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The effect of biceps tenotomy on superior humeral migration in arthroscopic repaired full-thickness supraspinatus tears

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Background: Lesions of the long head of the biceps (LHB) tendon are a prevalent injury that frequently coexists with rotator cuff injuries. This study aimed to assess the effect of supraspinatus (SST) repair with concurrent LHB tenotomy on superior migration of the humeral head. The acromiohumeral distance (AHD) was determined via ultrasound to evaluate the superior migration of the humeral head.
Methods: The study population was retrospectively recruited from patients who underwent unilateral arthroscopic repair of isolated degenerative full-thickness SST tears between January 2017 and December 2019. Patients were divided into 2 subgroups based on whether they underwent LHB tenotomies during arthroscopy. While 37 patients underwent arthroscopic single-row SST repair, the other 33 patients underwent arthroscopic single-row SST repair with LHB tenotomy. The subject group consisted of people who had undergone arthroscopic shoulder surgery. Contralateral shoulders without rotator cuff injuries were included in the control group. The AHD and SST thicknesses of patients were examined via the ultrasound in both groups and subgroups.
Results: The mean age in the SST repair group was 55.52 ± 4.58 years (range, 46-63 years), whereas it was 58.24 ± 3.98 (range, 52-73 years) in the SST repair + LHB tenotomy group. In the SST repair group, 57.6% of patients were female and 42.4% were male, whereas 56.8% and 43.2% were in the SST repair + LHB tenotomy group, respectively. The mean body mass index was 28.06 ± 1.31 kg/m^2 (range, 25.7-31.2 kg/m^2) in the SST repair group and 28.95 ± 1.79 kg/m^2 in the SST repair + LHB tenotomy group. Groups were not different for sex, surgery side, dominant side, tear size, and follow-up time; however, the SST repair + LHB tenotomy group had significantly higher mean age and body mass index than the SST repaired group. The mean AHD value and SST thickness were significantly less in both the rotator cuff repair group and the rotator cuff repair + LHB tenotomy group compared to the healthy shoulder. The mean AHD value was significantly lower in the SST repaired + LHB tenotomy group than in the SST repair group ($P = .02$).
Conclusion: The AHD was narrowed in patients who underwent LHB tenotomy and radiologically demonstrated the depressor effect of the LHB tendon on the humeral head. As a secondary outcome, we demonstrated that regardless of tenotomy, AHD could not be restored in patients who underwent arthroscopic single-row SST repair.

Superior humeral head migration is a secondary characteristic of rotator cuff injuries caused by an imbalanced dynamic force couple formed by the rotator cuff and deltoid muscles.[13,20] Weiner and Macnab underlined the role of the supraspinatus (SST) in humeral head depression in response to the superior pull on the humerus by the deltoid.[19] Additionally, the long head of the biceps tendon (LHBT) acts as a humeral head depressor in shoulders with rotator cuff injuries.[9,11] However, its precise function in the shoulder joint remains unknown.[10] The LHBT is regarded as the proverbial step-child of the shoulder joint. Kessell and Watson[16] described the LHBT as *"somewhat of a maverick, easy to inculpate but difficult to condemn."* Lippman[21] likened the LHBT to the appendix: *"An unimportant vestigial structure unless something goes wrong with it."* There remains a lack of consensus on the LHBT's true function in

Haseki Training and Research Hospital Ethical committee approved this study, Decision no: 325 16/12/2021.

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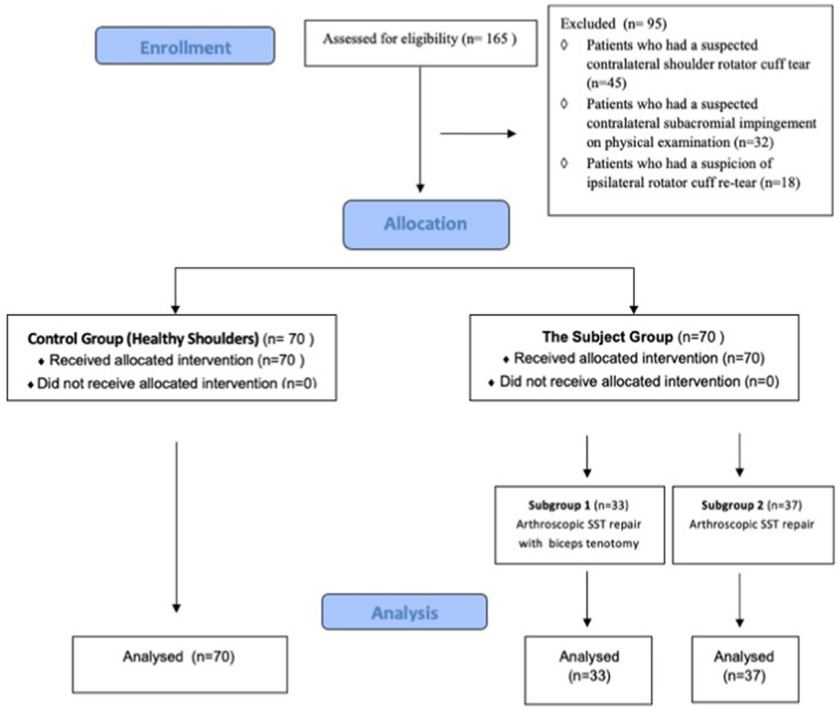

Figure 1 Flowchart of study populations.

shoulder biomechanics. According to some, LHBT is a vestige that can be readily excised or tenodesed if symptomatic. Others ascribe the LHBT to a plethora of functions.[9,10]

LHBT lesions are a prevalent disease that frequently coexists with rotator cuff injuries. The literature revealed that 36.1%-88% of arthroscopic rotator cuff repairs have a damaged LHBT.[4,7] Additionally, the LHBT lesion is related to an increased size of rotator cuff tears.[23] Tenotomy and tenodesis are surgical treatments to manage symptomatic LHBT lesions. Biceps tenotomy is a simpler procedure with a shorter intraoperative duration and fewer postoperative restrictions, resulting in a faster full-activity resumption.[24]

However, the function of the LHBT as an active humeral head depressor or dynamic functional stabilizer in the glenohumeral joint ceases after tenotomy. This may cause superior humeral head migration, which is frequently examined using X-ray, magnetic resonance imaging (MRI), or ultrasound (US). The US provides a straightforward comparison with the contralateral shoulder without exposing the patient to radiation.[1,5,12]

To our knowledge, no clinical study has been conducted on the effect of concurrent LHB tenotomy on superior humeral head migration in patients undergoing rotator cuff repair. The primary hypothesis was that concurrently performing biceps tenotomy with rotator cuff repair would result in AHD narrowing or superior humeral head migration in the following years. Hence, this study aimed to determine the effect of concurrent LHB tenotomy and arthroscopic SST repair on superior humeral head migration. AHD was measured using the US to determine the superior humeral head migration. Additionally, the thickness of the SST in both shoulders was evaluated via the US to determine the changes during the SST repair. Thus, the effect of SST thickness on AHD was also evaluated.

Materials and methods

Study design

This study was approved by the ethics committee of Haseki Training and Research Hospital and was conducted in accordance with the principles of the Declaration of Helsinki (protocol no 325/2021). The inclusion criteria were patients who underwent unilateral arthroscopic repair of isolated degenerative full-thickness SST tears and had at least 1-year follow-up after surgical treatment. Patients with suspected contralateral shoulder rotator cuff tear or subacromial impingement and suspected ipsilateral rotator cuff retear on physical examination, and patients operated on any shoulder for any other reason were excluded from the study (Fig. 1). Between January 2017 and December 2019, 165 patients who underwent unilateral arthroscopic repair of isolated degenerative full-thickness SST tears were contacted by phone and invited to the outpatient clinic. After meeting the exclusion criteria, 70 patients were included in the study. Patients were divided into 2 subgroups according to their LHB tenotomy during arthroscopy. While arthroscopic single-row SST repair was performed in 37 patients, arthroscopic single-row SST repair was performed with LHB tenotomy in the other 33 patients. Biceps tenodesis was not applied to any of the patients.

The subject group consisted of individuals who had undergone arthroscopic shoulder surgery. The control group included healthy contralateral shoulders that were free of rotator cuff tears. The AHD and SST thicknesses were evaluated in the US between shoulders with arthroscopic repair and contralateral healthy shoulders from the same patients. Additionally, the AHD and SST thicknesses of patients who underwent biceps tenotomy were compared with those who did not during arthroscopic surgery.

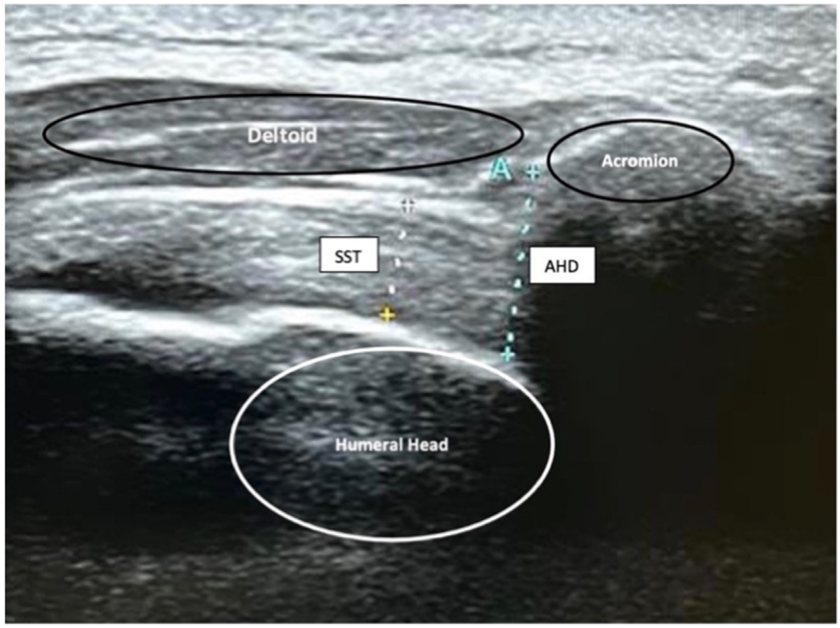

Figure 2 Ultrasonographic evaluation of the shoulder joint. *SST*, supraspinatus; *AHD*, acromiohumeral distance.

Table I
Demographic and clinical characteristics of patients with full-thickness supraspinatus tear who underwent arthroscopic single-row repair.

Number of patients	70
Mean age (y)	56.96 ± 4.45 (46-73)
Sex	
Female	40 (57.1%)
Male	30 (42.9%)
Surgery side	
Right	44 (62.9%)
Left	26 (37.1%)
Dominant side	
+	50 (28.6%)
-	20 (71.4%)
BMI (kg/m^2)	28.53 ± 1.63 (25.4-34.6)
Tear size	
Small (<1 cm^2)	15 (21.4%)
Medium (1-3 cm^2)	26 (37.1%)
Large (3-5 cm^2)	29 (41.4%)
Mean follow-up (mo)	27.69 ± 4.97 (24-44)

BMI, body mass index.

Sample size calculation

Power analyses were performed using the G-power 3.1 statistical analysis program. The effect size, the alpha, and the power (1-beta) were used to estimate the required sample size, that is, 2.11, 0.05, and 0.95, respectively. We used 33 samples in one group and 37 samples in the other group.

Surgical technique

All arthroscopic procedures were done in the beach chair position under general anesthesia or a brachial plexus interscalene block. Following the use of standard portals (posterior, lateral, and anterior), additional portals were constructed when needed to release adhesions and mobilize tendons. The glenohumeral joint was entered via a posterior portal, and a routine diagnostic arthroscopic assessment was conducted. The subacromial space was probed, and a lateral portal was made to determine the size and structure of the tear. All patients underwent subacromial decompression and acromioplasty following the cuff tear size measurement with the probe. SST tears were arthroscopically repaired in all cases using the single-row repair method. Biceps tenotomy was performed on patients with symptomatic degenerative LHBT lesions involving >50% of the tendon, depending on the patient's age and activity level. LHB tenotomy was performed with a bipolar electrode that cut the biceps tendon at its insertion on the supraglenoid tubercle.

US measurements

All patients underwent US scanning by a specialist with over 10 years of clinical experience in performing musculoskeletal US scanning. Measurements were repeated in 20 shoulder joints of 10 patients 1 week apart before starting the study to test measurement reliability. First, an AHD measurement was taken with the participant in a sitting position. Each subject was positioned, seated on a chair in their normal seated posture, arms in a neutral position, and hands resting on the lap. Each patient's ultrasonographic measurement was performed using the US (Toshiba Aplio 500; Toshiba Medical Systems, Osaka, Japan). The patient was sitting with the upper extremity in a neutral position. A 5-14 MHz linear transducer was placed on the anterior surface of the acromion in the coronal plane.

The US transducer was positioned longitudinally along the acromion's center to determine the AHD. After visualizing both the acromion and humerus, the transducer was moved forward until the most anterior portion of the acromion was visible, along with a clear sight of the humeral head underneath, at which point the image was taken. The AHD was defined as the smallest distance between the anterior acromion's inferolateral edge and the humeral head's most superior aspect (Fig. 2). Two measurements were conducted on each shoulder and the mean value was noted. The SST thickness was determined for all individuals using the same position. The transducer was positioned above the anterior aspect of the shoulder, directly anterior to the acromion's anterior-lateral border. The precise location of tendon thickness evaluation was then identified, and 2 measurements were taken with the

Table II
Comparison of demographic and clinical characteristics of the subgroups.

Variables	SST repaired (n = 33)	SST repaired with LHB tenotomy (n = 37)	*P* value
Mean age (y)	55.52 ± 4.58 (46-63)	58.24 ± 3.98 (52-73)	**.01***
Sex			.95†
Female	19 (57.6%)	21 (%56.8%)	
Male	14 (42.4%)	16 (43.2%)	
Surgery side			.90†
Right	21 (63.6%)	23 (62.2%)	
Left	12 (36.4%)	14 (37.8%)	
Dominant side			.82†
+	24 (72.7%)	26 (70.3%)	
-	9 (27.3%)	11 (29.7%)	
BMI (kg/m^2)	28.06 ± 1.31 (25.7-31.2)	28.95 ± 1.79 (25.4-34.6)	**.02***
Tear size			.52*
Small (<1 cm^2)	9 (27.3%)	6 (16.2%)	
Medium (1-3 cm^2)	11 (33.3%)	15 (40.5%)	
Large (3-5 cm^2)	13 (39.4)	16 (43.2%)	
Mean follow-up (mo)	27.91 ± 4.53 (24-42)	27.49 ± 5.38 (24-44)	.73*

SST, supraspinatus; *LHB*, long head of the biceps; *BMI*, body mass index.
*Independent samples *t*-test.
†Pearson's Chi-Square test, Bold values indicate significance.

Table III
Comparison of postoperative ultrasound measurements between the repair and healthy shoulder.

	SST repaired group (n = 33)		
	Repaired side	Healthy side	*P* value
AHD (mm)	7.98 ± 0.95 (6-9.9)	8.94 ± 1.21 (6.4-11.1)	**<.001***
SST tendon thickness (mm)	5.57 ± 1.32 (3.2-7.6)	6.5 ± 1.24 (4.5-9.1)	**.003***
	SST repaired + LHB tenotomy group (n = 37)		
	Repaired side	Healthy side	*P* value
AHD (mm)	7.41 ± 0.83 (5.8-8.9)	8.77 ± 0.97 (7.4-11)	**<.001***
SST tendon thickness (mm)	5.32 ± 1.21 (3.2-7.6)	6.19 ± 1.12 (4.5 ± 9.1)	**<.001***

AHD, acromiohumeral distance; *SST*, supraspinatus; *LHB*, long head of the biceps.
*Paired Samples *t*-test, Bold values indicate significance.

Table IV
Comparison of postoperative ultrasound measurements on repaired shoulders between the SST repair group and the SST repair + LHB tenotomy group.

	SST repaired (n = 33)	SST repaired with LHB tenotomy (n = 37)	*P* value
AHD (mm)	7.98 ± 0.95 (6-9.9)	7.41 ± 0.84 (5.8-8.9)	**.01***
SST thickness (mm)	5.57 ± 1.32 (3.2-7.6)	5.32 ± 1.21 (3.2-7.6)	.40*

AHD, acromiohumeral distance; *SST*, supraspinatus; *LHB*, long head of the biceps.
*Independent samples t-test.

mean value recorded. Each subject was thoroughly examined bilaterally using the US. The AHD and SST thicknesses were assessed using the US on both healthy and arthroscopically repaired shoulders.

Statistical analysis

The statistical analysis was performed using Statistical Package for the Social Sciences software version 20.0. (IBM Corp., Armonk, NY, USA). The intraclass correlation coefficient (ICC) with a 95% confidence interval (CI) was used to examine the test reliability of AHD and SST thickness measurements. A score of >0.90 indicated excellent reliability. Data were tested for normality using the Kolmogorov–Smirnov test. Comparison between groups was conducted with the independent sample *t*-test for quantitative variables and Pearson's chi-square test for qualitative variables when necessary. Paired sample *t*-tests were used to compare SST thickness and AHD between groups (repaired and healthy sides). A two-sided *P* value of <.05 was considered significant.

Results

Table I summarizes the demographic and clinical details of all patients. The mean age in the SST repair group was 55.52 ± 4.58 years (range, 46-63 years), and the mean age in the SST repair + LHB tenotomy group was 58.24 ± 3.98 (range, 52-73 years). In the SST repair group, 57.6% of patients were female and 42.4% were male, whereas 56.8% and 43.2% were in the SST repair + LHB tenotomy group, respectively. The mean body mass index was 28.06 ± 1.31 kg/m^2 (range, 25.7-31.2 kg/m^2) in the SST repair group and 28.95 ± 1.79 kg/m^2 in the SST repair + LHB tenotomy group. The groups were not different for sex, surgery side, dominant side, tear size, or follow-up time; however, the SST repair + LHB tenotomy group had a significantly higher mean age and mean body mass index than the SST repair group (Table II). For the AHD measurement in 10 patients (20 shoulders), excellent intraobserver reliability was demonstrated with an ICC of 0.93 (95% CI: 0.89-0.95). The intraobserver reliability of the SST thickness measurement in 10 patients (20 shoulders) was excellent, with an ICC of

Table V
Comparison of ultrasound measurements on healthy shoulders of patients who underwent contralateral SST repair and SST repair with LHB tenotomy.

	SST repaired (n = 33)	SST repaired with LHB tenotomy (n = 37)	*P* value
AHD (mm)	8.94 ± 1.21 (6.4-11.1)	8.77 ± 0.97 (7.4-11)	.50
SST tendon thickness (mm)	6.5 ± 1.24 (4.5-9.1)	6.19 ± 1.12 (4.5-9.1)	.27

AHD, acromiohumeral distance; *SST*, supraspinatus; *LHB*, long head of the biceps.

0.91 (95% CI: 0.87-0.93). AHD and SST thickness measurements of rotator cuff repair, rotator cuff repair + LHB tenotomy, and healthy sides are summarized in Table III. The mean AHD value and SST thickness were significantly lower in both the rotator cuff repair group and the rotator cuff repair + LHB tenotomy group compared to the healthy shoulder (Table III). AHD and SST thickness measurements for repaired shoulders in the SST repair group and the SST repair + LHB tenotomy group are summarized in Table IV. The mean AHD value was higher in the SST repair group than in the SST repair + LHB tenotomy group, with a statistically significant difference ($P = .01$). No statistically significant difference was found in SST thickness between the groups ($P = .40$) (Table IV). AHD and SST thickness measurements for healthy shoulders in the SST repair group and the SST repair + LHB tenotomy group are summarized in Table V. No statistically significant difference was found in the mean AHD value and SST thickness ($P = .50$, .27) (Table V).

Discussion

The medium-term effect of concomitant biceps tenotomy on AHD was evaluated in patients who underwent arthroscopic single-row repair of an isolated degenerative full-thickness SST tear using the US. We validated the effects of rotator cuff surgery on AHD by comparing them to the AHD measurements on the intact side. To our knowledge, this is the first radiological study in the literature that evaluates the depressor effect of the LHB tendon on the humeral head. We found that the AHD narrowed following concurrent biceps tenotomy and remained narrow compared to the healthy side following rotator cuff repair when isolated, degenerative, full-thickness SST tears were repaired.

The subacromial area, or AHD, defined as the shortest distance between the acromion and the humerus, can be measured with X-rays, MRI, computed tomography, and US.[8,18] Among these various, imaging modalities, ultrasonography is noninvasive, radiation-free, highly validated ($r > 0.8$) compared to X-ray, and less costly compared to MRI.[2,15] Therefore, we preferred the use of the US in AHD measurement. Various techniques have been described in AHD measurement using the US; however, we performed the measurements in the coronal plane and with the arm in the neutral position as standard.[15,17,22] The AHD distance can vary according to age, gender, and physical activity, thus the control group was determined as the patient's intact shoulder for measurement comparison. Additionally, we wanted to demonstrate the repair's success by assessing the SST thickness following cuff repair through ultrasonography.

The rotator cuff and LHBT are known as dynamic stabilizers during shoulder movement. Despite the role of LHBT in the shoulder, its function remained debatable.[14,26] The electromyography analysis revealed that LHBT acts as a glenohumeral joint stabilizer in an unstable glenohumeral joint, but not in a stable glenohumeral joint.[25] Biomechanical studies have shown that LHBT is a dynamic humeral head depressor; however, clinical evidence has not been demonstrated.[3,9] This study is a unique one that clinically reveals the dynamic depressor effect of LHBT on the humeral head. The AHD was used to demonstrate the dynamic depressor effect of LHBT per humerus and was compared with a group of patients who had undergone biceps tenotomy to ascertain the effect on the biceps. The STT repair + LHB tenotomy group had a significant narrowing of AHD in this study. This narrowing was attributable to the LHBT's dynamic stabilizing effect. Additionally, an inadequate difference in the intact side AHD and SST thicknesses between patients who underwent SST repair and those who underwent SST repair with LHB tenotomy supports these findings.

After comparing the AHD of the intact shoulder and that of the rotator cuff repaired shoulder, we discovered a significantly narrower AHD in the rotator cuff repaired group. We identified 3 causes to restore the AHD inability. Firstly, we performed a single-row repair surgery. According to the literature, the AHD distance was much higher in the patient group treated with double rows.[6] Secondly, patients treated in the early stages of rotator cuff tears were not chosen for surgical treatment. The literature reported that the AHD distance was more completely restored in the group of patients who are surgically treated in the early phase.[14] Thirdly, the possibility of a re-rupture was considered. Therefore, patients whose physical examination suggested the likelihood of rupture were excluded.

The major limitation includes the inability to quantify the preoperative AHDs due to the retrospective nature of the study. Secondly, a significant difference was found between the 2 groups in terms of age and gender. Thirdly, we did not examine the clinical outcomes of AHD and LHB tenotomy. Finally, AHD was only evaluated using the US and the volume of the subacromial region was not quantified. However, the control group selected from the healthy side of patients and the large sample size were the major strength of this study.

Conclusions

We found that AHD narrowed in individuals who underwent biceps tenotomy and radiologically confirmed that the LHB had a depressing effect on the humeral head. AHD could not be restored in patients who received arthroscopic single-row SST repair, regardless of tenotomy, as a secondary result.

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