Biceps tenodesis combined with rotator cuff repair increases functional status and elbow strength

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Abstract

Purpose: The aim of the present study was to prospectively evaluate the elbow flexion and supination strengths and the functional outcomes of patients following arthroscopic rotator cuff repair combined with simultaneous biceps tenodesis.

Methods: 19 patients who underwent arthroscopic rotator cuff repair and biceps tenodesis with at least 24 months of follow-up were included. Patients were evaluated using a visual analog scale (VAS) for bicipital groove pain, American Shoulder and Elbow Surgeons (ASES), and constant scores (CS), biceps apex distance (BAD), elbow flexion, and supination strengths.

Results: The VAS for biceps groove measurement averages in the postoperative 6th, 12th, and 24th months was lower in comparison to preoperative data and was considered to be statistically significant (p<.05). The constant score, an average of all postoperative measurements and scores, was found to be higher than preoperative values and was considered to be statistically significant (p<.01). There was a significant difference in the operated and non-operated forearm supination and elbow flexion muscle strength measurements at the postoperative 3- and 6-month follow-ups (p<.01).

Conclusion: Arthroscopic biceps tenodesis into the anchors of the lateral row in combination with rotator cuff repair provides an increase in the strength of elbow flexion and forearm supination, while decreasing pain.

Level of Evidence: Level IV

Keywords
Rotator cuff tear, biceps, tenodesis, supination, strength, arthroscopic surgery

Date received: 15 December 2020; Received revised 29 September 2021; accepted: 13 October 2021

Introduction

Rotator cuff tears are associated with a long head of biceps pathology (LHBT) in 30–69% of cases.¹,² Lesions of LHBT can cause pain due to the following reasons: associated lesions in the labral complex, tendinopathy or tenosynovitis, partial or complete tendon tears or instabilities (such as subluxation, dislocation, and the pulley effect) in the LHBT.³-⁶

The preferred treatment is usually tenotomy or tenodesis for relieving pain associated with biceps pathologies.⁷ Tenotomy is an easy, time-saving procedure that reduces
pain effectively\textsuperscript{8,9} and preserves the strength and tension of the muscle. Therefore, tenodesis is preferred for younger patients and heavy laborers.\textsuperscript{10,11}

Compared to open subpectoral biceps tenodesis, arthroscopic suprapectoral biceps tenodesis has distinct advantages, including minimal soft tissue dissection, less scar formation, and no need for an assistant to retract soft tissue.\textsuperscript{12} When tenodesis is performed, many different factors affect tendon repair, including tendon quality and strength of the stitch. The most vulnerable part of the suture is the start of the chain, where the suture passes through. For improving strength, Lafosse et al. (2006) introduced a new technique called the Lasso stitch,\textsuperscript{13} which showed superior biomechanical properties in overcoming load failure compared to compressive rivet and interference screw.\textsuperscript{14} Some authors also stated that the Lasso loop technique has less humeral fracture risk (theoretically associated with drilling) than interference screw.\textsuperscript{12}

Tenodesis seems to be associated with higher forearm supination and elbow flexion strength compared to tenotomy.\textsuperscript{15–18} Little is known regarding elbow strength compared to preoperative levels when two common procedures, biceps tenodesis and rotator cuff repair, are performed simultaneously. Hufeland et al.\textsuperscript{19} reported that isolated arthroscopic suprapectoral biceps tenodesis using the interference screw increased elbow flexion from 12 months onward compared to preoperative values, but they did not consider the supination strength.

Although the biomechanical properties of the Lasso stitch were investigated in some studies, there are limited studies investigating functional outcomes.\textsuperscript{18} The purpose of our study is to prospectively evaluate the elbow flexion and supination strengths and the functional outcomes of patients after arthroscopic rotator cuff repair combined with simultaneous biceps tenodesis. We hypothesized that rotator cuff repair combined with biceps tenodesis, similar to the technique described by Levy JC,\textsuperscript{20} would increase both the flexion and supination strengths of the elbow compared to preoperative levels at an early period.

Uschok et al.\textsuperscript{18} investigated functional outcomes of the shoulder and elbow strength compared to contralateral elbow and stated that there may be loss of elbow flexion strength which is not clinically significant. Elbow supination strength was not investigated in this study.\textsuperscript{18} Moorthy et al. aimed to review the literature and suggested if tenotomy or tenodesis is the preferred option in patients who undergo rotator cuff repair. They conclude that there is a lack of higher-level studies to make a decision for a worldwide-accepted algorithm.

Materials and methods

The present study is a prospective case series of a single surgeon’s (O.H.) practice and all the data of the included patients have been collected prospectively and reviewed retrospectively. We reviewed patients who underwent arthroscopic proximal biceps tenodesis and arthroscopic rotator cuff repair between January 2015 and December 2017. First, 22 patients with full-thickness rotator cuff tears and biceps tendinosis were selected for this study. Among them, 19 patients were included in the study; three patients were excluded due to traumatic re-rupture of the rotator cuff. Therefore, 19 patients underwent simultaneous rotator cuff repair and biceps tenodesis.

Figure 1. Elbow flexion strength at 90° flexion (a, b) and forearm supination strengths (c, d) of both operated and non-operated side elbows were measured using a digital dynamometer. (Lafayette manual muscle tester, IN, USA, kg).

Figure 2. Biceps tendon cut after Lasso loops.
including comprehensive physical tests specific to rotator cuff lesions (Jobe test, rent sign, Hawkins test, external/internal lag sign, etc.), biceps lesions (Speed test, Yergason test, tenderness, etc.), as well as radiographic examinations using MRI. We evaluated the patients preoperatively in terms of arm dominance, trauma history, bicipital groove tenderness, a visual analog scale (VAS) for pain, functional shoulder score (American Shoulder and Elbow Surgeons (ASES) score) and elbow-forearm muscle strength measurements (both operated and non-operated sides).

The rotator cuff tear and LHB lesion were reconﬁrmed intraoperatively. Patients with full-thickness tears of the supraspinatus (and infraspinatus) and patients with partial subscapularis tears with full-thickness supraspinatus (and infraspinatus) tears were included. Only one of the 19 patients (5.26%) had a partial subscapularis tear with a full-thickness supraspinatus tear. Subscapularis repair was not performed in this patient. A partial tear of the biceps pulley was described as injury or gross partial. The arms of the patients were fully rotated internally and externally to evaluate the stability of the biceps tendon. If the biceps tendon was displaced from the groove, it was defined as subluxation or dislocation. After intraoperative evaluation of LHB tendon, those having LHB with inﬂammation, a partial tear of the LHB tendon, a partial tear of the biceps pulley, LHB with tendon subluxation were included in the study. The study was approved by the institutional local ethical committee (Dokuz Eylül University Ethical Committee, IRB no: 2020/06–39). All the patients were informed about the study and consent forms were obtained.

**Inclusion and exclusion criteria**

Patients who had been treated with arthroscopic double-row repair of rotator cuff tear and biceps tenodesis with a minimum follow-up of 24 months and also fit well with follow-ups were included in the study. Exclusion criteria included patients who had massive or irreparable rotator cuff tears, isolated subscapularis tears, LHB tendon dislocation, glenohumeral osteoarthritis, acromioclavicular joint osteoarthritis, a previous history of upper extremity surgery from the ipsilateral or non-operated (shoulder/elbow/
forearm/wrist surgery), dementia, rheumatoid arthritis, or any inflammatory arthritis.

**Evaluation of the patients**

All patients were evaluated preoperatively, using the American Shoulder and Elbow Surgeons Score (ASES),\textsuperscript{21} Constant score (CS),\textsuperscript{22} VAS for biceps groove tenderness on digital palpation, and biceps apex distance (BAD)\textsuperscript{23,24} for the operated side. Biceps apex distance is the distance from the inner margin of the pectoralis major tendon to the apex of the biceps.\textsuperscript{23,24} Elbow flexion strength at 90° flexion of and the supination strengths of the forearm for operated and elbows and forearms of non-operated side were measured using a digital dynamometer (Lafayette manual muscle tester, IN, USA, kg) (Figure 1).

**Surgical technique**

Surgery was performed under general anesthesia in the lateral decubitus position. After the creation of standard posterior and anterior portals, two lasso loops were created passing through the biceps tendon (Figure 2). Tenotomy was performed and suture strands were kept at the anterior portal for later tenodesis. The arthroscope was placed at the subacromial bursa and conventional double-row repair of supraspinatus tendon was performed. Sutures from the biceps tendon were incorporated into lateral row anchors similar to the technique of Levy JC\textsuperscript{20} (Figure 3). No additional coracoacromial ligament complete release or subacromial decompression was performed.

**Postoperative rehabilitation**

Postoperatively, an abduction sling was applied and patients performed passive exercises, preventing supination of the forearm and external rotation of arm beyond neutral. Active assisted range of motion (ROM) exercises were begun 4 weeks after the operation. All evaluations were repeated at the 3-, 6-, 12-, and 24-month follow-ups postoperatively (Figure 4).

**Statistical analysis**

Data analysis was performed using the SPSS [Statistical Package or the Social Sciences for Windows, version 22.0 (IBM, SPSS Statistics, New York, USA)]. The Standard deviations and arithmetic means of repeated patient measurements prior to surgery and at postoperative 3-, 6-, 12-, and 24-month follow-ups were calculated. Repeated Multivariate Tests were used to determine whether or not the differences in repeated measurements were significant. Prior to this test, the homogeneity of variants was assessed by Mauchly’s Test of Sphericity, and if it was homogeneous ($p > .05$), a parametric Repeated Multivariate Test was used in the analysis. In cases where significant differences were determined in the repeated tests, the Bonferroni pairwise comparison test was implemented to determine the measurements causing the differences. If variants were not homogeneous, a non-parametric–related sample Friedman Test was used in the analysis. Tables of pairwise comparisons were not made. The constant score, ASES, VAS for biceps groove, BAD, elbow flexion and forearm supination strength scores were analyzed by paired multivariate tests. The analysis included independent variables of age (years), duration of pain before surgery (months), tear size (ordinal), the existence of diabetes, gender, and smoking status. $p < .05$ was considered significant.

**Results**

The mean age of the patients was 57.4 ± 9.2 (41–73). Fourteen of the patients were female and five were male. The rotator cuff tear was detected as small (<1 cm) in five, medium (1–3 cm) in nine, and large (3–5 cm) in five patients (Table 1).

### Table 1. Characteristics of patients undergoing surgery.

| Arthroscopic biceps tenodesis with rotator cuff repair (n) | p-value |
|----------------------------------------------------------|---------|
| Gender                                                   | n.s     |
| 5 male, 14 female                                        |         |
| Age (years)                                               | n.s     |
| 57.4 ± 9.2 (41–73)                                        |         |
| Dominant side (operated)                                 | n.s     |
| 10 (52.6%)                                               |         |
| Mean preoperative pain duration (months)                  | n.s     |
| 11.2 ± 10.4 (3–48)                                       |         |
| Rotator cuff tear size                                    |         |
| Small (<1 cm)                                            | n.s     |
| 5                                                        |         |
| Medium (1–3 cm)                                          |         |
| 9                                                        |         |
| Large (3–5 cm)                                           |         |
| 5                                                        |         |
| Diabetes mellitus                                        | n.s     |
| 4 (21.1%)                                                |         |
| Smoking                                                  | n.s     |
| 7 (36.8%)                                                |         |

n.s: non-significant ($p > .05$).
The constant score, the average of all postoperative measurements and scores, was found to be higher than preoperative values and was considered to be statistically significant \((p<.01)\). In the pairwise comparisons, although there were no differences between the 6-month and 12-month average scores \((p > .05)\), other groups differed in averages \((p<.01)\). The average ASES scores of all measurements after the operation were higher than preoperative measurements. Again, in the pairwise comparisons, all measurement score averages were different from each other \((p<.01)\) (Figure 4). The VAS for biceps groove measurement averages of postoperative 6th, 12th, and 24th months were lower in comparison to preoperative data and were considered statistically significant \((p<.01)\). The average scores at the third month were insignificant in comparison to preoperative data \((p > .05)\) (Table 2).

No Popeye sign was observed in any of the patients. The difference in BAD measurements conducted preoperatively and at the 24th month was 0.6 cm. Yet, the BAD measurements at the third, 6th, 12th, and 24th months did not show any statistical differences to the preoperative data \((p > .05)\).

The forearm supination strength of the operated side was significantly higher than preoperative values. The forearm supination strength of the operated side did not differ significantly regardless of whether it was dominant or not (Pillai’s Trace, \(F=1.31, p = .313\)). In other words, being the dominant arm was not considered to be significant in terms of muscle supination regaining preoperative strength.

Elbow flexion strength on the operated side was significantly higher than the preoperative strength \((p<.01)\). There was no significant difference between dominant and non-dominant arms in terms of elbow flexion strength (Pillai’s Trace, \(F=1.54, p = .245\)). There was a significant difference in the operated and non-operated forearm supination and elbow flexion muscle strength measurements at the postoperative 3- and 6-month follow-ups \((p < .01)\) (Table 3) (Figure 5).

### Table 2. Comparison of the mean scores of the scales used to evaluate the functions of patients following arthroscopic biceps tenodesis with rotator cuff tear.

| Repeated measure | Constant score mean (SD) | ASES mean (SD) | VAS (biceps groove) mean (SD) | BAD (cm) mean (SD) |
|------------------|--------------------------|----------------|-------------------------------|--------------------|
| Preoperative     | 38.2 (12.38)             | 30.1 (11.32)   | 7.9 (1.78)                    | 8.9 (1.26)         |
| Postop 3rd month | 55.7 (15.23)             | 58.7 (17.91)   | 4.1 (2.90)                    | 9.3 (1.07)         |
| Postop 6th month | 66.0 (19.60)             | 73.0 (16.92)   | 1.1 (1.31)                    | 9.4 (1.08)         |
| Postop 12th month| 71.5 (16.72)             | 77.7 (13.91)   | 0.7 (1.11)                    | 9.5 (1.07)         |
| Postop 24th month| 94.4 (4.59)              | 91.8 (10.21)   | 0.2 (0.54)                    | 9.5 (1.06)         |
| Repeated Multivariate Tests | \(F = 142.5, p < .001\) | \(F = 102.9, p < .001\) | \(F = 66.9, p < .001\) | \(F = 1.61, p = .226\) |

ASES: American Shoulder and Elbow Surgeons Score; VAS: visual analog scale; BAD: biceps apex distance.

### Table 3. Comparison of mean forearm supination and elbow flexion muscle strength of patients after surgery.

| Repeated measure | Forearm supination strength (FSS) (kg.) mean (SD) | Elbow flexion strength (EFS) (kg.) mean (SD) |
|------------------|--------------------------------------------------|---------------------------------------------|
| Measure          | Non-operated side                               | Operated side                              | Mean difference   | Non-operated side | Operated side | Mean difference |
| Preoperative     | 7.7 (2.88)                                      | 4.4 (2.56)                                 | 3.4 (2.43)*       | 10.9 (4.35)       | 5.9 (3.74)    | 5.0 (2.73)*     |
| Postop 3rd month | 8.2 (2.74)*                                     | 6.4 (2.68)*                                | 1.7 (2.00)*       | 12.0 (4.95)       | 8.6 (4.78)*   | 3.4 (2.42)*     |
| Postop 6th month | 8.9 (2.86)*                                     | 7.9 (2.68)*                                | 1.0 (1.56)*       | 12.6 (5.04)*      | 10.6 (5.06)*  | 2.0 (2.30)*     |
| Postop 12th month| 10.1 (3.23)*                                    | 9.3 (2.80)*                                | 0.7 (1.55)        | 17.0 (12.25)*     | 11.9 (5.21)*  | 5.1 (13.11)     |
| Postop 24th month| 10.8 (3.38)*                                    | 10.5 (3.35)*                               | 0.3 (0.67)        | 17.1 (12.21)*     | 14.3 (5.47)*  | 2.8 (0.97)      |
| Repeated Multivariate Tests | \(F = 7.2, =0.002\) | \(F = 21.2\) | \(p < .001\) | \(F = 6.3\) | \(F = 23.7\) | \(p < .001\) |

*Paired Samples Test is significant at the < .05 level (two-tailed).

Discussion

This study showed that rotator cuff repair combined with biceps tenodesis increases the strengths of both supination and elbow flexion while decreasing biceps groove pain compared to preoperative values in the early postoperative period. This was the main finding of our study.

Similar findings were reported by Hufeland et al.\(^9\) The 22 patients included in their study were randomized for tenodesis and tenotomy. They concluded that there was no significant difference in flexion and supination strengths...
between the tenodesis and tenotomy groups after 12 months. In contrast to our study, they did not perform additional rotator cuff repair and also performed the biceps tenodesis using the interference screw.

The addition of rotator cuff tear repair possibly contributed to an increase in the strengths in our study. The technique for biceps tenodesis was similar to the technique described by Levy JC. However, two simpler Lasso loops were created and incorporated into the lateral row anchors instead of the Krackow technique, and the tendon was not exteriorized. This might have resulted in an increase of BAD compared to preoperative levels due to some degree of distal migration of the biceps tendon. Nevertheless, it does not seem to have improved during the first postoperative 3-month period and reaches a plateau thereafter. Mazocca et al. reported higher ASES scores in patients who underwent subpectoral biceps tenodesis without rotator cuff lesion than in patients who had concomitant rotator cuff lesion. Boileau et al. conducted a retrospective study to evaluate the outcomes of arthroscopic biceps tenotomy or tenodesis in patients who underwent surgery due to persistent shoulder pain. They concluded that both arthroscopic tenotomy and tenodesis can reduce pain.

In a study conducted by Checchia et al., 15 patients with rotator cuff tears and biceps tendon pathology were operated on. The authors stated excellent results in 11 patients while reporting satisfactory results as 93.4%. They evaluated the patients according to UCLA scores and detected Popeye signs in only one patient. The mean follow-up period of the patients was 32.4 months. We use ASES and Constant scores instead of UCLA to evaluate the patients. The mean follow-up period of the patients was 24 months in our study. Another study with 114 participants was conducted by MacDonald et al. It revealed good outcomes for both tenotomy and tenodesis groups. We did not compare the outcomes of tenodesis and tenotomy. Tenodesis was performed on all the patients included in our study.

Gialanelia et al. investigated the short-term effect of biceps surgery on rehabilitation and functional outcomes. They included 93 patients in their study. Twenty-five patients underwent rotator cuff surgery in addition to biceps tendon surgery, and 68 of them underwent only cuff repair. They evaluated Constant scores, ROM, pain, and UCLA at admission, the end of rehabilitation, and the postoperative 6th month. The patients who underwent simultaneous biceps tendon surgery and rotator cuff repair showed poorer functional outcomes in the postoperative 6th month. In our study, the elbow flexion and forearm supination values of the operated side were nearly double the preoperative values by the postoperative 6th month.

Saltzman et al. concluded that arthroscopic techniques are more commonly preferred if the surgeon decides to perform concomitant procedures. In our study, we also preferred to perform arthroscopic procedure for rotator cuff repair combined with biceps tenodesis. One of the advantages of the technique we used is providing a simple and low costing surgical procedure by performing biceps tenodesis and double-row rotator cuff repair simultaneously.
In contrast to our study, Yi et al.\textsuperscript{24} reported a higher degree of bicipital pain in the arthroscopic supraperartoral biceps tenodesis group compared to the open subpectoral group in the early postoperative period without a difference before 6 months. The VAS scores of the arthroscopic group at the postoperative 3rd month were similar to the present study (3±1). Preoperative, postoperative ASES and CS scores were higher, probably due to the inclusion of only small- and medium-sized tears. More patients in the arthroscopy group had an increase of BAD.\textsuperscript{24}

Shang et al.\textsuperscript{29} conducted a meta-analysis to compare tenodesis and tenotomy groups combined with rotator cuff repairs. The results showed no significant differences in terms of ASES scores, elbow flexion strength index, forearm supination index, and range of motion. However, only a few randomized controlled studies were included in this meta-analysis.\textsuperscript{29} We did not compare tenotomy and tenodesis patients; our study contained only one group of patients who underwent biceps tenodesis. This is one of the limitations of our study.

The disadvantages of LHB tenotomy are higher risks of Popeye signs and loss of flexion and supination strength in the elbow.\textsuperscript{30} It has been shown that tenodesis and tenotomy have resulted in good or excellent results in 74% and 77% of cases, respectively. Moreover, persistent pain related to tenodesis was reported in 24% of cases.\textsuperscript{31} In our study, the patients had almost halved pain levels by the 3rd month. In addition, we did not notice Popeye deformity in any patient. In a study by Schiefer et al.,\textsuperscript{32} arthroscopic proximal biceps tenodesis was performed using interference screws. Elbow flexion and supination strength tests were conducted in both arms, and no difference was found between the two sides. Similar to our study, none of the patients had Popeye deformity.

Baumgarten et al.\textsuperscript{33} evaluated patients by comparing those who underwent primary arthroscopic rotator cuff repair with and without biceps tenodesis. They stated no difference between groups and concluded that arthroscopic biceps tenodesis with simultaneous rotator cuff repair is safe and effective.\textsuperscript{33} A study involving 30 patients (12 of whom had a rotator cuff tear) who underwent isolated biceps tenotomy by Gill et al.\textsuperscript{34} They showed a significant improvement in function and a reduction in pain. We performed tenodesis on our patients and observed a decrease in pain and an increase in both forearm supination and elbow flexion.

In this study, the muscle strength measurements of the patients were compared with those of the non-operated side as a control group. When the measurements from the preoperative period to the postoperative 24th month were compared, it was found that the elbow flexion and forearm supination strength of the operated side reached a level similar to the non-operated side muscle strength as of the postoperative 12th month ($p > .05$). An unexpected situation of waste increase in muscle strength was observed in the non-operated side parallel to the increase in muscle strength on the operated side. The difference between the elbow flexion strength in the preoperative period and postoperative 24th month muscle strength measurements on the non-operated side was 6.2 kg ($p < .001$) and the difference in the forearm supination strength was 3.1 kg ($p < .001$). Among the reasons for this situation are: patients had been exposed to pain for approximately 1 year (mean preoperative pain duration: 11.2 ± 10.4 months), so they tended to avoid using these extremities (decreased quality of life and daily activity level); the patients felt better in terms of psychology and strength after the operation. We think that there may be an increase in motivation, strength, quality of life, and daily activity level of patients with strength measurements. However, in this study, patients were not evaluated in terms of these parameters.

Various studies showed the effect of anxiety and depression on the outcomes of rotator cuff repair surgery.\textsuperscript{35-37} Lau et al. aimed to evaluate the effect of anxiety or depression on the ASES score.\textsuperscript{38} They concluded that stronger feelings of anxiety or depression cause lower preoperative and postoperative scores. However, it is correlated with better improvement following surgery. A systematic review conducted by Kennedy et al. to determine whether the patients with rotator cuff tear were affected by psychosocial factors.\textsuperscript{39} For this purpose, they identified 980 articles. This study stated that psychosocial factors significantly affect the level of disability and preoperative pain.\textsuperscript{38} Similarly, Cho et al.\textsuperscript{36} suggested that the success of rotator cuff surgery may improve health-related quality of life and psychological status. Although we did not directly evaluate our patients pre- or postoperatively for any anxiety and depression, we believe the positive effects observed on the non-operated side may have resulted from these positive psychological outcomes.

Limitations of the present study include lack of a control group, short follow-up time, and the limited number of the patients. A control group consisting of rotator cuff repair with biceps tenotomy or consequences of patients with Popeye deformity remains to be clarified and both are the subject of future studies. Our hypothesis was proven as the increase of both supination and elbow flexion strengths were observed as early as the 3-month follow-up. Further studies are needed to clarify our findings.

**Conclusions**

In conclusion, arthroscopic biceps tenodesis into the anchors of the lateral row combined with rotator cuff repair provides an increase in the strength of elbow flexion and forearm supination as well as a decrease in pain. These improvements have been observed not only on the operated...
side but also the non-operated side, which was affected positively in the early postoperative period.

**Authors’ contribution**

Conception and design: All authors; administrative support: AI Kilic, O Hapa, R Ozmanevra, and ND Demirkiran; provision of study materials or patients: AI Kilic, O Hapa, R Ozmanevra, and O Gursan; collection and assembly of data: AI Kilic, O Hapa, and O Gursan; data analysis and interpretation: AI Kilic, R Ozmanevra, and ND Demirkiran; manuscript writing: All authors; final approval of manuscript: All authors.

**Declaration of conflicting interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Funding**

The author(s) received no financial support for the research, authorship, and/or publication of this article.

**Ethical approval**

This study was approved by the Ethics Committee of Dokuz Eylül University (No: 2020/06–39).

**Informed consent**

Signed informed consent for publication was obtained from all authors.

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**Abbreviations**

| Abbreviation | Definition |
|--------------|------------|
| ASES | American Shoulder and Elbow Surgeons Score |
| CS | Constant Score |
| VAS | Visual analog scale |
| BAD | Biceps apex distance |
| MRI | Magnetic resonance imaging |
| LHB | Long head of the biceps brachii tendon |
| ROM | Range of motion |
| UCLA | University of California—Los Angeles Shoulder Scale |
| EFS C | Elbow Flexion Strength—Contralateral side |
| EFS Op | Elbow Flexion Strength—Operated side |
| FFS C | Forearm Supination Strength—Contralateral side |
| FFS Op | Forearm Supination Strength—Operated side |