All-Arthroscopic Suprapectoral Versus Open Subpectoral Tenodesis of the Long Head of the Biceps Brachii Without the Use of Interference Screws

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Purpose: To compare patient-reported outcomes and healing rates after open subpectoral and all-arthroscopic suprapectoral biceps tenodesis without the use of interference screws in patients with more than 2 years of follow-up. **Methods:** Patients with at least 2 years of follow-up who underwent open subpectoral biceps tenodesis or all-arthroscopic suprapectoral biceps tenodesis without concomitant rotator cuff repair, labral repair, or Mumford procedure were considered for enrollment in the study. They were evaluated for visual analog scale (VAS), American Shoulder and Elbow Surgeons (ASES) score, and satisfaction with function and biceps contour. Ultrasonography was performed to evaluate the integrity of the tenodesis site and measure biceps muscle diameters on each arm. **Results:** Forty-nine patients were eligible for our study and of these, 38 were able to participate. Twenty-three patients had open subpectoral biceps tenodesis and 15 received all-arthroscopic suprapectoral biceps tenodesis. The average follow-up time was 4.5 years (range 2-9.1 years). There were no significant differences in anterior shoulder pain VAS, ASES scores, or satisfaction rates. The average anterior shoulder VAS was 0.7 ± 1.1 for the open group and 0.9 ± 1.8 for the arthroscopic group ($P = .74$). The mean ASES score for the open group was 90.6 ± 11.4 and 91.4 ± 13.9 for the arthroscopic group ($P = .69$). All patients had an intact tenodesis site on ultrasonography and the ratio of operative to nonoperative biceps diameters was 100.2% ± 12.8% for the open group and 99.1% ± 10.8% for the arthroscopic group ($P = .66$). There were no infections and no brachial plexus injuries in either group. **Conclusions:** Open subpectoral biceps tenodesis and all-arthroscopic suprapectoral biceps tenodesis are both successful surgeries with consistently positive outcomes. Tenodesis can be performed in either location without interference screw fixation with durable, reliable results. **Level of Evidence:** Level III, retrospective comparative trial.

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Pathology of the long head of the biceps brachii tendon is a common problem encountered by shoulder surgeons. Many clinical entities may contribute to pain from the biceps tendon, including SLAP tears, medial subluxation or dislocation of the biceps, and partial or complete ruptures and tears of the biceps tendon.[1] Clinically, these patients will present with progressive anterior shoulder pain centered over the biceps groove that is exacerbated with use and overhead activity.[2]

Treatment for biceps pathology may include nonoperative or operative interventions. Nonoperative treatment can include anti-inflammatories, physical therapy, activity modifications, and corticosteroid injections.[2] Those patients who fail conservative treatment are candidates for surgical management, although the optimal surgery is debatable.[3,4] Biceps tenotomy and tenodesis are 2 commonly performed procedures with advocates for each.[5] Biceps tenotomy has been recommended by some authors as it is simpler to perform and requires no postoperative rehabilitation or restrictions.[3] However, it may result in a postoperative "popeye deformity," and some patients may complain of cosmetic deformity, biceps cramping, and fatigue

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pain.[6] Biceps tenodesis can help minimize these complications while also improving anterior shoulder pain.[2,7] Tenodesis has therefore become more popular for treating biceps pathology in younger patients, athletes, and laborers.[2]

The use of tenodesis has been increasing in the recent past with a 1.7-fold increase in procedures performed between 2008 and 2011, when 44,932 procedures were performed.[8] Many techniques have been described, with various forms of arthroscopic and open procedures being performed at the rotator interval, in the biceps groove, as well as in the suprapectoral and subpectoral regions.[9-13] These methods employ several fixation strategies, and biomechanical testing has shown interference screw fixation and bone tunnel fixation as stronger constructs than other tested techniques.[14] A more recent biomechanical study by Sampatacos et al.[15] comparing intraosseous fixation to interference screw fixation showed the intraosseous technique to have higher failure loads and deformation compared with interference screws. Although the use of interference screws has become very popular, there is limited clinical research on bone tunnel techniques that do not use interference screws.

This study seeks to compare patient-reported outcomes and healing rates after open subpectoral and all-arthroscopic suprapectoral biceps tenodesis without the use of interference screws in patients with more than 2 years of follow-up. We hypothesized that there will be no difference in healing rates or outcome scores between the all-arthroscopic and open biceps tenodesis patients.

Methods

This study is a retrospective review comparing patients who underwent open subpectoral biceps tenodesis and all-arthroscopic biceps tenodesis. After obtaining institutional review board approval, billing records were reviewed to identify patient charts that had Current Procedural Terminology codes for open subpectoral tenodesis (23430) and all-arthroscopic tenodesis (29828) from January 2007 to February 2014.

Inclusion/Exclusion Criteria

We reviewed charts for patients who had open subpectoral tenodesis performed by one author (J.P.B.) as well as those patients who had arthroscopic biceps tenodesis by 2 other surgeons (M.H.G. and S.J.S.) who performed their particular technique exclusively during the study window. All surgeons are fellowship-trained sports surgeons with large shoulder practices and greater than 10 years of experience in practice. Patients were eligible for participation if they were at least 2 years out from surgery. Our goal was to focus our evaluation on biceps pathology, so exclusion criteria included concomitant rotator cuff repair, Mumford procedure, labral repair, or capsular plication. Patients were excluded if they had prior open shoulder surgery, were younger than 18 years, or were unable to provide consent. Following these criteria, 49 patients were eligible for participation.

All-Arthroscopic Surgical Technique

All patients were positioned in the lateral decubitus position and underwent a diagnostic 15-point examination.[16] Once biceps pathology was identified, the biceps was encircled with a no. 2 braided suture through the rotator interval to maintain its length-tension relation. The biceps was released off its insertion and attention was turned to the subacromial space where the biceps groove was identified and unroofed. A spinal needle was introduced from a point 6.5 to 7 cm distal and perpendicular to the midpoint of a line between the anterior and lateral portals. The scope was placed in the lateral portal, and both the biceps tendon and bicipital groove were marked with dye at the level of the spinal needle. A portal was made at this position and the biceps was externalized. A grasping, locking suture was tied around the biceps tendon at the level of the dye mark, and the proximal diseased tendon was amputated. The biceps tendon was sized and an opening in the cortex was drilled for this size at the location of the dye mark that was previously placed. This mark was approximately 1.5 cm proximal to the pectoralis tendon. Two 7/64″ drill holes were also made approximately 1.5 cm distal to this point and polydioxanone (PDS) suture was sequentially passed through these drill holes and out the larger proximal hole. The 2 limbs from the no. 2 suture around the biceps were then sequentially passed and the biceps tendon was dunked into the bone tunnel and tensioned, creating the modified intraosseous technique.[15] These sutures were then tied around the biceps tendon, thereby aligning the previously made dye marks and maintaining the length-tension relation. After closure, patients were placed in an UltraSling (DJO, Vista, CA).

Open Tenodesis Surgical Technique

All patients were positioned in the lateral decubitus position and underwent 15-point diagnostic arthroscopy. Once the decision was made to perform biceps tenodesis, a percutaneous spinal needle was passed through the rotator interval and biceps tendon and no. 1 polydioxanone was passed through the tendon to hold it in place after release. Once bursoscopy was performed and no additional pathology was seen, the open portion of the procedure began. The arm was taken out of traction, the beanbag was deflated, and the patient was carefully rolled into a semi-supine position. An incision was then made centered over the pectoralis major tendon in line with the axillary fold. The pectoralis major tendon was identified, and the plane under this tendon was opened with finger dissection. The

biceps groove was identified, and a sharp bent Homan retractor was placed on either side of the groove, directly adjacent to the bone. Care was taken while placing the medial retractor so as to protect the musculocutaneous nerve and avoid brachial plexus injury. The biceps groove was then opened and a mark was made at the point of tenodesis with bovie. A no. 2 high-strength suture was started at this position (to maintain the original length-tension relation) and passed in locking fashion approximately 3 cm proximally. The biceps tendon was externalized and the diseased portion of the tendon amputated. A small drill hole was made at the previously made bovie mark. The biceps tendon was sized and a drill hole of the corresponding size was made approximately 1 cm proximal to the small drill hole. A suture passer was placed in the distal hole and a shuttling suture was delivered through the larger proximal hole. The high-strength proximal suture end was shuttled out the distal hole and used to dunk the biceps into the proximal hole. Suture ends were tied over the bone bridge, maintaining its correct length-tension relation.[17] The incision was closed in layers, and patients were placed in an UltraSling.

Both groups of patients underwent the same postoperative physical therapy that included immediate elbow and wrist range of motion (ROM). Shoulder pendulums were begun after 1 week of surgery. Slings were continued for 6 weeks, and active assisted ROM was started at 6 weeks postoperatively. Patients were allowed to begin resisted biceps activity at 12 weeks postoperatively with subsequent return to sports and heavy activity at 4 to 6 months.

Consent/Outcomes

Patients were contacted by telephone for participation in the study and scheduled for an evaluation at the clinic. At that time, informed consent was obtained prior to enrollment in the study. Patients were asked to fill out a questionnaire regarding their satisfaction with their function, satisfaction with their biceps contour, daily anterior shoulder visual analog scale (VAS) pain score (Fig 1), and American Shoulder and Elbow Surgeons (ASES) shoulder score. Satisfaction questions were graded on a 0 to 10 scale, with 0 being completely dissatisfied, 5 being somewhat satisfied, and 10 being completely satisfied. Demographic data including age, gender, height, weight, body mass index, smoking status, and diabetes status were collected. Patients also identified hand dominance, asked of possible complications, and other surgeries after their biceps tenodesis. Study subjects were examined for strength with isometric manual testing of elbow flexion at their side and shoulder forward flexion. Elbow ROM was tested from full elbow flexion to full extension, and shoulder forward flexion and abduction were recorded. An ultrasonographic examination was conducted to identify the integrity of the biceps insertion site and the diameter of the biceps muscle on the operative and contralateral sides. Integrity of the biceps insertion was graded as intact or not intact. Muscle diameter was measured at the midpoint between the pectoralis major insertion and the antecubital crease with the elbow in full extension and the shoulder in neutral position (Fig 2). All ultrasonographies and examinations were performed by an independent orthopedic surgeon who did not perform surgery on the patient. Charts were then verified for demographic data, surgeries performed, and workers compensation insurance status.

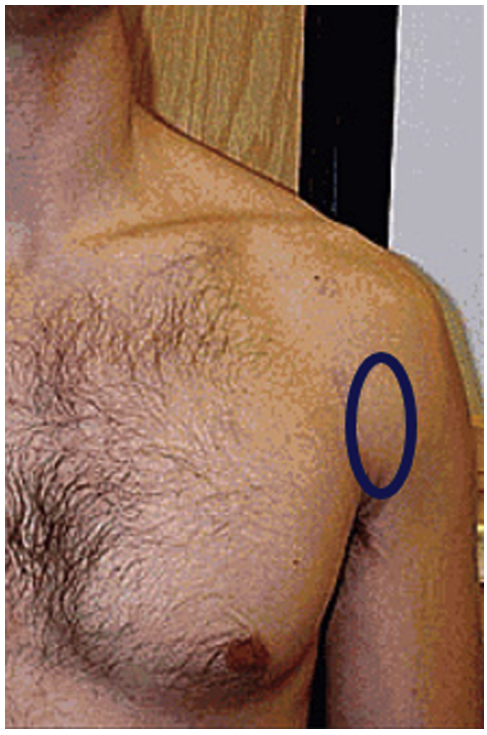

Fig 1. Patients were asked how much pain they had in the circled area on a daily basis using a visual analog scale from 0 to 10.

Statistical Analysis

An a priori power analysis was conducted to determine the minimum number of patients needed to adequately power our study. The minimum clinically important difference in ASES score ranges from 12 to 17.[18] We used a significance level (α) of .05 and assumed a standard deviation of ± 12 within each group to determine that we would need at least 15 patients in each group to detect a difference of 15 on the ASES score.

The *P* values for comparing continuous data that followed the normal distribution (age, height, weight, and body mass index) were computed using post hoc *t* tests under a parametric 1-way analysis of variance model. The *P* values for comparing nonnormal continuous data were computed using the corresponding

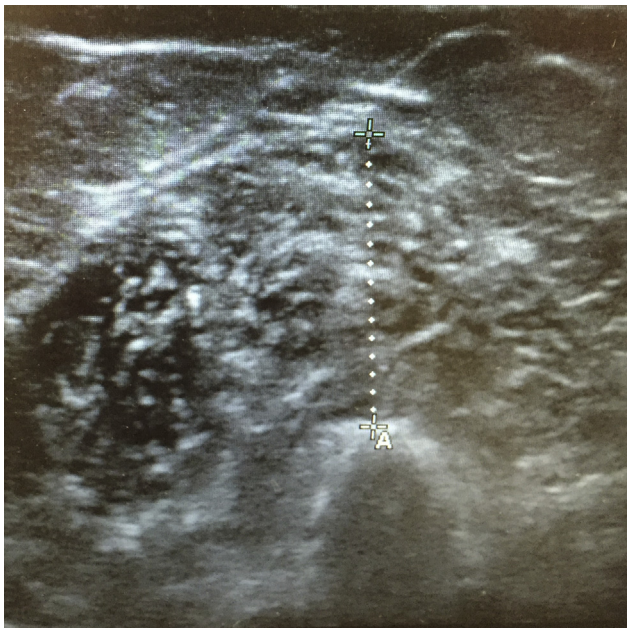

Fig 2. Axial ultrasonograph depicting the measurement for the biceps diameter.

nonparametric Kruskal-Wallis method. The *P* values for comparing proportions were computed using Fisher exact test.

Results

Forty-nine patients were eligible for the study and met the eligibility criteria with at least 2 years of follow-up. Of these 49 patients, 2 patients declined to participate and 9 patients were lost to follow-up. The remaining 38 patients made up the study group (Fig 3). There were 23 patients who had open biceps tenodesis and 15 patients in the all-arthroscopic group. All of the 38 patients were able to fill out the questionnaire and ASES score, but because of patients moving out of the study area 6 patients in the open group and 2 in the all-arthroscopic group were unable to have ultrasonographic examinations. All patients had at least 2 years of follow-up, with the open group averaging 68.5 months from surgery (range 32-109 months) and the all-arthroscopic group averaging 33.4 months from surgery (range 24-55 months).

Patient demographic information showed no significant differences in age, gender, body mass index, dominant arm surgery, or workers compensation status (Table 1). A significant difference was seen in follow-up time between the 2 groups, with the open group averaging 68.5 months from surgery and the all-arthroscopic group averaging 33.4 months from surgery ($P = .00001$). Concomitant procedures performed included 9 subacromial decompressions in each group ($P = .32$) and 1 patient in the arthroscopic group who had removal of loose bodies and a lipoma excision. No patients in the open group had prior surgery, and there were 4 patients in the arthroscopic group who had prior arthroscopic rotator cuff repair that was healed on MRI and 1 patient had a prior arthroscopic subacromial decompression ($P = .006$).

There were no significant differences in patient outcomes between the groups, including daily VAS for anterior shoulder pain, ASES scores, or satisfaction with function and contour (Table 2). Ultrasonography revealed that 100% of the biceps tendons were intact on evaluation and all had healed in place in both the open and arthroscopic groups (Fig 4). Biceps diameters differed between the 2 groups, with the open group being significantly larger on both the operative and nonoperative sides. However, the ratio of the operative side to the contralateral side was not significant (Table 2).

Elbow ROM between the groups was not statistically significant and measured 1.1° to 136.9° for the open patients and 0.4° to 133.7° for the all-arthroscopic patients ($P = .36$). Shoulder forward flexion was 169.2° ± 14.9° in the open group and 168.2° ± 11.0° in the arthroscopic group ($P = .61$). Shoulder abduction between the groups was also not statistically significant and measured 161.7° ± 22.6° for those with open tenodesis and was 158.9° ± 20.0° for the all-arthroscopic patients ($P = .44$). On manual isometric strength testing, there was no significant difference in elbow flexion strength between groups ($P = 1.00$).

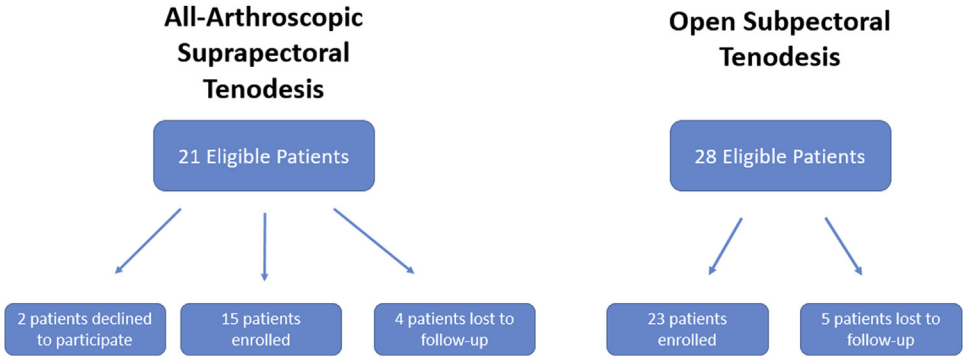

Fig 3. Flowchart of patient allocations and numbers enrolled.

Table 1. Demographic Data for Open and Arthroscopic Groups

	Open Biceps Tenodesis	All-Arthroscopic Biceps Tenodesis	*P* Value
Patients enrolled, n (%)	23 (82.1)	15 (71.4)	
Follow-up, mo, mean ± SD	68.5 ± 23.8	33.4 ± 8.1	.00001
Age, yr, mean ± SD	56.6 ± 10.7	60.0 ± 10.2	.46
BMI, mean ± SD	29.4 ± 5.8	27.3 ± 3.0	.32
Male sex, n (%)	21 (91.3)	10 (66.7)	.09
Dominant arm, n (%)	15 (71.4)	10 (66.7)	.76
Smoker, n (%)	4 (17.4)	1 (6.7)	.63
Diabetic, n (%)	1 (4.3)	3 (20.0)	.28
Workers compensation, n (%)	5 (23.8)	1 (6.7)	.37

BMI, body mass index; SD, standard deviation.

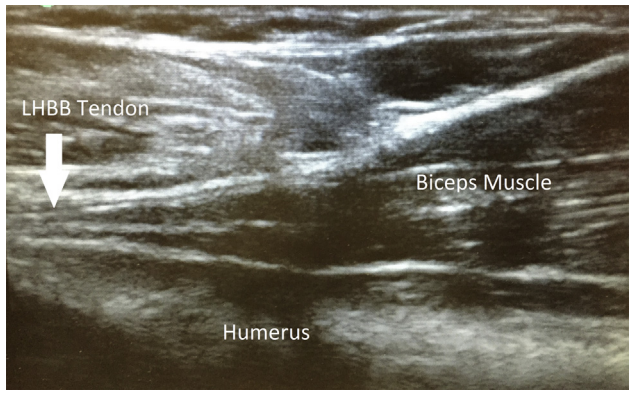

Fig 4. Sagittal ultrasonograph of the biceps musculotendinous junction, with normal triangular contour indicating an intact biceps tenodesis. (LHBB, long head of biceps brachii.)

There were no infections, no brachial plexus injuries, and no failures for any of the patients in this study. Two patients in the open group did go on to have another shoulder surgery for rotator cuff tears that occurred several years after their biceps tenodesis surgery.

Discussion

Our hypothesis was confirmed as ASES scores were similar and not statistically significant between the open and arthroscopic groups (90.6 open vs 91.4 arthroscopic). Patients also had a very low anterior shoulder VAS pain score, which measured 0.7 and 0.9 in the open and all-arthroscopic groups, respectively. With an average of 4.5 years of follow-up, patients were found to be very satisfied with their results in regard to function as well as contour for both groups. Ultrasonographic examinations revealed that all 30 patients that were available for the ultrasonographic portion of the study had an intact tenodesis site. This is somewhat better than other previously published studies that show intraosseous failure rates around 8%.[19] Although no patients in this study group had a failed tenodesis, other patients checked during a pilot study with failed tenodeses or tenotomies had a biceps diameter almost 50% larger. This would be expected as the biceps muscle contracts, with a resulting popeye deformity under these circumstances.

Table 2. Comparison of Outcomes for Open Biceps Tenodesis and All-Arthroscopic Patients

	Open Biceps Tenodesis	All-Arthroscopic Biceps Tenodesis	*P* Value
Daily anterior shoulder VAS score, mean ± SD	0.7 ± 1.1	0.9 ± 1.8	.74
ASES score, mean ± SD	90.6 ± 11.4	91.4 ± 13.9	.69
Satisfaction with function, mean ± SD	8.9 ± 1.8	9.3 ± 1.2	.81
Satisfaction with contour, mean ± SD	9.1 ± 1.4	9.2 ± 1.2	.96
Intact tenodesis on US, n (%)	17 (100)	13 (100)	1.00
Operative biceps diameter, cm ± SD	3.0 ± 0.6	2.4 ± 0.5	.02
Contralateral biceps diameter, cm ± SD	3.0 ± 0.6	2.4 ± 0.5	.01
Ratio of biceps diameter, % ± SD	100.2 ± 12.8	99.1 ± 10.8	.66

ASES, American Shoulder and Elbow Surgeons; SD, standard deviation; US, ultrasonograph; VAS, visual analog scale.

The findings of this study are similar to other groups that have compared open subpectoral biceps tenodesis to all-arthroscopic suprapectoral biceps tenodesis, although these groups used interference screws as their fixation method.[18,20] Gombera et al.[20] looked at 23 patients who underwent open subpectoral biceps tenodesis and compared them to 23 patients who had all-arthroscopic suprapectoral biceps tenodesis. Similar to our patient population, this group excluded concomitant rotator cuff repair and labral repair. They found no significant difference in patient satisfaction scores or ASES scores between their groups. They also found no significant difference with return to play, which was 78.3% for arthroscopic and 69.6% for open. They did report 2 minor complications in the open group, including 1 case of postoperative erythema that resolved with PO antibiotics and 1 case of brachial plexopathy that resolved with observation. Werner et al.[18] also compared arthroscopic suprapectoral biceps and open subpectoral biceps tenodesis and reported results similar to ours. They looked at 62 patients with regard to Constant-Murley scores, ASES scores, single assessment numeric evaluation, Simple Shoulder Test, long head of the biceps scores, and Veterans RAND scores and found no statistically significant differences between the groups with more than 2 years of follow-up. Similar to our study, this group did not find any brachial plexus injuries, but they did report ROM deficits in 9% of their patients during postoperative rehabilitation. They also excluded concomitant rotator

cuff tears and used interference screws much like the Gombera study.

Compared with these prior studies, satisfaction rates and ASES scores are in line with prior data. One notable difference between this study and previously published studies is the use of different fixation methods. However, the favorable clinical outcomes with interference screws and bone tunnel fixation is consistent with biomechanical studies showing similar mechanical strengths.[14] The fixation method employed in our study does perform well biomechanically[15] and is also a low-cost alternative to more expensive fixation techniques. Our study did have 2 patients in the open group that went on to have revision shoulder surgery for rotator cuff repairs years after their tenodesis surgery. This occurred 5 and 10 years after their first surgery, respectively. Neither of the other published studies[18,20] had reoperations, and we feel that this is due to our longer average follow-up of 4.5 years, versus 2.5 and 3.1 years in the previously published studies.

We found similar outcomes between our 2 groups and further studies may be needed to clarify which surgery is best for individual patients. With no musculocutaneous nerve injuries in this study group, open biceps tenodesis can be seen as a safe procedure compared with all-arthroscopic biceps tenodesis. One caveat for the all-arthroscopic technique is that increased arthroscopy time is needed and it may require advanced training and practice before attempting as swelling and prolonged pump pressures can potentially lead to adverse results. Future studies may look at operative time between the 2 techniques as another important variable. Zhang et al.[21] looked at tenotomy versus arthroscopic tenodesis in the biceps groove and found that on average, tenodesis added 10 minutes of operative time to each case ($P < .001$). Their technique involved tenodesis in the groove and is a simpler and likely faster technique than all-arthroscopic suprapectoral biceps tenodesis. Therefore, it is expected that even more time would be needed to allow for the technique described in this paper, which was not something that we evaluated because different surgeons were performing the 2 procedures. Sanders et al.[22] found 45.4% of proximal arthroscopic biceps tenodesis patients required revision, whereas only 7.7% of open distal biceps tenodesis were revised. This group brought attention to the possibility of negative outcomes if the long head of biceps brachii tendon is left in the groove after tenodesis. One notable difference between their arthroscopic tenodesis technique and ours is the location of the tenodesis site. This group incorporated their tenodesis proximal to the biceps groove and our location was distal, 1.5 cm proximal to the pectoralis tendon. The advantage of the techniques used in this paper is that all "hidden lesions" of the biceps tendon are addressed. Moon et al.[23] described "hidden lesions" in 100% of biceps tendons in the middle of the biceps groove and 77.8% of biceps tendons in the distal extra-articular portion. Therefore, proximal fixation of the biceps may leave these diseased portions of the biceps and might contribute to continued pain.

This study has several strengths that should be mentioned. The average follow-up of 4.5 years in this report is greater than previously published studies comparing open versus arthroscopic biceps tenodesis. The study group was focused and homogenous as we excluded concomitant rotator cuff repairs as well as labral repairs and acromioclavicular resections. The VAS employed in this study was equally focused to detect anterior shoulder pain in a way that patients could understand (Fig 1). There was also ultrasonographic evaluation of the tenodesis site to verify the integrity of the repair as well as ultrasonography data to show that biceps muscle diameters maintained their size after surgery.

Limitations

There are some weaknesses to this report that are also important to understand. As this is a retrospective study, we were unable to capture all the possible patients and lost some patients who could not be contacted. The study was also not randomized and the patients received the surgery that was thought to be best for them at that time. However, all patients received the form of biceps tenodesis that their surgeon employed during the study period and there was no variation in the type of tenodesis that individual surgeons performed. Patients with prior open shoulder surgery were excluded as they had bone augmentation procedures for instability and were outliers with regard to pain and function before their tenodesis surgery. This is a selection bias considering that 5 patients with prior arthroscopic procedures were included because their pre-tenodesis function was in line with the rest of the study group. There was a significant difference in follow-up time between the groups, with a mean follow-up of 68.5 months for the open group and 33.4 months for the arthroscopic group ($P = .00001$), but it is unlikely that significant changes take place in patient outcomes from 3 to 6 years after surgery. As this was a specific patient population, it may be difficult to generalize to patients with multiple pathologies, including concomitant rotator cuff tears and other pain generators.

Conclusions

Open subpectoral biceps tenodesis and all-arthroscopic suprapectoral biceps tenodesis are both successful surgeries with consistently positive outcomes. Tenodesis can be performed in either location without interference screw fixation with durable, reliable results.

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