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Morphometric and volumetric analysis of the bicipital groove in patients with biceps tendinitis: a comparative radiological study

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ABSTRACT

Aims: The relationship between bicipital groove morphology and biceps tendon pathology remains controversial, and few studies have evaluated volumetric parameters. To investigate whether patients with biceps tendinitis have distinct morphometric and volumetric features of the bicipital groove compared with asymptomatic individuals.

Methods: This retrospective study included 36 patients who underwent surgical treatment for biceps tendon pathology (tenodesis or tenotomy) and 66 asymptomatic controls with available shoulder MRI and CT scans. Exclusion criteria were prior shoulder surgery or fracture, labral lesions, adhesive capsulitis, inflammatory arthritis, advanced osteoarthritis, inadequate imaging quality, and prior corticosteroid injection. Radiological parameters included total opening angle (TOA), medial wall angle (MWA), groove width, groove depth, and groove volume measured on CT and MRI. Volumetric analysis was performed using OsiriX software. Inter- and intra-observer reliability was tested with intraclass correlation coefficients (ICCs).

Results: Compared with controls, patients with biceps tendon pathology had significantly narrower groove width (10.26 vs 11.62 mm, p=0.010), greater depth (6.50 vs 5.52 mm, p=0.001), smaller TOA (75.73° vs 90.98°, p=0.001), larger MWA (51.23° vs 44.42°, p=0.001), and lower groove volumes on both CT (0.704 vs 0.918 mm^3, p=0.001) and MRI (0.623 vs 0.794 mm^3, p=0.001). No significant differences were found between tenodesis and tenotomy subgroups, or between male and female patients. ICC values indicated excellent inter- and intra-observer reliability (0.84–0.91).

Conclusion: Patients with biceps tendinitis exhibit a narrower, deeper, and smaller bicipital groove compared to asymptomatic individuals, suggesting that groove morphology may represent a potential risk factor for tendon pathology. Volumetric analysis provides a novel and reliable tool for characterizing this anatomy. However, due to the limited sample size, group heterogeneity, and retrospective design, these results should be interpreted as preliminary and hypothesis-generating.

Keywords: Biceps tendinitis, tenodesis, tenotomy, volumetric analysis

INTRODUCTION

The long head of the biceps tendon (LHBT) plays an important role in shoulder function, but its exact contribution to glenohumeral stability remains debated.[1,2] While the tendon is a well-established dynamic stabilizer at the elbow, its biomechanical role at the shoulder has been reported variably, including humeral head depression, limiting excessive rotation, and supporting the biceps-labral complex.[3-5] Despite these theories, clinical evidence is inconclusive.

Pathologies of the LHBT are recognized as important causes of shoulder pain and dysfunction.[6,7] In younger patients, particularly athletes, isolated tendinopathy may occur, whereas in older adults, it is often associated with rotator cuff tears or subacromial impingement.[8,9] Clinical differentiation from rotator cuff disorders can be challenging due to overlapping features, but imaging plays a critical role in diagnosis.[10,11] LHBT-related pain may result from tendinopathy, instability, subluxation, dislocation, or pre-rupture changes.[2,12,13]

Although the etiology of biceps tendinitis is multifactorial, anatomical features of the bicipital groove have been proposed as contributing factors.[14-17] Narrow, deep, or steep-walled grooves may predispose the tendon to increased mechanical stress, instability, or degeneration.[2,18,19] However, most prior studies have focused on linear and angular morphometric parameters, and little is known about volumetric characteristics of the groove.[20,21]

The objective of this study was to evaluate and compare morphometric and volumetric features of the bicipital groove between patients with biceps tendinitis and asymptomatic controls. We hypothesized that patients with tendinitis

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would present with narrower, deeper grooves and reduced volumetric space, which may contribute to tendon pathology.

METHODS

Ethics

This retrospective radiological study was conducted in accordance with the principles of the Declaration of Helsinki and University of Health Sciences Ankara Health Researches and Application Center Medical Specialization Ethics Committee approved (Date: 29.11.2017, Decision No: 279). As part of routine clinical practice at our institution, all patients had previously provided general informed consent allowing the use of anonymized clinical and imaging data for research purposes. No additional procedures were performed for this study.

Patient Selection

The institutional shoulder arthroscopy database was reviewed for the period between January 2015 and December 2023. Patients who underwent surgical treatment for biceps tendon pathology (open subpectoral tenodesis or arthroscopic tenotomy) and who had both preoperative CT and MRI scans available were considered eligible.

The control group consisted of asymptomatic individuals who underwent shoulder CT and MRI for unrelated reasons (e.g., trauma screening, suspected instability, or other non-biceps-related indications). These individuals had no clinical or radiological evidence of biceps tendon or rotator cuff pathology, confirmed through medical records, physical examination, and radiological reports.

Exclusion Criteria

Patients were excluded if they had any of the following:

- Prior history of shoulder fracture or surgery,
- Labral pathology, adhesive capsulitis, or instability requiring surgery,
- Inflammatory arthritis or advanced glenohumeral osteoarthritis,
- Prior corticosteroid injection within the past 6 months,
- Poor-quality or incomplete imaging studies preventing reliable morphometric or volumetric analysis.

Radiological Assessment

Morphological assessment of the bicipital groove was performed using the following parameters: total opening angle (TOA), medial wall angle (MWA), groove width, groove depth, and groove volume. CT images were obtained with a slice thickness of 2.5 mm, and MRI images with a slice thickness of 4.0 mm. Measurements were taken at the axial level corresponding to the deepest portion of the Groove (**Figure 1**).

Volumetric Analysis

Groove volume was measured using OsiriX software (Pixmeo, Geneva, Switzerland). On axial CT and T1-weighted MRI sequences, the anatomical boundaries of the groove were manually traced slice-by-slice, and the software calculated groove volume in mm^3 (**Figure 2, 3**).

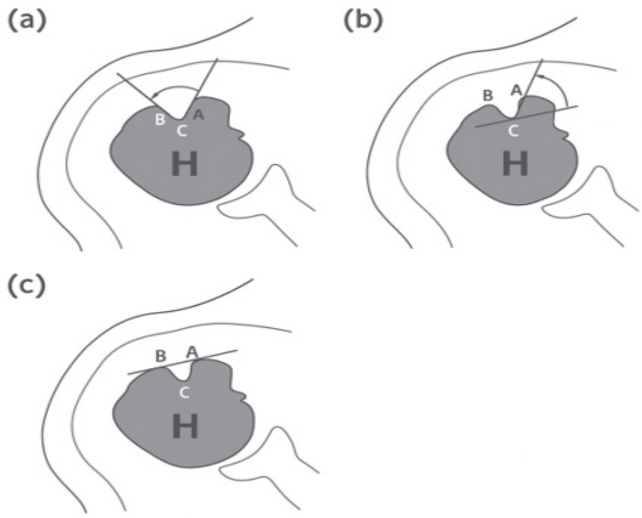

Figure 1. Tomographic measurements of the morphological structure of the bicipital groove

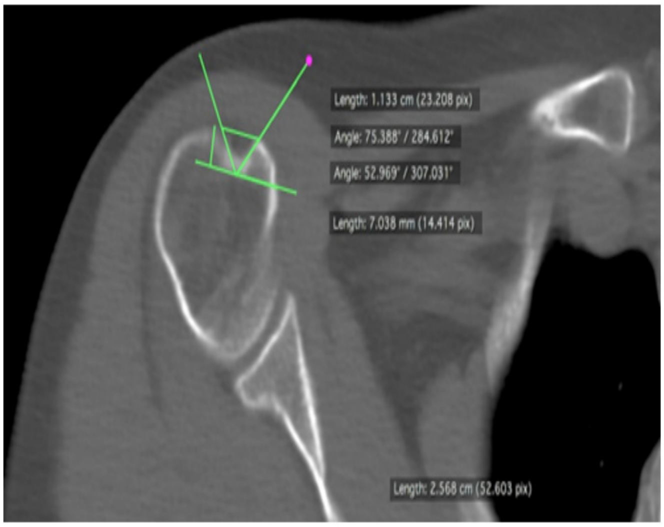

Figure 2. Measurement of the depth, width, TOA, and MWA of the bicipital groove of the 54-year-old female patient from the study group in axial CT
TOA: Total opening angle, CT: Computed tomography

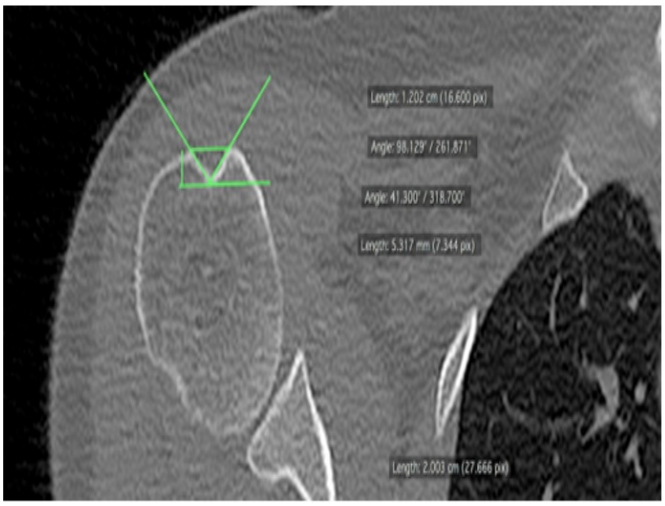

Figure 3. Measurement of the depth, width, TOA, and MWA of the bicipital groove of the 37-year-old female patient from the control group in axial CT
TOA: Total opening angle, MWA: Medial wall angle, CT: Computed tomography

- **Total opening angle (TOA):** The angle between the line (CB), which connects the highest point of the tuberculum majus and the deepest point of the bicipital groove, and the line (CA), which connects the highest point of the tuberculum minus and the deepest point of the bicipital groove.
- **Medial wall angle (MWA):** The angle between the line (CA) connecting the highest point of the tuberculum minus and the deepest point of the bicipital groove, and the line (C) passing through the deepest point of the bicipital groove and parallel to the line connecting the apex of the tuberculum majus to the tuberculum minus.
- **Bicipital groove depth:** The distance between line (C), passing through the deepest point of the bicipital groove, and line (BA), connecting the highest points of the tuberculum majus and tuberculum minus. Bicipital groove width: The span between the uppermost points of the tuberculum majus and tuberculum minus (BA).

Bicipital groove volume was measured using OsiriX imaging software (Pixmeo, Geneva, Switzerland). For consistent volumetric assessment on MRI, T1-weighted sagittal sequences, which provide better visualization of bone structures, were utilized. The anatomical boundaries of the bicipital groove were manually traced with the pencil tool on consecutive axial CT and axial T1-weighted MRI images, where both the greater and lesser tubercles were visible. After manual segmentation, the software automatically calculated the groove volume in cubic millimeters (mm^3), based on the outlined cross-sectional areas and respective slice intervals (**Figure 4**).

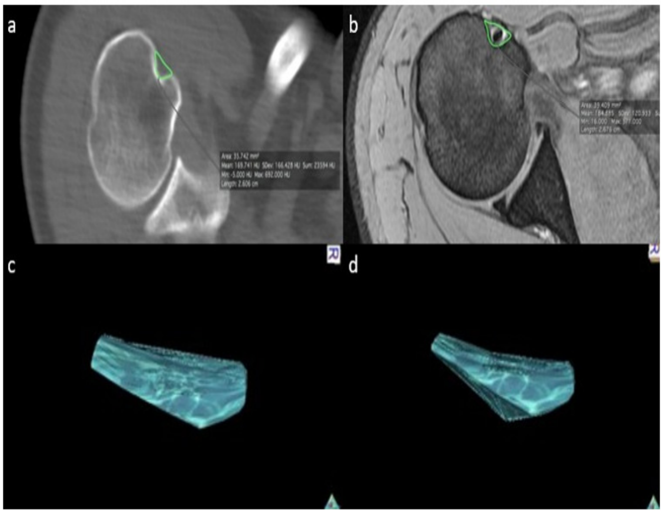

Figure 4. Volumetric assessment of a 51-year-old male patient from the study group. (**a**) On serial axial CT images, the cross-sectional area of the bicipital groove was outlined by manually tracing its anatomical boundaries using the pencil tool in OsiriX software. (**b**) A similar method was applied to axial T1-weighted MR images, with the boundaries of the groove marked on each slice where the greater and lesser tubercles were visible. Cross-sectional areas from all relevant slices were calculated, and the software then integrated these areas to determine the total bicipital groove volume in cubic millimeters (mm^3). (**c, d**) The final three-dimensional volumetric reconstructions from CT and MRI data, respectively, as rendered by the software
CT: Computed tomography, MRI: MRI: Magnetic resonance imaging

Observer Reliability

Radiological measurements were independently performed by one author blinded to patient identifiers and clinical information. To assess reproducibility, measurements were repeated by a second observer. Intra-rater reliability was evaluated by repeating all measurements six weeks later. Intraclass correlation coefficients (ICCs) with 95% confidence intervals were calculated to determine inter- and intra-observer reliability.

Statistical Analysis

The data analyses were performed using SPSS for Windows, version 30.0 (SPSS Inc., Chicago, IL, USA). Normality was tested using the Shapiro–Wilk test. Continuous variables were compared between groups using independent-samples Student's t-test. Pearson correlation coefficients were calculated to assess relationships between continuous parameters. A p-value of <0.05 was considered statistically significant. ICC values were classified as poor (<0.5), moderate (0.5–0.75), good (0.75–0.9), or excellent (>0.9).

RESULTS

A total of 126 patients underwent biceps tenotomy or tenodesis during the study period. Of these, 36 patients (24 females, 12 males; mean age 53 years, range 38–61; 20 right and 16 left shoulders) met the inclusion criteria and were included in the study group. Surgical procedures consisted of open subpectoral tenodesis in 22 patients and arthroscopic tenotomy in 14 patients (**Table 1**).

Table 1. Concomitant surgical procedures performed in the tenodesis group, tenotomy group, and overall study cohort

	Rotator cuff repair	Subacromial decompression	Acromioplasty	Total
Tenodesis	14	6	2	22
Tenotomy	12	10	4	14
All study groups	26	16	6	36

The control group included 66 asymptomatic individuals (42 females, 24 males; mean age 46 years, range 36–55; 34 right and 32 left shoulders) who underwent MRI and CT for reasons unrelated to biceps pathology. None had clinical or radiological evidence of biceps tendon or rotator cuff disease.

Morphometric and Volumetric Comparison

Compared with controls, the study group demonstrated (**Table 2**):

- Significantly narrower groove width (10.26±1.12 mm vs 11.62±1.08 mm, p=0.010),
- Greater groove depth (6.50±0.82 mm vs 5.52±0.76 mm, p=0.001),
- Smaller TOA (75.73°±6.45 vs 90.98°±5.93, p=0.001),
- Larger MWA (51.23°±4.32 vs 44.42°±4.11, p=0.001),

Table 2. A comparative analysis was performed between the study and control groups for bicipital groove width, depth, TOA, MWA, and volumetric measurements obtained from CT and MRI

Parameter	Study group	Control group	p value
Width (mm)	10.26	11.62	0.010
Depth (mm)	6.50	5.52	0.001
TOA (°)	75.73	90.98	0.001
MWA (°)	51.23	44.42	0.001
CT volume (mm^3)	0.704	0.918	0.001
MRI volume (mm^3)	0.623	0.794	0.001

TOA: Total opening angle, MWA: Medial wall angle, CT: Computed tomography, MRI: Magnetic resonance imaging. Statistically significant differences were observed between the two groups across all parameters

- Lower groove volumes on CT (0.704±0.081 mm^3 vs 0.918±0.094 mm^3, $p=0.001$) and MRI (0.623±0.067 mm^3 vs 0.794±0.082 mm^3, $p=0.001$).

Subgroup Analysis

- No significant differences were found between the tenodesis and tenotomy groups in any measured parameter (width, depth, TOA, MWA, CT volume, MRI volume; all $p>0.05$) (**Table 3**).

Table 3. A comparative analysis was performed between the tenodesis and tenotomy subgroups within the study cohort regarding bicipital groove width, depth, TOA, MWA, and CT- and MRI-derived volumetric measurements

Parameter	Tenodesis	Tenotomy	p value
Width (mm)	10.59	9.73	0.390
Depth (mm)	6.30	6.80	0.258
TOA (°)	78.24	71.78	0.135
MWA (°)	48.81	55.05	0.063
CT volume (mm^3)	0.685	0.734	0.618
MRI volume (mm^3)	0.602	0.655	0.390

TOA: Total opening angle, MWA: Medial wall angle, CT: Computed tomography, MRI: Magnetic resonance imaging. No statistically significant differences were found between the two groups across any of the assessed parameters

- No significant sex-based differences were detected in groove morphology (all $p>0.05$) (**Table 4**).

Table 4. A comparison between female and male participants in the study group was performed to assess differences in bicipital groove width, depth, TOA, MWA, and volumetric measurements derived from CT and MRI

Parameter	Female	Male	p value
Width (mm)	9.96	10.86	0.261
Depth (mm)	6.54	6.42	0.851
TOA (°)	73.86	79.45	0.190
MWA (°)	51.30	51.09	0.779
CT volume (mm^3)	0.676	0.761	0.399
MRI volume (mm^3)	0.653	0.653	0.574

TOA: Total opening angle, MWA: Medial wall angle, CT: Computed tomography, MRI: Magnetic resonance imaging. No statistically significant differences were found between the sexes in any of the parameters evaluated

Correlation Analysis

Pearson correlation analysis showed:

- Groove width correlated positively with TOA ($r=0.595$, $p<0.001$) and MRI-derived volume ($r=0.428$, $p=0.002$), and negatively with MWA ($r=-0.617$, $p<0.001$).
- Groove depth correlated positively with MWA ($r=0.373$, $p=0.007$) and negatively with TOA ($r=-0.643$, $p<0.001$).
- CT- and MRI-derived groove volumes showed a strong positive correlation ($r=0.746$, $p<0.001$).

Observer Reliability

Inter- and intra-observer reliability for groove measurements demonstrated excellent agreement (**Table 5**).

Table 5. Intraclass correlation coefficients (ICCs) for inter- and intra-observer reliability

Parameter	Inter-observer ICC (95% CI)	Intra-observer ICC (95% CI)
Width (mm)	0.89 (0.82–0.93)	0.91 (0.86–0.94)
Depth (mm)	0.87 (0.80–0.92)	0.90 (0.85–0.94)
TOA (°)	0.86 (0.78–0.91)	0.88 (0.82–0.93)
MWA (°)	0.84 (0.76–0.90)	0.87 (0.81–0.92)
CT volume (mm^3)	0.91 (0.86–0.95)	0.93 (0.89–0.96)
MRI volume (mm^3)	0.90 (0.85–0.94)	0.92 (0.88–0.95)

ICC: Intraclass correlation coefficient, TOA: Total opening angle, MWA: Medial wall angle, CT: Computed tomography, MRI: Magnetic resonance imaging

DISCUSSION

The most important finding of this study was that patients with biceps tendinitis exhibited a distinct bicipital groove morphology compared with asymptomatic controls, characterized by narrower width, greater depth, smaller TOA, larger MWA, and lower volumetric measurements. These consistent differences suggest that groove shape may play a role as a potential anatomical risk factor for the development of biceps tendon pathology.

Previous cadaveric and imaging studies have proposed that the geometry of the bicipital groove can influence tendon stability and gliding mechanics, but findings have remained inconclusive.[18,19] Our results provide further support to the hypothesis that a narrow and steep groove may act as a constraining structure, leading to increased mechanical stress, frictional forces, and instability during shoulder motion. Conversely, the wider and shallower grooves observed in the control group may facilitate smoother tendon movement and reduce loading stress.

A novel aspect of our study was the use of volumetric analysis in addition to conventional morphometric measurements. Volumetric assessment provided a comprehensive representation of the three-dimensional space available for the tendon. Importantly, groove volumes were consistently lower in patients with biceps tendon pathology on both CT and MRI, and volumetric measurements strongly correlated with linear and angular parameters. This reinforces the reliability of volumetric analysis and suggests that it may serve as an additional imaging biomarker in evaluating risk factors for tendon pathology.

Although no significant differences were found between the tenodesis and tenotomy subgroups, or between male and female patients, these negative results should be interpreted cautiously due to the limited sample size. The absence of surgical subgroup differences indicates that groove morphology is unlikely to be the primary determinant of surgical choice, but prospective studies with larger cohorts may clarify whether specific morphologies respond differently to surgical techniques.

Our findings are also in line with research on patient-specific morphology in other musculoskeletal regions. For instance, trochlear groove dysplasia in the knee has been associated with patellar instability, acetabular morphology with hip impingement, and facet joint orientation with spinal degeneration.[22-25] These parallels highlight the importance of anatomical variations across joints in predisposing to pathology. Applying a similar concept to the shoulder, the bicipital groove can be considered a morphological determinant of biceps tendon health.

Limitations

Nevertheless, the results should be interpreted within the context of the study's limitations. The retrospective design introduces potential selection bias, and the relatively small sample size, particularly in subgroup analyses, reduces statistical power. The presence of concomitant surgeries in the patient group is another confounding factor, making it difficult to isolate the effect of groove morphology. Furthermore, only basic statistical tests were applied, and no multivariate analysis was performed to control for additional variables. Manual segmentation for volumetric analysis may introduce observer variability, although excellent inter- and intra-observer reliability was demonstrated with high ICC values.

This study demonstrated that patients with biceps tendinitis exhibit distinct morphological characteristics of the bicipital groove compared with asymptomatic individuals. These include narrower width, greater depth, smaller TOA, larger MWA, and reduced volumetric space. Such features may contribute to altered tendon biomechanics and increased risk of pathology.

CONCLUSION

The addition of volumetric analysis provided a novel and reliable approach to characterizing groove anatomy, complementing conventional morphometric parameters. However, due to the small sample size, retrospective design, group heterogeneity, and confounding effects of concomitant surgeries, the findings should be regarded as preliminary and hypothesis-generating. Larger, prospective studies are required to confirm these associations and to clarify the clinical significance of bicipital groove morphology in biceps tendon disorders.

ETHICAL DECLARATIONS

Ethics Committee Approval

University of Health Sciences Ankara Health Researches and Application Center Medical Specialization Ethics Committee approved (Date: 29.11.2017, Decision No: 279).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors declare no conflicts of interest.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All authors declare that they have participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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