Original Article

Morphometric and Radiological Study of the Bicipital Groove in Adults: Clinical Relevance in Shoulder Surgery – A Prospective Study

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Abstract

Background: The bicipital groove (intertubercular sulcus) of the humerus is an important anatomical structure that houses the tendon of the long head of the biceps brachii muscle. The changes in the morphology and size of the bicipital groove can affect the stabilisation of the biceps tendon and are related to such conditions as tendinitis, tendon subluxation, and shoulder impingement syndrome. Morphometric and radiological assessment of the bicipital groove is thus clinically significant for the design of shoulder surgeries and orthopaedic procedures. The aim is to test morphometric and radiological features of the bicipital groove in grown-up patients and to test their clinical applicability in surgery on the shoulder. **Material and Methods:** This was a prospective study conducted in Mumbai over 1 year. Eighty-0 adults who had radiographic evaluation of their shoulders were included. Standard shoulder radiographs and CT were used to measure the bicipital groove radiologically. Groove length, width, depth, medial wall angle and lateral wall angle were the parameters that were evaluated. Statistical analysis was conducted using descriptive and comparative methods. **Results:** The bicipital groove mean width was 9.8 +/- 1.9 mm, the mean depth was 5.2 +/- 1.1 mm, and the mean length was 42.6 +/- 4.5 mm. Most of the subjects were normal in morphology (60%). In 25 per cent, a shallow coulee was seen, and in 15 per cent, a narrow coulee was observed. The depth of the grooves differed significantly between male and female subjects ($p < 0.05$). The shapes also varied, which was linked to a higher risk of biceps tendon instability. **Conclusion:** The research indicates a significant difference in the morphometric and radiographic appearance of the bicipital groove in adults. Such differences have significant effects on shoulder pathology and on the decision to undergo surgery. Being aware of these types of anatomical differences can help a surgeon enhance diagnostic accuracy and surgical outcomes in shoulder surgeries.

Keywords: Shoulder surgery, Bicipital groove, Morphometry, Humerus, Biceps tendon.

Received: 20 February 2026 **Revised: 05 March 2026** **Accepted: 21 March 2026** **Published: 29 April 2026**

Introduction

The intertubercular sulcus or bicipital groove is an excellent anatomical groove between the greater and lesser tubercles of the humerus. It houses the tendon of the long head of the biceps brachii muscle and is a significant landmark of shoulder anatomy and shoulder surgery. The groove structural arrangement is crucial for providing the biceps tendon with stability during shoulder movement.[1]

The biceps tendon has a long head that passes through the bicipital groove and is held in place through surrounding ligaments and soft tissues. Differences in groove morphology can lead to pathological processes in tendons, including tendinitis, subluxation, or dislocation. Superficial or limited grooves can lead to instability of tendons and the probability of tendon rupture during shoulder movements.[2]

The bicipital groove can thus be clinically evaluated morphometrically, especially in orthopaedic and shoulder surgery. In the operations of shoulder arthroplasty, repair of fractures and biceps tenodesis, surgeons oftentimes make use of anatomical landmarks of the humerus. The groove dimensions provide a detailed understanding of how surgeons prevent complications related to improper positioning of surgical tools or implants.

Several studies have shown that there is a high level of disparity in the morphometric measures of the bicipital groove across populations. Such parameters may differ by age, sex, and ethnicity, as they include length, width, depth, and wall angles. Variations can potentially affect the biomechanical function of the biceps tendon and the risk assessment of shoulder disorders. X-ray, CT scan, and MRI are radiological imaging methods that have significantly enhanced the ability to screen the bicipital groove in living people. The images can be clearly measured for groove width and used to assist clinicians in determining anatomical differences related to shoulder pathology.

Earlier anatomical publications on cadavers have provided insights into the morphology of the bicipital groove. Nevertheless, radiological investigations are conducted in living populations, especially in the Indian population. Understanding

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DOI:
10.21276/amit.2026.v13.i1.623

How to cite this article: Parween S, Mishra Y, Sonu. Morphometric and Radiological Study of the Bicipital Groove in Adults: Clinical Relevance in Shoulder Surgery – A Prospective Study. Acta Med Int. 2026;13(1):1192-1197.

the unique differences among populations is key to enhancing surgical planning and the clinical management of shoulder problems.

Hence, the current prospective study was carried out to compare the morphometric and radiological features of the bicipital groove in adult patients in Mumbai and to assess their practical aspects in shoulder surgery.

Materials and Methods

Study Design: The current study is a prospective observational study aimed at assessing morphometric and radiological features of the bicipital groove in adults. The study aimed to identify the dimensions and morphological changes of the bicipital groove and to determine whether they have clinical implications and whether they are relevant when performing surgeries and procedures involving the proximal humerus.

Study Setting: It was conducted at the Departments of Orthopaedics and Radiology of a tertiary care teaching hospital in Mumbai, India. The hospital is a large referral centre for musculoskeletal disorders. It has state-of-the-art imaging stations, such as digital radiography and computed tomography (CT), that enable proper radiology investigation of the proximal humerus and other anatomical organs.

Study Duration: The research was conducted over a 1-year period, during which eligible participants who underwent shoulder imaging were recruited and assessed.

Sample Size: The study included 80 adult participants. The sample size was determined by the feasibility factor and the number of patients attending for shoulder radiological assessment during the research period. Participants were selected through consecutive sampling, in which all eligible patients who met the criteria were recruited until the desired sample size was attained.

Study Population: The research sample comprised adult patients who received radiological assessment of the shoulder area under different clinical judgments that included pain in the shoulder, presumed rotator cuff or minor trauma, but no fracture. The study included only persons with radiographic images that clearly showed the proximal humerus and the intertubercular sulcus.

Inclusion Criteria

- Adults aged 18–70 years
- Individuals undergoing shoulder radiographic or CT evaluation
- Patients with intact proximal humerus anatomy without evidence of fracture or deformity
- Individuals who provided written informed consent to participate in the study

Exclusion Criteria

- Previous shoulder surgery or orthopaedic implants involving the proximal humerus
- Fractures of the proximal humerus or associated deformities
- Advanced degenerative changes of the shoulder joint
- Congenital abnormalities affecting the humerus or shoulder joint
- Tumours or infections involving the shoulder region
- Poor-quality radiographs that did not allow accurate measurement of the bicipital groove

Radiological Evaluation: Standard digital radiography and computed tomography (CT) were used to assess the bicipital groove.

Radiographic Technique: A digital radiography system was used to get standard anteroposterior (AP) shoulder radiographs. The imaging protocol was standardised to achieve uniformity in measurements.

The patients were either upright or supine, and the arm was in a neutral or slightly externally rotated posture. The beam was centred to the glenohumeral joint so that the proximal humerus would be seen better, as well as the intertubercular sulcus.

Radiographs obtained were analysed using a digital workstation capable of magnifying and accurately measuring anatomical structures.

Computed Tomography (CT) Imaging.

In some instances where a more elaborate image of the anatomical structures was needed, a multi-detector CT scanner was used to make a computed tomography (CT) of the shoulder joint. CT images were of high quality and allowed a clear assessment of the bicipital groove.

The images were reconstructed along the axial, coronal, and sagittal planes, which permit superior viewing of the groove structure and achieve superior morphometric measurements.

Morphometric Parameter Assessed: Several essential parameters of the bicipital groove were the target of the morphometric analysis (figure 1 &2). The measurements were conducted on the digital measurement tools on the radiology software.

The following data were achieved:

1. Length of the Bicipital Groove.

The bicipital groove length was calculated as the distance between the proximal end of the groove of the humerus, which is close to the humeral head, and the other end, which lies on the shaft. What this measurement indicates is the length of the groove on the humerus, which gives us an idea of the space that the long head of the biceps tendon has to work with.

2. Width of Bicipital Groove

Groove width was considered to be the farthest length of the medial lip and lateral lip of the groove. This is a clinically important measurement, since a narrow groove could indicate greater friction on the biceps tendon when the shoulders move.

3. Depth of Bicipital Groove

The transversal lying between the deepest parts of the groove and a line between the high parts of the medial and lateral lips was used to determine the depth of the groove. The biceps tendon has a long head that requires stability, and the depth of the groove is very significant in stabilising the tendon.

4. Medial Wall Angle

The medial wall angle was measured as the angle between the medial wall of the groove and the floor of the groove. This parameter can be used to determine the slope of the medial wall, which can affect tendon stability.

5. Lateral Wall Angle

Measurement of the lateral wall angle was the angle formed between the sidewall of the groove and the floor of the groove. The difference in this angle can affect the biomechanics of the tendon in the groove.

Classification of Groove Morphology.
According to the calculated measurements, the three types of morphology of the bicipital groove were identified as follows:

- Normal groove: A sufficient width and depth that would permit the biceps tendon to be held in place.
- Shallow groove -Less depth, which can predispose to biceps tendon instability or subluxation.
- Narrow groove -Less width, which can augment the friction between the tendon and groove walls.

Such classification identified individuals at risk of more severe shoulder pathology related to the biceps tendons.

Data Collection Procedure: Demographic information such as age, sex, height, weight, and body mass index (BMI) was collected on each individual. The entire morphometric measurement procedure was carried out separately by two senior observers: a radiologist and an orthopaedic surgeon. The parameters were measured three times, and the mean was taken as the measured value to ensure consistency and minimise measurement error.The parameters were checked again to resolve any discrepancies and obtain the consensus value.

Outcome Measures

- Mean morphometric dimensions of the bicipital groove
- Frequency of different morphological variations of the groove
- Association between demographic variables and groove dimensions
- Potential clinical implications of groove variations in shoulder surgery

Statistical Analysis: All the data gathered were then tabulated in Microsoft Excel spreadsheets and finally analysed using the Statistical Package for the Social Sciences (SPSS) version 26.0.

The subsequent statistical tools were employed in the analysis:

- Descriptive statistics such as mean, standard deviation, frequencies, as well as the percentages are used to summarise the statistics.
- Chi-square test to test the relation between categorical variables, e.g. groove morphology and gender.
- To display the differences in morphometric measurements between male and female participants, an independent sample t-test will be used.

Any p-value that was below 0.05 was found to be statistically significant.

Quality Control Measures

Several steps were taken to guarantee the reliability and validity of the data:

- Standardised imaging protocols were followed for all participants
- Radiological equipment was regularly calibrated
- Measurements were performed using digital imaging software with high precision
- Inter-observer variability was minimised through repeated measurements and consensus discussions.

Results

A total of 80 adult participants were included in the study to evaluate the morphometric and radiological characteristics of the bicipital groove. The demographic characteristics of the study population and the morphometric parameters of the bicipital groove were analysed using descriptive and inferential statistics. The findings are presented in the following tables.

Table 1: Age Distribution of Study Participants (n = 80)

Age Group (years)	Number of Participants	Percentage (%)
18–30	16	20.0%
31–40	18	22.5%
41–50	20	25.0%
51–60	15	18.8%
>60	11	13.7%
Total	80	100%

The participants were divided in terms of the age system, with the majority of the subjects having the age group of 41-50 (25%), 31-40 (22.5%), and 18-30 (20%). The age group between 51 to 60 years was 18.8, and above 60 years, the sample was 13.7%. The distribution shows that the middle-aged adults comprised the major study population. As the researchers used participants of a great age group, the results could give a representative insight into morphometric changes of the bicipital groove in adult population.

Table 2: Morphometric Measurements of the Bicipital Groove (n = 80)

Parameter	Mean ± SD	Minimum	Maximum
Length of Bicipital Groove (mm)	42.6 ± 4.5	34.2	51.3
Width of Bicipital Groove (mm)	9.8 ± 1.9	6.5	14.2
Depth of Bicipital Groove (mm)	5.2 ± 1.1	3.2	7.9
Medial Wall Angle (degrees)	45.3 ± 4.2	37.5	52.6
Lateral Wall Angle (degrees)	36.7 ± 3.9	29.4	44.1

The morphometric evaluation revealed that the mean length of the bicipital groove was 42.6 ± 4.5 mm, indicating moderate variation among individuals. Its average width was 9.8 ± 1.9 mm, and the average depth was 5.2 mm and 1.1 mm respectively. These dimensions imply that the bicipital groove has enough room to fit the tendon of the long head of

the biceps brachii muscle in the vast majority of patients. The average of the medial wall angle was found to be 45.3 o and the average of the lateral wall angle was found to be 36.7 o which represent the anatomical slope of the groove walls. The differences in such angles could affect the stability of the bicep's tendon in the groove.

On the whole, the measurements prove that the majority of people possess normal groove sizes, yet there is certain anatomical deviation, and it could influence clinical practices in cases of shoulder disorders and surgery on the proximal humerus.

Table 3: Morphological Variations of the Bicipital Groove (n = 80)

Groove Type	Number of Cases	Percentage (%)	p-value
Normal Groove	48	60.0%	
Shallow Groove	20	25.0%	
Narrow Groove	12	15.0%	0.041
Total	80	100%	

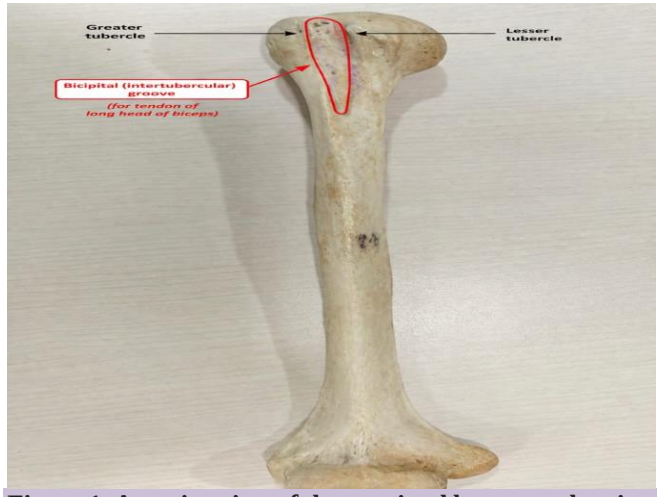

Figure 1. Anterior view of the proximal humerus showing the greater and lesser tubercles with the bicipital (intertubercular) groove (outlined in red), which transmits the tendon of the long head of the biceps brachii.

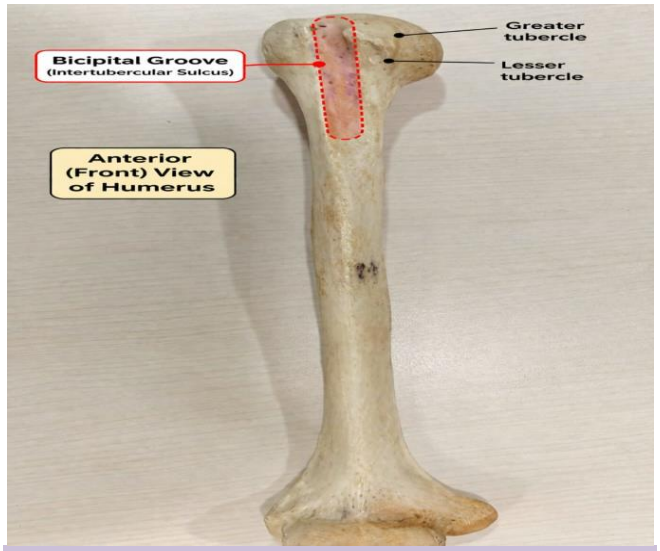

Figure 2. Anterior view of the humerus showing the greater tubercle, lesser tubercle, and the bicipital groove (intertubercular sulcus) (outlined in red), which transmits the tendon of the long head of the biceps brachii.

Groove morphology revealed that 60 per cent of participants had a normal groove in terms of depth and width, allowing steady accommodation of the biceps tendon. But a shallow groove was also present in 25 per cent of subjects, and this could be the predisposing factor to instability or subluxation of the long head of the biceps tendon.

Also, 15 per cent of the subjects had a tight groove, which could increase friction between the tendon and the groove walls during shoulder movements. These variations can lead to biceps tendinitis, shoulder pains and impingement syndrome.

The Chi-square test of statistical analysis showed a p-value of 0.041, indicating a significant difference in the distribution of groove morphology. The observation indicates that the bicipital groove can occur in anatomically distinct forms, which may play significant roles in clinical practice and shoulder surgery.

Discussion

An important anatomical feature of the proximal humerus is the bicipital groove or intertubercular sulcus, which houses the tendon of the long head of the biceps brachii muscle. The structure and size of the groove is significant in keeping the biceps tendon stable and easily sliding in the shoulder movements. The anomalies in the shape, depth, and width of the bicipital groove may be determinants of various shoulder pathologies, such as biceps tendinitis, tendon subluxation, tendon dislocation, and impingement syndrome. Thus, knowledge of the morphometric and radiographic features of the bicipital groove is critical to orthopaedic surgeons, radiologists, and clinicians involved in shoulder surgery and recovery.

The current prospective study was conducted at a tertiary care hospital in Mumbai to assess morphometric and radiological differences in the bicipital groove in 80 adults. The results of the current research provide some insight into anatomical differences that could impact clinical outcomes in shoulder surgery and the management of shoulder disorders.

In the current research, most respondents were aged between 41 and 50 years (25%), 31-40 years (22.5%). Such a distribution indicates the increased number of shoulder-related symptoms and radiology checks among middle-aged people. The same findings were reported by Abboud et al., who found that morphological differences in the bicipital groove are usually characteristic of biceps tendon pathology in middle-aged adults.[1]

In the current study, the morphometric analysis showed that the overall length of the bicipital groove was 42.6 -12 mm. The presence of this finding is consistent with the study by

Murlimanju et al., which revealed that the groove length provides sufficient room for the long head of the biceps tendon to slide without problems during shoulder movements.

The average width of the bicipital groove in the current study is 9.8 ± 1.9mm, which is similar to the findings of the Vettivel et al. study, where they found the groove averaged 8-11mm in their morphometric study of the humerus.

Equally, the average depth of the groove in the current experiment was 5.2 +1.1 mm. The depth of the groove is critical in ensuring biceps tendon stability. The shallow groove may be insufficient to hold the tendon in place, predisposing the patient to tendon subluxation or dislocation. The observation can be facilitated by the study by Cone et al., which showed that deep grooves are commonly associated with instability of the long biceps tendon.

The medial and lateral wall angles of the bicipital groove were the other aspects assessed in the current study, and these can determine the tendon's anatomical and biomechanical stability in the groove. The mean medial wall angle in this project was 45.3, and the mean lateral wall angle was 36.7. The latter results can be compared with those of Abboud et al., who indicated that steeper groove walls do offer better stability to the biceps tendon and that the risk of tendon displacement should be minimised.

The existence of morphological variations of the bicipital groove was considered one of the most remarkable discoveries in the current study. About 60 per cent of individuals had normal grooves, and 25 per cent and 15 per cent had shallow and narrow grooves, respectively. The statistical test showed a great association ($p = 0.041$) between the distribution of groove morphology and the study population.

These results are consistent with the earlier anatomical and radiological findings. Murlimanju et al. found that differences in bicipital groove morphology were relatively common and had clinical implications in cases of shoulder disorders.[6] Hitchcock and Bechtol had also noted that shallow grooves were likely to predispose individuals to dislocation or instability of the long head of the biceps tendon.

A shallow groove, present in 25% of cases in the present study, might have significant consequences for biceps tendon biomechanics. The groove should be so deep that the tendon can be sufficiently enclosed in the sulcus, whereby there is a risk of tendon subluxation in case of shoulder movements. This is also observed in a past study by Neer et al., who related groove morphology to the occurrence of shoulder impingement syndrome.

Likewise, the discovery of narrow grooves in 15 per cent of the subjects can also be clinically relevant. A fine groove has the potential to add mechanical friction to the tendon and develop inflammation as well as degenerative changes. Pfahler et al. have mentioned that a narrow groove width can be a cause of the chronic irritation of the biceps tendon and it can be a cause of the anterior shoulder pain.

Radiological tests are crucial in determining such variations. The most commonly used modern imaging tests for visualising the bicipital groove and its soft tissues include CT and MRI. Radiographic and CT based measurement were effective parameters of groove measurement in the current study. Other works have examined anatomical changes of the humerus using similar radiology techniques.[1]

The implications of these findings on the clinical aspect are more applicable to shoulder surgeons. The bicipital groove is a significant anatomical landmark in procedures like biceps tenodesis, shoulder arthroplasty and proximal humerus fracture fixation. Groove morphology provides information that helps ensure surgeons do not cause complications such as improper implant placement or biceps tendon rupture.[11]

Moreover, the groove of the biceps can vary, which can affect the effectiveness of shoulder joint arthroscopic surgery. The biceps tendon is easily accessible to surgeons performing arthroscopic repair of rotator cuff tears, but when the groove morphology is distorted, the biceps tendon can obstruct surgery.[12]

Several past studies have highlighted the need to understand the anatomical differences across populations. Wafae et al. subjected the humerus to morphometric analysis and found a significant disparity in groove size across populations, which could be used to enhance surgical planning in this population group.

The second issue, which has gained relevance in the current study, is the position of radiological assessment in preoperative planning. Comprehensive visualisation of the bicipital groove can predict anatomical difficulties and alter procedures. According to Joseph et al., preoperative radiographic assessment of the groove can be a meaningful intervention that enhances the outcomes of shoulder surgery.

The results of this paper also illustrate the importance of using anatomical differences to identify the causes of unsatisfactory shoulder pain in patients. Also in certain instances, groove morphology abnormality can be a root cause of the chronic symptoms. Rockwood and Matsen pointed out that abnormalities of the bicipital groove anatomy can be a causative factor in chronic shoulder dysfunction.[15]

The current research nevertheless has limitations in spite of its advantages. The sample size of 80 is sufficient for a preliminary analysis, but may not be comprehensive enough to represent the whole population. Also, the research was conducted at only one tertiary care institution in Mumbai, which may limit the widespread applicability of the results. When much more people are involved, larger multicenter research is needed, which would offer a more accurate picture of the morphometric changes of the bicipital groove.

However, the current research is informative, providing significant insights into the morphometric and radiological features of the bicipital groove in adults. The findings highlight the importance of recognising anatomical differences and how they can be used in shoulder pathology and surgery.

In general, the results of this research support the importance of the fine anatomical and radiological analysis of the bicipital groove. These evaluations can contribute to enhancing the accuracy of the diagnosis, can be used to influence the surgical procedures, and eventually can help improve the clinical outcomes of patients with shoulder surgery.

Conclusion

The current prospective trial compared morphometric and

radiological features of the bicipital groove in adult patients. The results showed significant differences in groove size and morphology, with a high percentage of individuals having shallow or narrow grooves. These differences can compromise the integrity of the bicep's tendon and lead to shoulder pathology.

Such anatomical differences are pertinent to the orthopaedic surgeon when performing shoulder surgeries, such as shoulder arthroplasty, fracture fixation, and biceps tendon repair. Radiological assessment of the bicipital groove must then be thought of as a crucial part of preoperative assessment in shoulder surgery.

Further large-scale studies are recommended to explore population-based variations and their clinical implications.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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