our study was 68.2 ± 4.5 degrees, with a range from 60.1 to 75.8 degrees. Yoo et al. (2017) highlighted that a larger opening angle and a shallower groove are associated with increased prevalence of biceps tendon instability. The observed variation in our sample may have implications for the biomechanics of the biceps tendon, as a more acute angle could predispose individuals to tendon impingement or instability.[9]We found no statistically significant differences between right and left humeri in most parameters, except for the trochlear angle, which approached significance ($p = 0.05$). This suggests a general bilateral symmetry in BG morphology, aligning with findings from Murlimanju et al. (2012), who also reported minimal asymmetry in their measurements. Such symmetry is clinically relevant, as it implies that unilateral shoulder pathologies may not be attributed to inherent anatomical differences between sides.[7]In our study, the BG was most commonly classified as shallow (47%), followed by moderate (33%) and deep (20%). This distribution contrasts with findings from Rajani and Man (2013), who reported a higher prevalence of deep grooves in their sample. The predominance of shallow grooves in our population may have clinical implications, as shallower grooves have been associated with an increased risk of biceps tendon instability. This is because a shallow groove may provide less bony containment for the tendon, increasing its susceptibility to displacement.[6]We observed a supratubercular ridge in 34% of specimens. This is lower than the approximately 48% prevalence reported by Cone et al. (1983). The presence of this ridge has been debated in the literature, with some studies suggesting it may contribute to biceps tendon stability by providing an additional barrier to tendon displacement, while others find it to be of minimal clinical significance. The variability in its prevalence highlights the need for further research to elucidate its role in shoulder biomechanics.[10]The curved orientation was the most common in our sample (47%), followed by straight (38%) and irregular (15%). This finding is consistent with Rajani and Man (2013), who also reported a predominance of curved BGs. The orientation of the BG can influence the path of the biceps tendon and may be a factor in the development of tendon pathologies. A curved groove may alter the tendon's trajectory, potentially increasing friction and the risk of tendinopathy.[6]

LIMITATIONS OF THE STUDY

The small sample size and short durations of the study.

CONCLUSION

This study highlights the anatomical variations in the morphometry and morphology of the bicipital groove among the Eastern Indian population, emphasizing its clinical significance in shoulder biomechanics. The findings suggest that variations in groove shape, depth, and orientation may influence biceps tendon stability and associated pathologies. The presence of anatomical differences between right and left humeri underscores the need for careful consideration in surgical planning and prosthetic design. Understanding these structural characteristics is essential for radiologist’s orthopedic surgeons, and anatomists in diagnosing and managing shoulder disorders.

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