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ORIGINAL ARTICLE

Radiological and clinical evaluation of long head of biceps tendon function in the glenohumeral joint

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ABSTRACT

Objectives: The aim of the study was to investigate the relationship between biceps pathologies and radiological measurements in massive rotator cuff tears treated arthroscopically.

Patients and methods: Between December 2015 and December 2018, a total of 145 patients (56 males, 89 females; mean age: 62.2±9.7 years; range, 28 to 87 years) with supraspinatus and/or infraspinatus full-thickness tear larger than 3 cm and who underwent arthroscopic rotator cuff repair were retrospectively analyzed. Biceps pathologies detected during arthroscopy were divided into four groups. Group 1: biceps tendinitis or without biceps pathology; Group 2: biceps partial/degeneration tear; Group 3: biceps dislocation/instability; Group 4: complete biceps head rupture. Radiological measurements were calculated from the preoperative magnetic resonance imaging and anteroposterior X-ray images of the patients.

Results: A total of 65.5% of the lesions were on the right arm and 34.5% were on the left arm. All patients had posterior superior rotator cuff tears which could be surgically repaired. A total of 22.1% of the patients had no biceps tendinitis/biceps pathology, 20.7% had biceps instability/dislocation, 28.3% had biceps degeneration/partial rupture, and 29% of patients had biceps total rupture. Patients in Group 4 had a statistically significantly higher superior migration of the humeral head distance (p=0.012) than Group 2, and patients in Group 2 had a statistically significantly higher coracohumeral distance (p=0.042) than patients in Group 4. There was no significant difference in the other measurements among the groups.

Conclusion: The long head of the biceps, of which function has not yet been clearly elucidated, is one of the superior and anterior stabilizing forces of the humeral head.

Keywords: Biceps pathology, coracohumeral distance, rotator cuff, superior humeral migration.

The biomechanics of the glenohumeral joint is achieved by the interaction of both static and dynamic stabilizing structures. Static stabilizers are bone anatomy, intra-articular negative pressure, joint capsule, and glenoid labrum. Dynamic stabilizers include the rotator cuff muscles and other muscle structures surrounding the shoulder joint. Although the function and biomechanics of the rotator cuff muscles are known, the function and biomechanics of the long head of biceps tendon (LHBT) have not been fully clarified, yet.[1]

Biceps long head tendon rupture has been described in the literature as a possible source of shoulder pain.[2] Although it is known that the function of the biceps brachii is forearm supination, there are still debates regarding the function of the LHBT. Itoi et al.[3] showed that the LHBT stabilized the humeral head anteriorly during the abduction and external rotation position. Pagnani et al.[4] reported that the multicentric movement of the humeral head in all directions decreased, when they applied a 55-Newton load to the LHBT. Since the loads applied to the LHBT in the studies are not physiological, the biomechanics and function of the tendon have not been fully elucidated. The LHBT pathologies can be separated as conditions with and without rotator

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cuff pathologies.[5] Isolated LHBT lesions are divided into three main classifications: tendinitis, instability, and rupture.[6] While the joint anatomy may affect the formation of these pathologies, there may also be changes in joint biomechanics and stabilization due to the occurring pathologies.

In the present study, we aimed to radiologically contribute to the clinical understanding of the biomechanical role of the LHBT, of which clinical function is not sufficiently understood and to perform radiological measurements related to shoulder joint morphology.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Necmettin Erbakan University Meram Medical Faculty, Department of Orthopedics and Traumatology between December 1st, 2015 and December 31st, 2018. Magnetic resonance imaging (MRI), X-ray scans, and arthroscopy video archives of 650 patients who underwent shoulder arthroscopy were evaluated. A total of 145 patients (56 males, 89 females; mean age: 62.2±9.7 years; range, 28 to 87 years) who met the inclusion criteria (patients with supraspinatus and or infraspinatus full-thickness tear larger than 3 cm and who underwent arthroscopic rotator cuff repair) were included. Exclusion criteria were as follows: patients with subscapularis tears, patients with shoulder instability, patients with superior labral anterior posterior (SLAP) lesion (since SLAP lesions would affect biceps measurements), patients with advanced shoulder arthritis, patients with an unrepairable tear, and patients with additional shoulder pathology. The patient group of our study consisted of patients with large supraspinatus and or infraspinatus tears that could be repaired arthroscopically. We chose this patient group, in particular, as it is a patient group that is frequently seen in arthroscopic shoulder surgery and is a group that is associated with different biceps pathologies.

FIGURE 1. Group 1 normal/solid biceps appearance.

Long head of biceps tendon pathologies detected during arthroscopy were divided into four groups. Group 1 (normal/tendinitis) consisted of 32 (22%) patients (Figure 1), Group 2 (degenerated/partial tear) of 41 (28.3%) patients (Figure 2), Group 3 (unstable/dislocated) of 30 (20.7%) patients (Figure 3), and Group 4 (totally ruptured) of 42 (29%) patients (Figure 4).

Acromiohumeral distance (AD), critical shoulder angle (CSA), coracohumeral distance (CD), acromial index (AI), humeral head diameter/glenoid length ratio measurements were made using preoperative MRI and true anteroposterior X-ray images.

Acromiohumeral distance: AD was first described by Golding.[7] It is determined by measuring the closest groove of the acromion and humerus in T1 sections of the preoperative coronal, sagittal-oblique

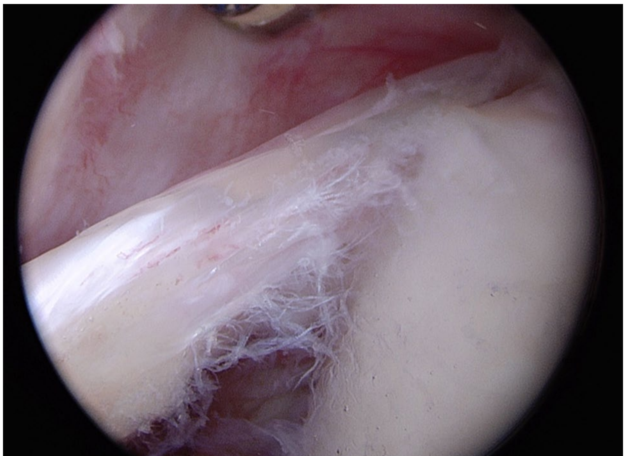

FIGURE 2. Group 2 biceps lesion (degenerated tear).

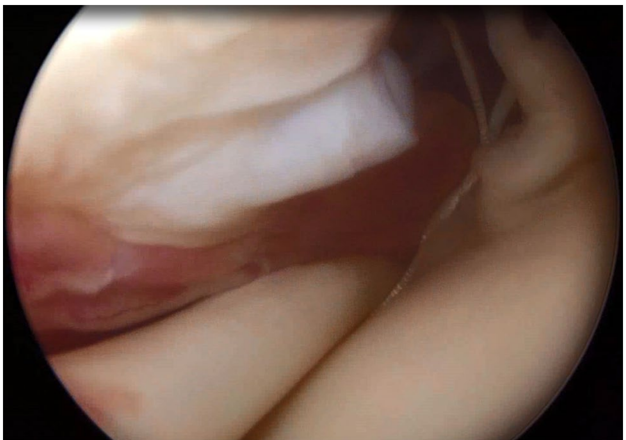

FIGURE 3. Group 3 biceps lesion (unstable biceps).

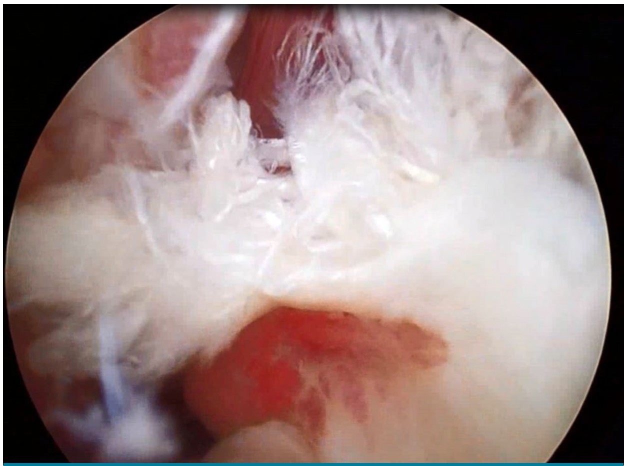

FIGURE 4. Group 4 lesion of the long head of the biceps (total ruptured stump appearance).

FIGURE 5. Acromiohumeral distance.

MRI scans (Figure 5). Distance measurement between 7 to 13 mm was accepted as normal on the shoulder radiograph.

Coracohumeral distance: Gerber et al.[8] used CD to describe subacromial impingement syndrome. It is determined by measuring the shortest distance between the coracoid process and the tuberculum minus in the T1 axial and sagittal-oblique images of the preoperative MRI scans of the patients (Figure 6).

Acromial Index: AI was described by Nyffeler et al.[9] It is the ratio of the distance between the line passing through the upper and lower parts of the glenoid and the lateral prominence of the acromion, and the length connecting the upper and lower bony prominences of the glenoid to the tuberculum majus in the true anteroposterior shoulder radiograph (Figure 7).

Critical shoulder angle: Moor et al.[10] described CSA in 2013. The angle formed by the line passing through the upper and lower parts of the glenoid

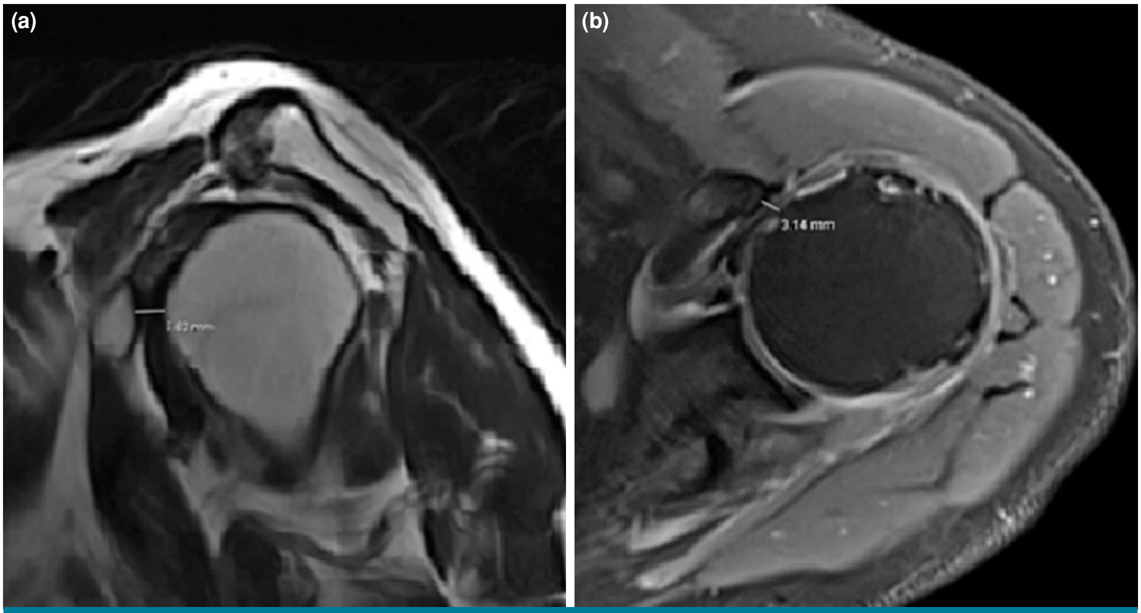

FIGURE 6. Coracohumeral distance: **(a)** Sagittal-oblique section, **(b)** axial section.

and the line passing from under the glenoid to the lateral part of the acromion in the actual anterior-posterior radiograph of the shoulder creates the angle (Figure 8). Since this angle would vary with the position of the scapula during X-ray, it must be calculated exactly on the true anteroposterior radiograph.[10,11]

Superior migration of the humeral head (SMHH): It was first described by Golding.[7] In T1-weighted MRI sagittal sections, during neutral rotation with the patient in the supine position, SMHH is determined by measuring the distance from the center of the glenoid articular surface and the humeral head (Figure 9).[12,13]

The ratio of the upper and lower lengths of the humeral head and glenoid (H/G): This ratio has not yet been used in the literature. In our study, we calculated the distance ratio between the diameter of the humeral head and the superior-inferior of the glenoid to measure the LHBT migration distance from the glenoid origin in the sagittal shoulder MRI (Figure 10). We used this measurement to answer the following question; Does the larger diameter of the humeral head compared to the glenoid effect the tension of the LHBT and pave the way for the formation of biceps pathologies?

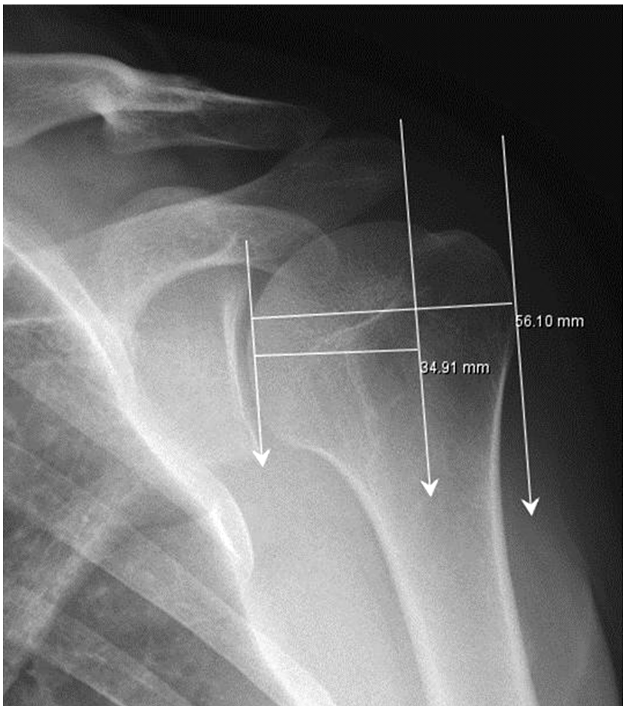

FIGURE 7. Acromial Index.

Arthroscopic procedure

Standard shoulder arthroscopy was performed in all patients in the lateral decubitus position with a 20 to 30° angle posteriorly and the arm positioned in 45° abduction and 15° flexion by applying longitudinal traction. The posterior portal was used as the imaging portal. Intra-articular pathologies were intervened through the anterior portal and the rotator interval. Biceps long head tendon pathologies were evaluated. Tenodesis was applied to biceps pathologies (extensive tendinitis, degenerated tear, instability) under 50 years, and tenotomy was applied to other patients. The posterior and or superior cuff tear was repaired with tendon-tendon/tendon-bone

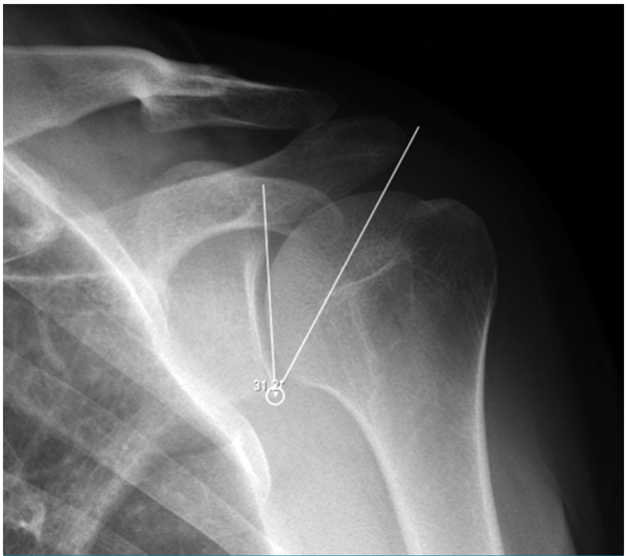

FIGURE 8. Critical shoulder angle.

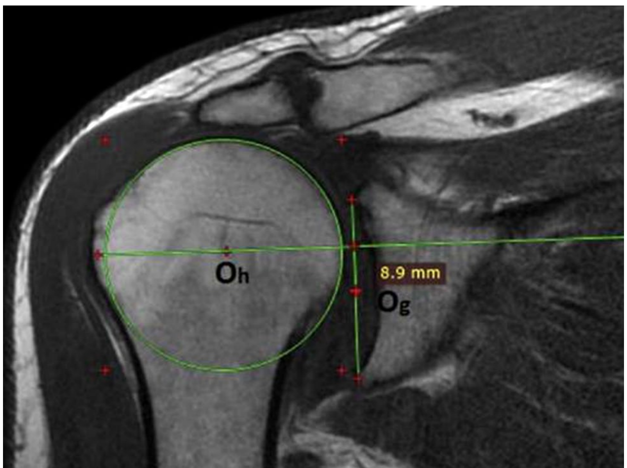

FIGURE 9. Superior migration of the humeral head.[13]

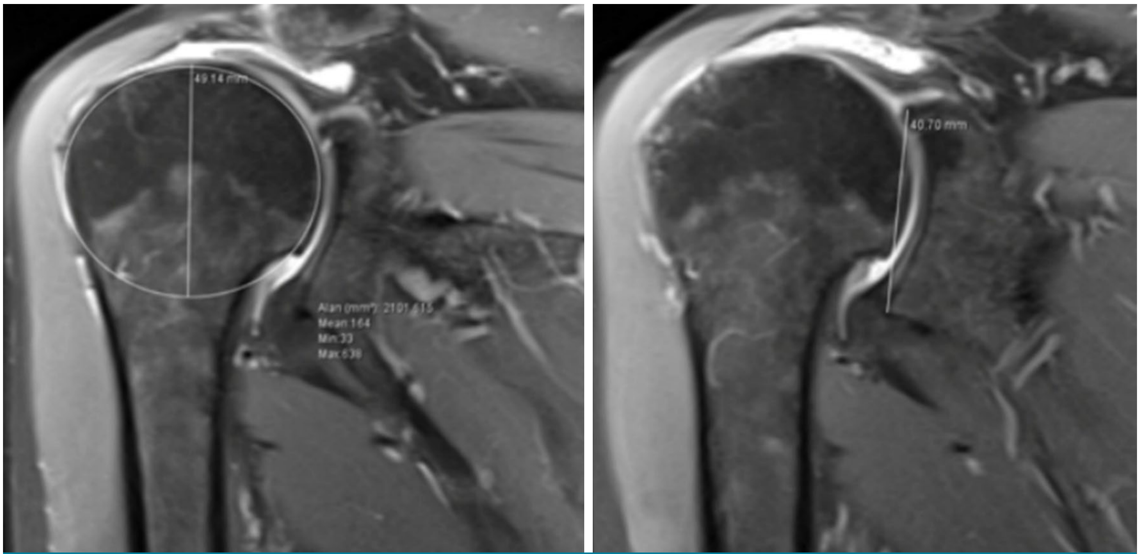

FIGURE 10. Humeral head and glenoid articular surface superior inferior ratio.

or tendon/bone sutures according to the tears' shape. Long head of biceps tendon pathologies observed during arthroscopy were recorded and classified.

Statistical analysis

Statistical analysis was performed using the SPSS version 18.0 software (SPSS Inc., Chicago, IL, USA). Continuous data were expressed in mean ± standard deviation (SD) or median (min-max), while categorical data were expressed in number and frequency. The relationship between categorical data was analyzed using the chi-square test. Comparisons for the normally distributed numerical data were made using the one-way analysis of variance (ANOVA) and Student t-test. The Mann-Whitney U test and Kruskal-Wallis test were used, if numerical data were not normally distributed. The groups that had a significant difference in the Kruskal-Wallis test were determined regarding the cause by using the Dunn-Bonferroni post-hoc test. The Pearson and Spearman rho correlation analyses were used to identify the direction and magnitude of the relationship between numerical variables. A p value of <0.05 was considered statistically significant.

RESULTS

The lesion was on the right arm in 95 (65.5%) of the patients and on the left arm in 50 (34.5%) patients. Biceps pathologies in addition to the rotator cuff disease in the patients are given in detail in Table I.

The mean duration of complaints was 17.7±35.4 (range, 0.5 to 240) months. The data of the measurements calculated from the radiological images of the patients are given in Table II.

According to the biceps pathology groups, the mean SMHH was 3.9±1.1 in Group 1, 3.3±1.3 in Group 2, 4.1±1.3 in Group 3, and 4.5±1.9 in Group 4. When biceps pathology groups were compared, a statistically significant difference was found among the groups regarding SMHH (p=0.009). As a result of the post-hoc analyses made to identify which group/groups the difference originates from, the patients in Group 4 (with biceps rupture) had a significantly higher SMHH distance (p=0.012) than patients in Group 2 (with biceps degeneration/tear) (Table III, Figure 11).

TABLE I
Demographic data of patients

	n	%
Sex		
Female	89	61.4
Male	56	38.6
Side		
Right	95	65.5
Left	50	34.5
Biceps pathology		
None-tendinitis	32	22
Degenerate-partial tear	41	28.3
Unstable-dislocated	30	20.7
Totally ruptured	42	29

TABLE II
Descriptive data of patients

	Mean±SD	Median	Min-Max
Age (year)	62.2±9.7	63	28-87
Duration (month)	17.7±35.4	5	0.5-240
H/G	1.3±0.9	1.27	1.05-1.53
Acromiohumeral distance (mm)	7.3±2.3	7.6	1.2-15.7
Coracohumeral distance (mm)	10.4±3.5	10	2-24
SMHH (mm)	3.9±1.5	4	1-13
Critical shoulder angle (degrees)	43.2±5.2	43	30-56
Acromial Index	0.8±0.1	0.82	0.6-1

SD: Standard deviation; H/G: Ratio of the upper and lower lengths of the humeral head and glenoid; SMHH: Superior migration of the humeral head.

TABLE III
Comparison of SMHH distances, CD and AI ratios according to biceps pathology groups of the patients

	SMHH (mm)		CD distance (mm)		AI (mm/mm)	
	Median	Min-Max	Median	Min-Max	Median	Min-Max
Biceps pathology						
Group 1	4	1.3-6.5	10	4-19	0.8	0.62-1
Group 2	3.5	1-6	11	2-24	0.82	0.6-1
Group 3	4.14	1.5-8	10	8-19	0.84	0.65-0.93
Group 4	4.5	1-13	8.8	3.7-15	0.81	0.61-0.9
*p**	**0.009**		**0.026**		0.4	

SMHH: Superior migration of the humeral head; CD dist.: Coracohumeral distance; AI: Acromial Index; * Kruskal-Wallis test.

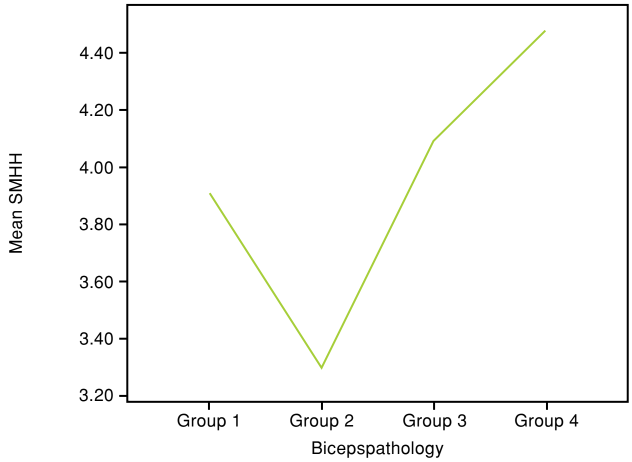

FIGURE 11. Line Chart Showing the SMHH Averages of the Patients Included in the Study by Biceps Pathology Groups.
SMHH: Superior migration of the humeral head.

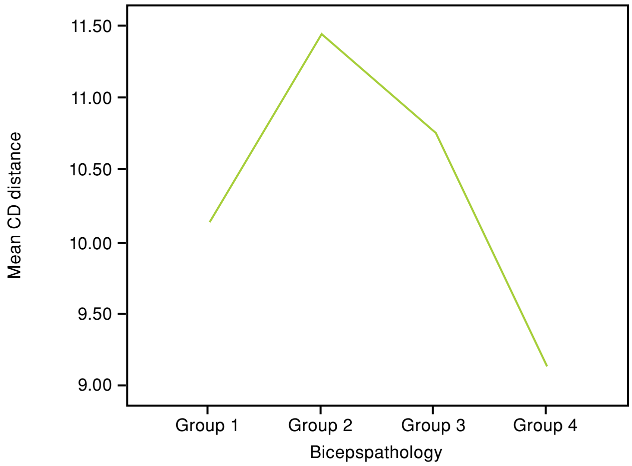

FIGURE 12. Line chart showing the CD averages of the Patients Included in the study by biceps pathology groups.
CD: Coracohumeral distance.

TABLE IV
Comparison of H/G ratios, AD distances and CSA grades according to biceps pathology groups of the patients

	H/G	AD distance (mm)	CSA (degrees)
	Mean±SD	Mean±SD	Mean±SD
Biceps pathology			
Group 1	1.3±0.1	7.7±2.7	43.1±4.8
Group 2	1.3±0.1	6.9±2.1	43.4±5.5
Group 3	1.3±0.1	8.0±2.1	44.5±4.1
Group 4	1.3±0.1	6.8±2.2	42.1±5.7
*p**	0.931	0.071	0.270

H/G: Ratio of the upper and lower lengths of the humeral head and glenoid; AD: Acromiohumeral distance; CSA: Critical shoulder angle; * One-way ANOVA test.

According to the biceps pathology groups, the mean CD was 10.1±3.2 in Group 1, 11.4±4.4 in Group 2, 10.8±2.4 in Group 3, and 9.1±2.8 in Group 4. When biceps pathology groups were compared, the patients in Group 2 (with biceps degeneration/tear) had a significantly higher CD distance ($p=0.042$) than the patients in Group 4 (with biceps rupture) (Table III, Figure 12).

According to the biceps pathology groups, there was no significant difference between the biceps pathology groups regarding AI rates (Table III).

According to the biceps pathology groups, there was no significant difference between the biceps pathology groups regarding AD distances, CSA grades, and H/G ratios (Table IV).

DISCUSSION

The main conclusion of our study is that the long head of the biceps tendon prevents the superior and anterior migration of the humeral head in the shoulder joint. Many studies in the literature, it has been shown that the humeral head migrates superiorly when tenotomy is performed on the long head of biceps tendon.[3,14-17] These results support our study. In response to these studies, Yamaguchi et al.'s[18] electromagnetic studies on patients with rotator cuff tears; they mentioned that the long head of the biceps tendon had no effect on shoulder biomechanics, but was effective on elbow contraction. In another study, Youm et al.[19] showed that glenohumeral joint mechanics did not change in cadavers with SLAP 2 lesions. Although the function of the LHBT continues to be discussed in the literature, many studies shows that the long head of the biceps tendon is effective in glenohumeral stability and prevents superior humeral migration.[20,21]

The head-suppressing effect of the rotator cuff is frequently mentioned in the literature;[22] in our study, we wanted to question the effect of variable long head of biceps lesions on the humeral head position in patients with posterior superior rotator cuff tears in addition to the literature. Our study was able to answer this question; the superior humeral migration was higher, and the CD was significantly reduced in the totally ruptured biceps group compared to other groups, which clinically proves that the LHBT, of which biomechanical role is controversial, has an important function in preventing the anterior and SMHH.

Superior migration of the humeral head was first described by Golding.[7] Weiner and Macnab[23] reported the migration of the humeral head and narrowing of the AD secondary to a rotator cuff tear.[23] The LHBT is an important force vector acting on the glenoid cavity. The main of our study is that the LHBT contributes to the prevention of superior excursion of the humeral head.[24] The fact that SMHH values were lower in the group with degenerated LHBT (Group 2) than the patients in other groups shows us that there may be individual differences in LHBT tension. In addition, if the supraspinatus tendon, which also has a head depressing effect, is torn in patients with a tense, but intact LHBT shows that the LHBT is degenerated by resisting the superior humeral migration as much as possible. Also, when there is a tear or instability in the LHBT, the increase in the SMHH supports our view. In a cadaver study conducted by Kumar et al.,[14] in a group of patients with a total rupture of the LHBT, significant superiorly migration occurred at the beginning of the humerus. However, anterior translation was unable to be evaluated in this study.

In the study by Bezer et al.,[12] the patients were evaluated in three groups: (isolated supraspinatus tear, supraspinatus + infraspinatus tear, supraspinatus + infraspinatus + subscapularis tear), and SMHH was examined. While there was no significant difference between the first two groups, the third group was significantly different from the other groups. The authors concluded that the subscapularis tear would be defeated by the lifting function of the deltoid, and the humeral head would expel superiorly, but the LHBT was ignored in this study. We believe that we can evaluate LHBT function more adequately by selecting patients with intact subscapularis tendon and isolated supraspinatus tendon rupture in our study groups.

In the study of Cetinkaya et al.,[13] SMHH and AD were evaluated in patients with rotator cuff tears. They showed that the AD and the SMHH were highly correlated in all groups of rotator cuff tears. In the aforementioned study, they reported that the SMHH in the group of patients with subscapularis tear did not increase and that the subscapularis tear did not cause subacromial impingement syndrome. In this study, the effect of LHBT tears on the SMHH was ignored. In our study, we observed the significant effect of the ruptured LHBT group on the SMHH, and we believe that this result would contribute to the literature. The fact that SMHH was lower in Group 1 and Group 3 compared to Group 4 indicates that the structure that prevents the SMHH is not only LHBT, but other factors are also effective. Despite the degenerated tear in the LHBT in some patients after a supraspinatus tear, the low superior humeral migration is an indication that the most important structure preventing migration in this patient group is LHBT.

Gerber et al. [8] used the CD to describe subcoracoid impingement syndrome. In healthy individuals, the CD is over 10 mm. In our study, the difference in the CD measurement group was also caused by the difference between the degenerate/tear and ruptured groups. The decrease in CD in LHBT ruptures shows that LHBT is also effective in the anterior stability of the humeral head.

On the other hand, considering that there may be anatomical differences in CD measurements; the higher CD in the group with degenerated LHBT than in the group with normal LHBT creates excessive tension on the tendon resulting in degeneration or tear in the biceps in cases where the anterior (anatomical) distance of the head is large. If the distance is small, we can assume that the humerus head can attempt to expel superiorly and cause tendinitis in the LHBT.

In their study, Leite et al.[25] found that the CD and the coracoid index had a significant predictive value in diagnosing subscapularis tears and LHBT tears. In our study, the coronal distance was significantly narrowed in patients with ruptured LHBT.

In two similar studies by Moor et al.[10] and Song et al.,[26] the CSA had a high correlation with rotator cuff tear above 35° and a significant correlation with osteoarthritis in measurements below 30°. Shingawa et al.[27] reported similar results by measuring the CSA in Japanese society. In our study, the CSA was above 30° in all groups, but no significant results were obtained for the biceps pathology subgroups for CSA.

Golding[7] accepted an AD of 7 to 13 mm in a healthy human shoulder by measuring the true shoulder anteroposterior radiograph. Goutallier et al.,[28] in their study investigating the effect of rotator cuff tears on the AD, reported that the AD was significantly narrowed in the group of patients with infraspinatus tears compared to other muscle tears. In our study, we found no significant difference in terms of AD among the groups. However, although it was not significant, the fact that the AD was narrower in Group 2 and Group 4 patients compared to other patients may indicate the importance of biceps tendon integrity and head depressing function.

Nyffeler et al.[9] reported that as the lateral extension distance of the acromion increased, the probability of supraspinatus tendon degeneration would also increase. In their study, the standard AI was 0.73, AI 0.6 in patients with rotator cuff tears, and 0.64 in patients with osteoarthritis. Ames et al.[29] showed that there was no significant relationship between the size of the AI and the size of the rotator cuff tears. However, they found that patients with a large AI used more anchors to repair their tears, and postoperative shoulder rehabilitation evaluations were lower.[28] In our study, we found no significant difference among the groups in terms of AI.

In the current study, the H/G ratio was calculated by measuring and proportioning the distance between the humeral head diameter and the glenoid superior-inferior to measure the distance traveled by the LHBT from the glenoid origin in sagittal shoulder MRI. We found no significant difference between biceps pathologies and the H/G ratio. We also showed that the distance covered by LHBT was not a significant variable for the development of biceps pathologies.

Nonetheless, there are some limitations to this study. Although our study is not a clinical biomechanical study, it was able to radiologically reveal the effect of LHBT pathologies on the superior and anterior migration of the humeral head in patients with the same rotator cuff tears.

In conclusion, the LHBT, of which function has not yet been clearly elucidated, is one of the anterior and superior stabilizing forces of the humeral head. We believe that the present study may contribute to the literature for functions of LHBT.

Ethics Committee Approval: The study protocol was approved by the Necmettin Erbakan University Meram Medical Faculty Pharmaceutical and Non-Medical Device Research Ethics Committee (date: 13.09.2019, no: 2019/2038). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Design, data processing, analysis and interpretation, literatur review, writing the article, references and fundings, materials, other: N.D.; Idea/consept, control/supervision, data collection, critical review: M.O.

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