EJMI

DOI: 10.14744/ejmi.2019.16512
EJMI 2019;3(4):293–299

Research Article

Effects of Bicipital Groove Bony Morphology on the Stability of Long Head of the Biceps Tendon

Rasime Pelin Kavak,[1] Meltem Ozdemir,[1] Evrim Duman[2]

[1]Department of Radiology, University of Health Sciences Dışkapı Yıldırım Beyazıt Training and Research Hospital, Ankara, Turkey
[2]Department of Orthopedic and Traumatology, University of Health Sciences Dışkapi Yıldırım Beyazıt Training and Research Hospital, Ankara, Turkey

Abstract

Objectives: To investigate the bony morphologic characteristics of the bicipital groove and to determine their relations with the long head of the biceps tendon (LHBT) instability on magnetic resonance imaging (MRI).

Methods: The depth of the bicipital groove (DBG), the medial wall angle (MWA) and the total opening angle (TOA) were measured on the shoulder MRI of 536 patients with anterior shoulder pain. 450 patients with a normally-located LHBT determined stable LHBT, 86 patients with subluxation or dislocation of the LHBT determined unstable LHBT. We assessed the relationship between measurements and LHBT stability and analyzed the cut-off values of the measurements to identify the long head of the biceps tendon instability.

Results: The incidence of partial rotator cuff rupture, total rotator cuff tear, tendinosis and superior labral lesions were significantly higher in patients with unstable LHBT ($p<0.05$). In patients with unstable LHBT, DBG was shallower, medial wall angle was narrower and TOA was higher compared to those with stable LHBT. We recorded high sensitivity and specificities for the cut-off values of 5.65 mm for DBG 53.3° for MWA, and 87.1° for TOA to determine the presence of the unstable LHBT.

Conclusion: DBG, MWA and TOA can be used as stability criteria for LHBT.

Keywords: Bicipital groove, long head of the biceps tendon, magnetic resonance imaging, medial wall angle, groove depth, total opening angle

Cite This Article: *Kavak RP, Ozdemir M, Duman E. Effects of Bicipital Groove Bony Morphology on the Stability of Long Head of the Biceps Tendon. EJMI 2019;3(4):293–299.*

The disorder of the long head of the biceps tendon (LHBT) is a well-known source of anterior shoulder pain. LHBT pathologies occur because of the degeneration and friction between the anterosuperior and coracoacromial movement of the shoulder.[1, 2] This leads to partial or complete tearing of the biceps and tendinopathy, which leads to instability.[2] The bicipital groove is an important anatomic localization which plays a role in the stability of the LHBT. Although the importance of the bony morphology of the bicipital groove in LHBT pathologies has been studied, there has been a minimal discussion about LHBT pathologies.[3, 4] During surgical procedures for LHBT, it has been noted that some bicipital grooves are narrow and deep and some are wide and shallow, which may be asso-

Address for correspondence: Rasime Pelin Kavak, MD. Radyoloji Bolumu, Saglik Bilimleri Universitesi Diskapi Yildirim Beyazit Egitim ve Arastirma Hastanesi, Ankara, Turkey
Phone: +90 312 596 20 00 **E-mail:** drrpelindemir6@hotmail.com

Submitted Date: May 28, 2019 **Accepted Date:** July 09, 2019 **Available Online Date:** October 02, 2019

ciated with instability.[4]

In recent years, magnetic resonance imaging (MRI) has become a preferred diagnostic method for the evaluation of shoulder joint pathologies because of the detailed imaging of the structures around the joint.[5] And MRI is useful in demonstrating the position of LHBTs in the bicipital groove.

Hence, we aimed to investigate the relationship between bicipital groove bony morphology and LHBT instability and to determine the cut-off values of the depth of the bicipital groove (DBG), the medial wall angle (MWA) and the total opening angle (TOA).

Methods

Patient Population and Study Design

The clinical records of 1093 patients who admitted with anterior shoulder pain in orthopedic and traumatology department, and underwent a shoulder MRI examination between 1 January 2016, and 1 January 2019 were retrospectively reviewed.

The exclusion criteria were as follows: (1) a history of trauma; (2) history of surgery; (3) history of inflammatory arthritis.; (4) complete biceps tendon tear; (5) history of the tumour. After applying the exclusion criteria, 536 patients remained. 450 shoulders of the patients had a normally-located and 86 shoulders of the patients had subluxation or dislocation of LHBT in MRI. Patients were aged between 36 and 68 years old. The ethical compliance of this study was approved in accordance with the Helsinki Declaration by the Hospital Local Ethics Committee, Ankara, Turkey.

MRI Protocol and Morphometric Measurements

All MRI examinations was performed on a 1.5 T MRI scanner (Magnetom, Aera, Siemens, Erlangen, Germany) with standard shoulder wrap. Patients were in the supine position, with the arm at the side at a neutral position. MRI evaluations were performed on a picture archiving and communication system (Extreme PACS, Ankara, Turkey).

All studies were performed using the standard protocol, which included oblique coronal proton density images (2800/38; field of view [FOV] 14 cm; slice thickness 3.5 mm; intersection gap 0.4 mm; matrix 320 × 256), axial, oblique coronal, and oblique sagittal fat-suppressed T2- weighted images (3400/50; FOV, 14 cm; slice thickness, 3.5 mm; intersection gap, 0.4 mm; matrix, 256 × 256) and oblique sagittal T1-weighted images (780/15; FOV 14 cm; slice thickness 3.5 mm; intersection gap 0.4 mm; matrix 320 × 256). Neither intravenous nor intraarticular gadolinium-based contrast agents were used for any of the examinations.

In axial consecutively images, the change of the LHBT in the bicipital groove was evaluated. Normal LHBT means; LHBT was in the optimum anatomic position in the bicipital groove (Fig. 1 a–d). LHBT subluxation means; LHBT was located in the medial in the bicipital groove instead of normal anatomical position, but maintaining partial contact (Fig. 1 e–h).[6] LBHT dislocation means; LBHT was not located in the bicipital groove, it was identified medially (Fig. 1 ı–l).[6] Subluxation and dislocation of the LHBT were evaluated as unstable LHBT.[7]

As previously mentioned, DBG, MWA, TOA measurements were performed for each patient from the deepest location of the bicipital groove at the midline.[3] The depth of the bicipital groove (DBG); is the vertical distance from the deepest point of the bicipital groove to the line connecting the highest points of the greater and lesser tubercles (Fig. 2a). The medial wall angle (MWA) is; the angle between the lines connecting the deepest point of the bicipital groove to the highest points of the greater and lesser tubercles (Fig. 2b). The total opening angle (TOA); is the angle between the line connecting the deepest point of the bicipital groove to the highest points of the greater tubercle and the line connecting the deepest point of the bicipital groove to the highest points of the lesser tubercle (Fig. 2c). Angle measurements were made in degrees, length measurement in millimetres.

All measurements were performed by two radiologists with 12 and 6 years of experience in musculoskeletal imaging and in a blinded manner for the findings of each other. To test the intra-observer reliability, one of the radiologists repeated all measurements three months after the first assessment.

Statistical Analysis

Data were analysed using SPSS software (IBM SPSS 25.0, IBM Corporation®, Armonk, NY, USA). The intra-and inter-observer reliability of MRI examinations was tested using kappa statistics. Mean, standard deviation and percentages were used in descriptive statistics. Mann–Whitney U test was used to compare quantitative data, and Pearson's Chi-square test was used to compare qualitative data. Spearman correlation test was used for the correlations of the morphological changes of the unstable LHBT group. Logistic regression analysis was used to analyse the factors affecting the instability. Receiver operating characteristic (ROC) curve analysis was used to calculate the cut-off value (cut-off), specificity and sensitivity of the data. $P<0.05$ was considered statistically significant.

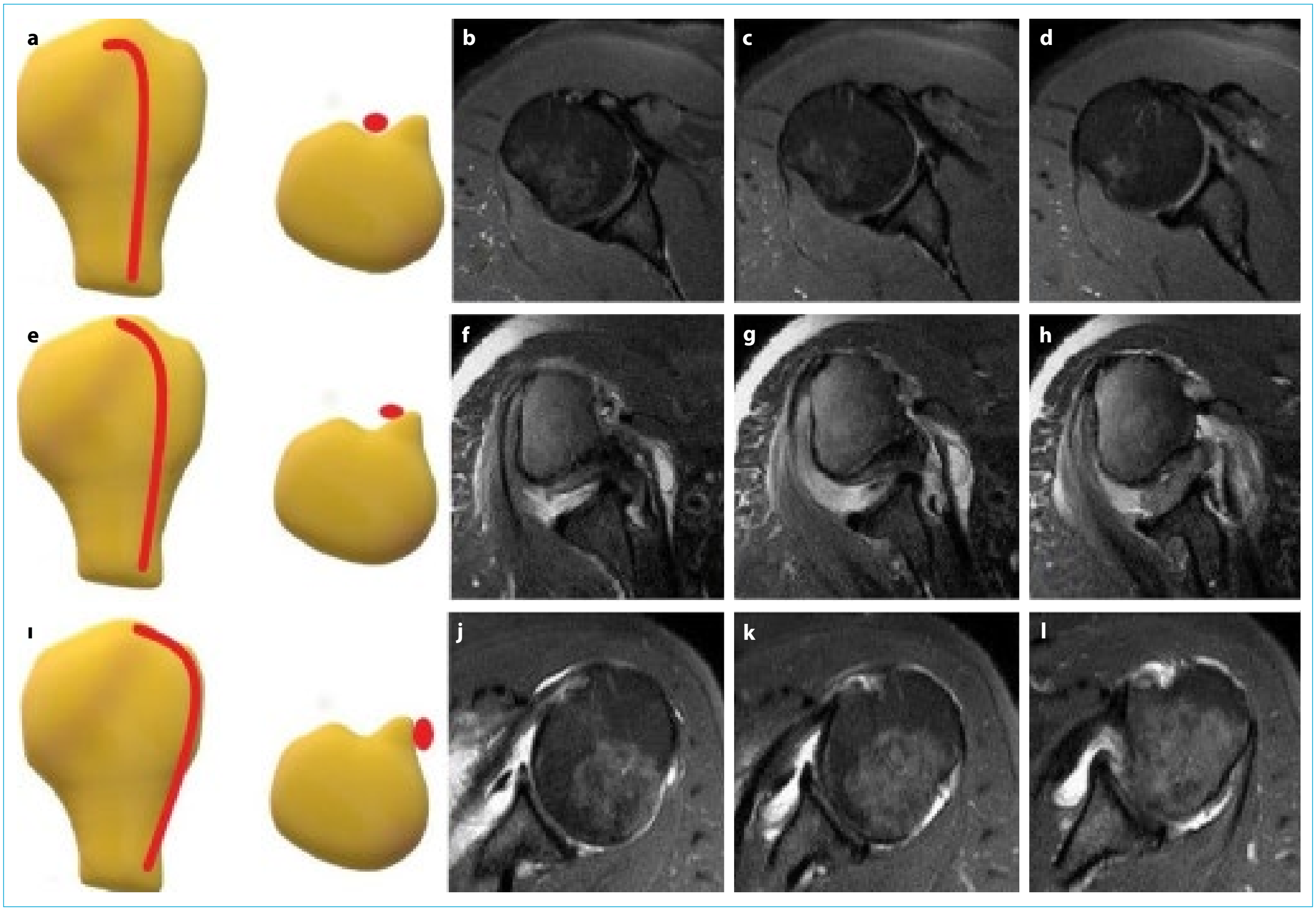

Figure 1. Illustrative shoulder figures demonstrate long head of the biceps tendon in the red line. Illustrative figures and axial magnetic resonance imaging sections through the bicipital groove of the patients with normal positioned **(a-d)**, subluxed **(e-h)**, and dislocated **(ı-l)** long head of the biceps tendon.

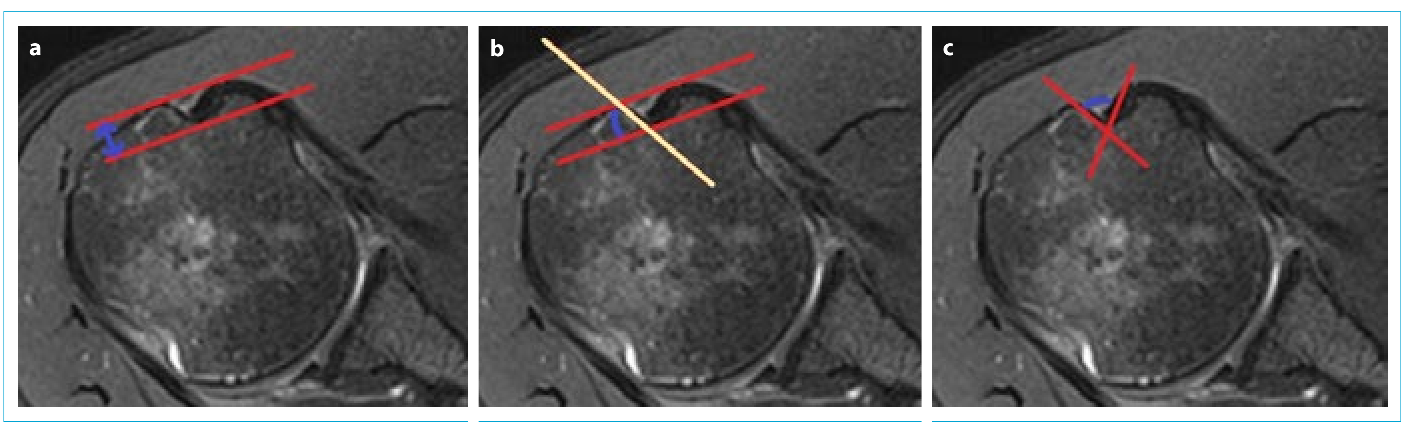

Figure 2. Axial magnetic resonance imaging sections through bicipital groove demonstrating the measurement methods of the bicipital groove depth **(a)** is the vertical blue distance between red lines, the medial wall angle **(b)** is the blue angle between the yellow line that cuts the parallel red lines and the total opening angle **(c)** is the blue angle between red lines.

Results

Demographic Data

There were 450 patients with stable and 86 with unstable LHBT. For patients with stable LHBT, 55.6% were female and 44.6% were male. For patients with unstable LHBT, 51.2% were female and 48.8% were male. There was no significant difference between the sex distributions of stable and unstable patient groups (p>0.05). The mean ages of the patients in the stable and unstable groups were 55.54±8.06

and 58.00±9.12, respectively. The mean age of the patients in the unstable group was significantly higher than that in the stable group (p<0.05).

Morphological Changes

The DBG, MWA and TOA values after MRI examination of the patients with stable and unstable LHBT were compared (Table 1). Results showed that the DBG of patients with unstable LHBT was lower, MWA was narrower and the TOA was significantly higher than those in the stable LHBT group (p<0.05). Table 2 shows that partial rotator cuff tear, total rotator cuff tear, tendinosis and superior labral lesions are seen more frequently in patients with unstable LHBT (p<0.05). However, the development of adhesive capsulitis and calcification did not differ significantly between groups (p>0.05). As shown in Table 3, the MWA of females with unstable LHBT is smaller than that in men (p<0.05). However, the DBG and TOA values did not show any significant changes (p>0.05). The frequency of pathological conditions in patients with unstable LHBT was examined according to their gender, and there was no significant difference (p>0.05; Table 4).

Correlation

As shown in Table 5, there was a positive correlation between the age and TOA values of patients with unstable LHBT (c>0, p<0.05). Depending on age, TOA increases.

Regression analyses

Logistic regression analysis was performed to determine

Table 1. Comparison of morphological data determined by MRI examination of patients with stable and unstable LHBT

	Stable (Mean±SD)	Unstable (Mean±SD)	Test	p
DBG	5.90±0.21	5.47±0.13	2520	<0.001
MWA	54.66±0.60	52.16±0.44	747	<0.001
TOA	83.61±10.30	86.27±6.34	13437	<0.001

Test: Mann-Whitney U, p<0.05 was considered significant. LHBT: long head of the biceps tendon; SD: standard deviation; DBG: bicipital groove depth; MWA: medial wall angle; TOA: total opening angle.

Table 2. Comparison of pathological data determined by MRI examination of patients with stable and unstable LHBT

	n	Stable n (%)	Unstable n (%)	Test	p
Partial rotator cuff tear					
None	450	386 (85.8)	65 (75.6)	5.626	0.018
Yes	86	64 (14.2)	21 (24.4)		
Total rotator cuff tear					
None	450	404 (89.8)	70 (81.4)	4.960	0.026
Yes	86	46 (10.2)	16 (18.6)		
Tendinosis					
None	450	358 (79.6)	33 (38.4)	62.055	<0.001
Yes	86	92 (20.4)	53 (61.6)		
Adhesive capsulitis					
None	450	418 (92.9)	82 (95.3)	0.697	0.404
Yes	86	32 (7.1)	4 (4.7)		
Calcification					
None	450	407 (90.4)	80 (93)	0.578	0.447
Yes	86	43 (9.6)	6 (7)		
Superior labral lesions					
None	450	407 (90.4)	62 (72.1)	22.231	<0.001
Yes	86	43 (9.6)	24 (27.9)		

Test: Mann-Whitney U; p<0.05 was considered significance. LHBT: long head of the biceps tendon.

Table 3. Evaluation of morphological characteristics of unstable patients according to gender

	Female (n=44)	Male (n=42)	Test	p
DBG (Mean±SD)	5.45±0.15	5.48±0.12	842.5	0.471
MWA (Mean±SD)	52.05±0.22	52.27±0.57	664	0.023
TOA (Mean±SD)	86.70±6.43	85.81±6.30	891	0.774

Test: Mann-Whitney U; p<0.05 was considered significance. DBG: bicipital groove depth; MWA: medial wall angle; TOA: total opening angle.

Table 4. Comparison of pathological data determined by MRI examination of patients with unstable LHBT

	n	Female (n, %)	Male (n, %)	Test	P
Partial rotator cuff tear					
None	65	32 (49.2)	33 (50.8)	0.398	0.528
Yes	21	12 (57.1)	9 (42.9)		
Total rotator cuff tear					
None	70	36 (51.4)	34 (48.6)	0.011	0.918
Yes	16	8 (50)	8 (50)		
Tendinosis					
None	33	16 (48.5)	17 (51.5)	0.154	0.695
Yes	53	28 (52.8)	25 (47.2)		
Adhesive capsulitis					
None	82	41 (50)	41 (50)	0.954	0.329
Yes	4	3 (75)	1 (25)		
Calcification					
None	80	43 (53.8)	37 (46.3)	3.072	0.080
Yes	6	1 (16.7)	5 (83.3)		
Superior labral lesions					
None	62	31 (50)	31 (50)	0.120	0.729
Yes	24	13 (54.2)	11 (45.8)		

Test: Mann-Whitney U; p<0.05 was considered significance. LHBT: long head of the biceps tendon.

the factors that directly affected the instability (Table 6). It was determined that DBG and MWA alone had an effect on instability (p<0.05). When we evaluated the likelihood ratio, DBG and MWA were <0.001 and 0.015, respectively.

Table 5. Evaluation of the correlation between the morphological characteristics of unstable patients according to their age

	Age
DBG	
r	-0.127
p	0.242
MWA	
r	0.053
p	0.628
TOA	
r	0.221
p	0.041

Spearman correlation test; p<0.05 was considered significant; r>0: positive; r<0: negative correlation; DBG: bicipital groove depth; MWA: medial wall angle; TOA: total opening angle.

Table 6. Logistic regression analysis of factors affecting instability

	Variables in the Equation					
	B	S.E.	Wald	df	Sig.	Exp. [B]
Age	-0.086	0.066	1.692	1	0.193	0.917
Partial rotator cuff tear	-0.221	1.374	0.026	1	0.872	0.802
Total rotator cuff tear	-0.106	1.581	0.004	1	0.947	0.900
Tendinosis	2.651	1.438	3.398	1	0.065	14.162
Superior labral lesions	2.844	2.176	1.709	1	0.191	17.187
DBG	-20.505	5.451	14.148	1	<0.001	<0.001
MWA	-4.212	.986	18.254	1	<0.001	0.015
TOA	0.052	.067	0.612	1	0.434	1.053
Constant	336.662	80.946	17.298	1	<0.001	1.623E+146

B: regression coefficient; standard error of the coefficient; Sig.: significant; Exp [B]; explanasial regression coefficient. DBG: bicipital groove depth; MWA: medial wall angle; TOA: total opening angle.

Cut-off value

The cut-off value of DBG was determined to be 5.65 mm, with 87.6% sensitivity and 86.5% specificity. The cut-off value of MWA was determined to be 53.3°, with 98.7% sensitivity and 97.7% specificity. The cut-off value of TOA was determined to be 87.1°, with 40% sensitivity and 70.9% specificity, the DBG values were below 5.65 mm, the MWA values were below 53.3° and the TOA values were above 87.1° (Fig. 3 and Table 7).

Intra- and Inter-Observer Reliability Assessment

Intra and interobserver intraclass correlation coefficients for all quantitative and semi-quantitative measurements were 0.81 and 0.89, respectively.

Discussion

In our study, we showed that patients with unstable LHBT can be identified radiologically by observing changes in bicipital groove bony morphology such as DBG, MWA and TOA. The high sensitivity and specificity for differentiation of LHBT patients according to stability and instability showed the importance of the morphological characteristics in defining LHBT pathologies. The LHBT is deep in the bicipital groove under normal conditions, and LHBT height is less than the DBG.[8] The superior glenohumeral ligament, the subscapularis and supraspinatus tendons are known as the main stabilisers, and the contours of the bicipital tuberosity also help in keeping the LBHT in the bicipital groove. [9, 10]

Anatomical variations in the bicipital groove may cause the LHBT to shift.[11] LHBT instability can result in both subluxation and dislocation. Although isolated biceps instability has been reported in previous studies, most agree that the relationship between biceps tendon instability and injury to the rotator cuff is unclear.[12] Although some studies show differences between patients in different parts of the world, the normal range is 4–5.1 mm for DBG 47°–56° for MWA and 78°–87° for TOA.[3, 8, 11, 13–15] Yoo et al.[16] reported that the DBG in patients with unstable LHBT was shallower, MWA was narrower and TOA was larger than those in patients with stable LHBT. In another study, Urita et al.[17] found

Table 7. Evaluation of area, cut off, sensitivity and specify of DBG, MWA and TOA values

	Area	Asymptotic 95% Lower Bound	Confidence Interval Upper Bound	Cut-off	Sensitivity	Specificity
DBG	0.935	0.915	0.955	5.65	% 87.6	% 86.5
MWA	0.981	0.964	0.998	53.3	% 98.7	% 97.7
TOA	0.347	0.301	0.394	87.1	% 40	% 70.9

DBG: bicipital groove depth; MWA: medial wall angle; TOA: total opening angle.

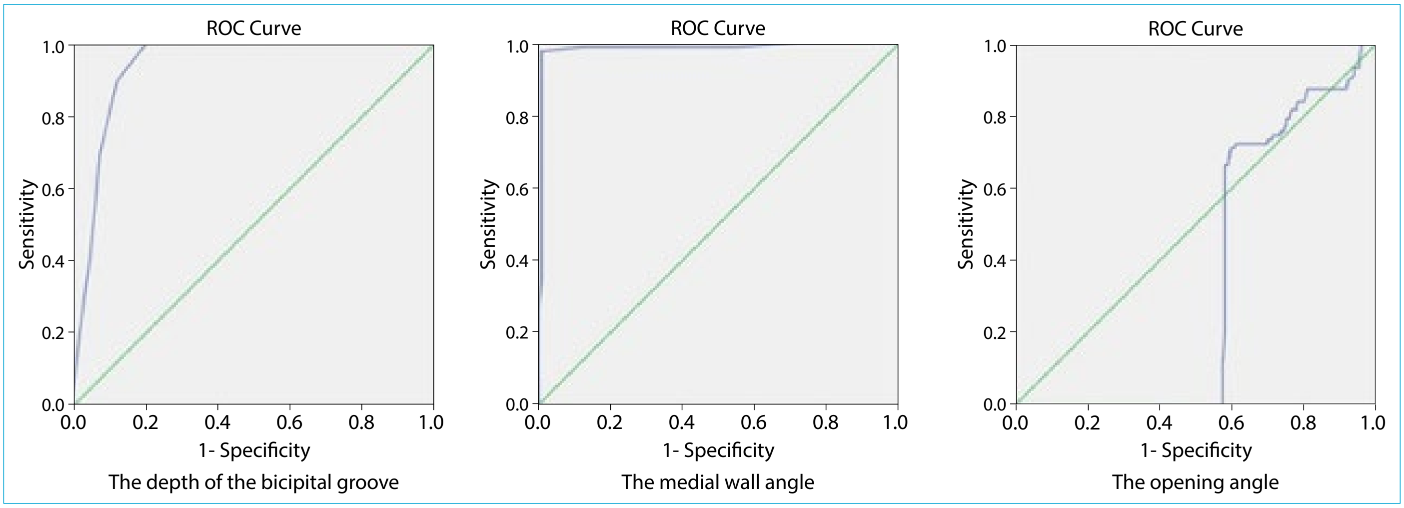

Figure 3. ROC curves for the measurements of the depth of the bicipital groove, the medial wall angle and the total opening angle.

out that patients with shallower DBG had greater incidence and amount of injury. Similarly, Pfahler et al.[18] suggested that, when DBG was lower than 2 mm, MWA was narrower and TOA was less than 80°, it was considered an LHBT pathology. However, that study did not provide information about stability. Furthermore, Spritzer et al.[19] reported a strong correlation between bicipital groove morphology and LHBT instability. By contrast, the study by Abbound et al. indicated that bicipital groove morphology was unrelated to LHBT pathologies.[3] In the present study, we found out that DBG was lower, MWA was narrower and TOA was larger in the unstable LHBT group when compared to the stable LHBT group. Importantly, logistic regression analyses in the current study found that DBG and MWA alone could affect the stability of LHBT. In addition, the current study demonstrated that gender should be prioritised in the radiological evaluation because MWA in women was narrower than that in men. We believe that stabilising LHBT in the bicipital groove leads to instability because of the continued dislocation of LHBT.

Beall et al.[20] indicated that the sensitivity of MRI was 52%. Zanetti et al.[21] showed that the sensitivity of MRI could be increased up to 90% with arthrography. Although Malavolta et al. showed that the sensitivity of MRI was 67% and specificity was 98%, for the detection of instability, specificity was 72% and sensitivity was 53%.[22] They stated that the synovial distension in the bicipital groove and shoulder rotation decreased the sensitivity to instability.[22] However, the sensitivity (87.6%, 98.7% and 40%) and specificity (86.5%, 97.7% and 70.9%) of DBG, MWA and TOA, respectively, were significantly higher in the current study. We believe that these parameters can be safely used in the evaluation of LHBT stability. One of the more significant findings that emerge from this study is the determination of the cut-off values of DBG, MWA and TOA. It was observed that DBG values below 5.65 mm, MWA values less than 53.3° and TOA values more than 87.1° may be important criteria in the evaluation of stability. The current findings add to a growing body of literature on bicipital groove bony morphology and LHBT instability.

Finally, disorders in the LHBT can be associated with many other shoulder pathologies, including inflammation and hypertrophy or stenosis of the bicipital groove. These have been reported to have an effect on stabilisation.[23] Yoo et al.[16] demonstrated that tendonitis, infections and partial or complete tear of the cuff may contribute to the development of LHBT instability. Another study conducted by Urita et al. stated that subscapularis rupture has an effect on LHBT stability.[17] In our study, the incidences of a partial cuff tear, complete cuff tear, tendinosis and superior labral lesions were significantly higher in patients with unstable LHBT. Abnormal processes such as infection developing in the region and damage to the anatomical structures responsible for stabilisation may lead to increased degeneration and abnormal movement of tendons.[24]

On the basis of the results of this study, it was found that bicipital groove bony morphology had an important effect on the development of LHBT pathologies. The high levels of sensitivity and specificity of DBG, MWA and TOA suggested that these parameters could be used as criteria for LHBT stability.

The major limitation of the current study is that because of the retrospective study design, the optimization of the arm position of the patients in the magnet was not possible. Our second limitation was that all measurements we performed only static instability assessment. Further prospective and dynamic studies with large series are needed to validate the cut-off values we obtained in our study.

Conclusion

Our findings suggest that DBG, MWA and TOA can be used as stability criteria for long head of the biceps tendon.

Disclosures

Ethics Committee Approval: The University of Health Sciences Dıskapi Yıldırım Beyazit Training and Research Hospital, Ankara, Ethics Committee granted approval for this study on September 10, 2018, no: 54/03.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – R.P.K.; Supervision – M.O.; Materials – E.D., R.P.K., M.O.; Data collection &/or processing – E.D., R.P.K., M.O.; Analysis and/or interpretation – R.P.K., M.O.; Literature search – R.P.K., E.D.; Writing – R.P.K.; Critical review – M.O., E.D.

References

1. Baggio M, Martinelli F, Netto MB, Martins RO, da Cunha RC, Stipp WN. Evaluation of the results from arthroscopic tenodesis of the long head of the biceps brachii on the tendon of the subscapularis muscle. Rev Bras Ortop 2016;51:157–62.[CrossRef]
2. Szabó I, Boileau P, Walch G. The proximal biceps as a pain generator and results of tenotomy. Sports Med Arthrosc Rev 2008;16:180–6. [CrossRef]
3. Abboud JA, Bartolozzi AR, Widmer BJ, DeMola PM. Bicipital groove morphology on MRI has no correlation to intra-articular biceps tendon pathology. J Shoulder Elbow Surgery 2010;19:790–4. [CrossRef]
4. Lee HI, Shon MS, Koh KH, Lim TK, Heo J, Yoo JC. Clinical and radiologic results of arthroscopic bíceps tenodesis with suture anchor in the setting of rotador cuff tear. J Shoulder Elbow Surg 2014;23:e53–e60. [CrossRef]
5. Houtz CG, Schwartzberg RS, Barry JA, Reuss BL, Papa L. Shoulder MRI accuracy in the community setting. J Shoulder Elbow Surg 2011;20:537–42. [CrossRef]
6. Walch G, Nove-Josserand L, Boileau P, Levigne C. Subluxations and dislocations of the tendon of the long head of the biceps. J Shoulder Elbow Surg 1998;7:100–8. [CrossRef]
7. Khil EK, Cha JG, Yi JS, Kim HJ, Min KD, Yoon YC, et al. Detour sign in the diagnosis of subluxation of the long head of the biceps tendon with arthroscopic correlation. Br J Radiol 2017;90:20160375. [CrossRef]
8. Rajani S, Man S. Review of bicipital groove morphology and its analysis in North Indian Population. ISRN Anat 2013;243780.
9. Gleason PD, Beall DP, Sanders TG, Bond JL, Ly JQ, Holland LL, et al. The transverse humeral ligament: a separate anatomical structure or a continuation of the osseous attachment of the rotator cuff ? Am J Sports Med 2006;34:72–7. [CrossRef]
10. Arunkumar K, Manoranjitham R, Delhi Raj U, Shalini R. Morphometric study of Bicipital groove in South Indian population and its clinical implications. Int J Anat Res 2016;4:2187–91. [CrossRef]
11. Wafae N, Santamaría LEA, Vitor L, Pereira LA, Ruiz CR, Wafae GC. Morphometry of the human bicipital groove (sulcus intertubercularis). J Shoulder Elbow Surg 2010;19:65–8. [CrossRef]
12. Eakin CL, Faber KJ, Hawkins RJ, Hovis WD. Biceps tendon disorders in athletes. J Am Acad Orthop Surg 1999;7:300–10.
13. Cone RO, Danzig L, Resnick D, AB Goldman. The bicipital groove: radiographic, anatomic, and pathologic study. AJR Am J Roentgenol 1983;141:781–8. [CrossRef]
14. Murlimanju BV, Prabhu LV, Pai MM, Shreya M, Prashanth KU, Kumar CG, et al. Anthropometric study of the bicipital groove in indians and its clinical implications. Chang Gung Med J 2012;35:155–9. [CrossRef]
15. Arquez HF. Morphological Study of Palmaris Longus Muscle. Int Arch Med 2017;10:215. [CrossRef]
16. Yoo JC, Iyyampillai G, Park D, Koh KH. The influence of bicipital groove morphology on the stability of the long head of the biceps tendon. J Orthop Surg 2017;25:2309499017717195.
17. Urita A, Funakoshi T, Amano T, Matsui Y, Kawamura D, Kameda Y, et al. Predictive factors of long head of the biceps tendon disorders-the bicipital groove morphology and subscapularis tendon tear. J Shoulder Elbow Surg 2016;25:384–9. [CrossRef]
18. Pfahler M, Branner S, Refior HJ. The role of the bicipital groove in tendopathy of the long biceps tendon. J Shoulder Elbow Surg 1999;8:419–24. [CrossRef]
19. Spritzer CE, Collins AJ, Cooperman A, Speer KP. Assessment of instability of the long head of the biceps tendon by MRI. Skeletal Radiol 2001;30:199–207. [CrossRef]
20. Beall DP, Williamson EE, Ly JQ, Adkins MC, Emery RL, Jones TP, et al. Association of biceps tendon tears with rotator cuff abnormalities: degree of correlation with tears of the anterior and superior portions of the rotator cuff. AJR Am J Roentgenol 2003;180:633–9. [CrossRef]
21. Zanetti M, Weishaupt D, Gerber C, J Hodler. Tendinopathy and rupture of the tendon of the long head of the biceps brachii muscle: evaluation with MR arthrography. AJR Am J Roentgenol 1998;170:1557–61. [CrossRef]
22. Malavolta EA, Assunção JH, Guglielmetti CL, de Souza FF, Gracitelli ME, Ferreira Neto AA. Accuracy of preoperative MRI in the diagnosis of disorders of the long head of the biceps tendon. Eur J Radiol 2015;84:2250–4. [CrossRef]
23. Khazzam M, George MS, Churchill RS, Kuhn JE. Disorders of the long head of biceps tendon. J Shoulder Elbow Surg 2012;21:136–45. [CrossRef]
24. Matzon JL, Graham JG, Penna S, Ciccotti MG, Abboud JA, Lutsky KF, et al. A Prospective Evaluation of Early Postoperative Complications After Distal Biceps Tendon Repairs. J Hand Surg Am 2019;44:382–6. [CrossRef]