Original Article

Subpectoral, Suprapectoral, and Top-of-Groove Biceps Tenodesis Procedures Lead to Similar Good Clinical Outcomes: Comparison of Biceps Tenodesis Procedures

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Purpose: To determine whether there is a difference in clinical results among open subpectoral (SB), arthroscopic low-in-groove suprapectoral (SP), and arthroscopic top-of-groove (TOG) locations in terms of patient-reported outcome measures for biceps tenodesis (BT) procedures using a global, self-reporting registry. **Methods:** We identified patients who underwent BT surgery in the Surgical Outcomes System registry. The inclusion criteria were isolated primary surgical procedures for BT, excluding patients with rotator cuff and labral repairs. Additional search requirements included repair location and 100% compliance with pretreatment and 2-year follow-up surveys. This study measured clinical outcomes comparing the 3 aforementioned techniques using the American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS) pain score, and Single Assessment Numeric Evaluation (SANE) score before treatment and at 3 months, 6 months, 1 year, and 2 years postoperatively. In addition, postoperative VAS pain scores were collected at 2 and 6 weeks. Statistical analysis was conducted using analysis of variance (Kruskal-Wallis test) and the Wilcoxon test. **Results:** A total of 1,923 patients from the Surgical Outcomes System registry qualified for the study; of these, 879 underwent the SB technique, 354 underwent the SP technique, and 690 underwent the TOG technique. There was no statistically significant difference in the demographic characteristics among the groups except that the TOG group was older: 60.76 years versus 54.56 years in the SB group and 54.90 years in the SP group ($P < .001$). In all groups, the ASES score statistically improved from before treatment (mean, 49.29 ± 0.63) to 2 years postoperatively (mean, 86.82 ± 0.80; $P < .05$). There were no statistically significant differences among the 3 groups in the VAS, ASES, and SANE scores at all time points ($P > .12$) except for the VAS score at 1 year ($P = .032$) and the ASES score at 3 months ($P = .0159$). At 1 year, the mean VAS score in the SB group versus the TOG group was 1.146 ± 1.27 versus 1.481 ± 1.62 ($P = .032$), but the minimal clinically important difference (MCID) was not met. The 3-month ASES Index scores in the SB, SP, and TOG groups were 68.991 ± 18.64, 66.499 ± 17.89, and 67.274 ± 16.9, respectively ($P = .0159$), and similarly, the MCID was not met. At 2 years, the ASES scores in the SB, SP, and TOG groups improved from 49.986 ± 18.68, 49.54 ± 16.86, and 49.697 ± 7.84, respectively, preoperatively to 86.00 ± 18.09, 87.60 ± 17.69, and 86.86 ± 16.36, respectively, postoperatively ($P > .12$). **Conclusions:** The SB, SP, and TOG BT procedures each resulted in excellent clinical improvement based on patient-reported outcome measures from a global registry. On the basis of the MCID, no technique was clinically superior to the other techniques in terms of VAS, ASES, or SANE scores at any time point up to 2 years. **Level of Evidence:** Level III, retrospective comparative study.

Biceps long head tendon pathology is a common source of anterior shoulder pain, with reports of biceps pathology seen at the time of shoulder arthroscopy in 40% of cases and in up to 76% in patients with full-thickness rotator cuff tears.[1-3] Although bicipital pathology is common, when conservative

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The authors report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received July 26, 2022; accepted March 23, 2023.

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2666-061X/22951

https://doi.org/10.1016/j.asmr.2023.03.007

treatment fails, surgical management remains controversial and is contentiously debated among shoulder specialists.[4]

Biceps tenotomy and tenodesis are well-established treatment options for recalcitrant biceps pathology.[4-8] Notwithstanding its simplicity, arthroscopic tenotomy has been shown to yield inferior clinical results compared with biceps tenodesis (BT).[5-7,9] In a meta-analysis of randomized clinical trials and cohort studies, Liu et al.[6] reported a relative risk of Popeye deformity of 3.29 in patients undergoing tenotomy versus tenodesis. Moreover, in the retrospective cohort studies analyzed, arm cramping was greater than 2 times more likely in tenotomy patients. In fact, over the past 10 years, national trends have shown that the incidence of biceps tenotomy has decreased while the techniques of open and arthroscopic tenodesis have increased significantly.[8,10,11] Most shoulder surgeons now opt for tenotomy in low-demand and medically compromised patients.[4,12]

Tenodesis is the preferred technique in healthy, active patients.[4,12] Two competing procedures based on location initially emerged: the mini-open subpectoral technique and the top-of-groove arthroscopic technique. In a retrospective series, Sanders et al.[13] reported that the arthroscopic technique was inferior to the open subpectoral technique with revision rates of 20.6% versus 6.8%. They concluded that techniques that did not release the biceps sheath or remove the tendon from the groove had an increased incidence of persistent pain requiring revision. To mitigate these concerns, a third location has evolved—the arthroscopic suprapectoral location—placing the site of the arthroscopic tenodesis below the groove but above the pectoralis, thereby eliminating any diseased tendon from the intertubercular groove.[14] Currently, BT procedures fall into 3 main groups based on the location of the tenodesis. There are strong proponents of each location, and there is no consensus regarding which is best.

The objective of our study was to determine whether there is a difference in clinical results among open subpectoral (SB), arthroscopic low-in-groove suprapectoral (SP), and arthroscopic top-of-groove (TOG) locations in terms of patient-reported outcome measures (PROMs) for BT procedures using a global, self-reporting registry. We hypothesized that there would be no significant difference in clinical outcomes among the SB, SP, and TOG techniques.

Methods

This study was a retrospective analysis of prospectively collected clinical outcomes of patients who underwent BT procedures between January 2011 and December 2019. A large, international, self-reporting registry, the Surgical Outcomes System (SOS; Arthrex, Naples, FL), was queried to select all patients who underwent BT procedures. Further criteria for inclusion in the study were patient compliance with the pretreatment and 2-year postsurgery surveys. Additionally, it was mandatory that the surgeon complete a survey describing the procedure, which included the technique, open or arthroscopic, and the location of the tenodesis, subpectoral, suprapectoral (low in groove), or at articular margin (top of groove). To obtain isolated biceps repairs, any patient who underwent concomitant labral or rotator cuff repair or revision surgery was excluded from the study. Patient demographic characteristics including age, sex, duration of symptoms, and shoulder dominance were also collected and analyzed.

The registry sent electronic, self-reporting surveys to enrolled patients to assess clinical outcomes, which included visual analog scale (VAS), American Shoulder and Elbow Surgeons (ASES) Index, and Single Assessment Numeric Evaluation (SANE) scores. Preoperative pain and function were determined by a retrospective review of prospectively collected data obtained before surgery. Postoperative pain and function data were collected prospectively and reviewed retrospectively at 4 time points: 3 months after surgery ± 2 weeks, 6 months after surgery ± 1 month, 1 year after surgery ± 2 months, and 2 years after surgery ± 2 months. Additionally, postoperative VAS pain scores were collected at 2 and 6 weeks. Patient and surgeon information in the SOS was deidentified; therefore, the number of facilities and postoperative protocol were unknown. This study complied with clinical research practices. In accordance with the Arthrex SOS, all patients who participated in the global registry were required to provide informed consent before their information was entered into the SOS. This study was approved by the Salus Institutional Review Board committee, an Association for the Accreditation of Human Research Protection Programs—accredited, unbiased nonprofit institutional review board (www.versiticlinicaltrials.org/salusirb).

Statistical and Covariate Analyses

Statistical analyses were performed using JMP software (version 15.0; SAS Institute, Cary, NC). A nonparametric analysis of variance (Kruskal-Wallis test) was performed to determine whether there were statistically significant differences in clinical outcome scores among the 3 groups at each time point. The Wilcoxon test was used to search for a difference in clinical outcomes among the 3 groups before treatment and at all postoperative time points, comparing 2 groups with each other (e.g., SB vs TOG). Pretreatment and postoperative clinical outcome scores were also compared based on the minimal clinically important difference (MCID) standard for BT. The MCID is 11 to

13 points for the ASES score, 3.5 points for the SANE score, and 1.6 points for the VAS score.[15,16] The MCID for the ASES score was used to perform a power analysis to set clinically relevant equivalence bounds. For the ASES scores at 3 months and 2 years, equivalence tests for mean differences yielded a power greater than 99%.

The significance level was set at $P < .05$. No adjustments for multiple comparisons were made. Results are reported as mean ± standard deviation. A post hoc power analysis using equivalence tests for mean differences was performed.

Results

Demographic Characteristics

We identified 11,002 patients who underwent either open or arthroscopic BT during the study period. The SOS database was further queried based on the inclusion and exclusion criteria, and 1,923 patients were included in the study. The patients were categorized into 3 groups based on surgical technique: open subpectoral (SB) technique (n = 879), arthroscopic low-in-groove suprapectoral (SP) technique (n = 354), and arthroscopic top-of-groove (TOG) technique (n = 690). The procedures were performed by 183 surgeons. Because compliance with the pretreatment and 2-year surveys was part of the inclusion criteria, the numbers of patients in each category at the pretreatment and 2-year follow-up time points were the same (Table 1). No statistically significant difference was noted for the demographic variables including sex, dominant shoulder, and duration of symptoms. The patients in the TOG group were significantly older than those in the other 2 groups, with a mean age of 60.76 ± 9.51 years versus 54.56 ± 11.75 in the SB group and 54.90 ± 10.58 in the SP group ($P < .0001$) (Table 2).

Table 1. Number of Patients Who Met Inclusion Criteria in Each Group

	Patients, n		
Time	VAS Score	SANE Score	ASES Score
Subpectoral location			
Before treatment	879	879	879
After treatment			
2 wk	810		
6 wk	838		
3 mo	821	798	803
6 mo	789	773	774
1 yr	783	779	777
2 yr	879	879	879
Suprapectoral location			
Before treatment	354	354	354
After treatment			
2 wk	332		
6 wk	334		
3 mo	326	320	323
6 mo	312	308	308
1 yr	315	313	313
2 yr	354	354	354
Top-of-groove location			
Before treatment	690	690	690
After treatment			
2 wk	654		
6 wk	658		
3 mo	655	653	651
6 mo	645	645	643
1 yr	638	633	632
2 yr	690	690	690

ASES, American Shoulder and Elbow Surgeons; SANE, Single Assessment Numeric Evaluation; VAS, visual analog scale.

VAS Scores

All groups showed marked improvement in mean VAS scores from preoperatively to postoperatively at all study time points including 3 months, 6 months, 1 year, and 2 years. The mean VAS score in the SB, SP, and TOG groups changed from 4.99 ± 2.44, 4.935 ± 2.16, and 4.898 ± 2.29, respectively, preoperatively to 1.389 ± 2.03, 1.252 ± 1.96, and 1.225 ± 1.81, respectively, at 2 years postoperatively. There was no statistically significant difference among the groups at any time point preoperatively or postoperatively other than at 1 year. At 1 year, the mean VAS score in the TOG group versus the SB group was 1.481 ± 1.62 versus 1.146 ± 1.27 ($P = .032$, Wilcoxon test) but did not meet the MCID of 1.6 for BT.[15] To determine whether one group had more pain in the early recovery period, we reviewed the VAS scores at 2 and 6 weeks. There was no statistically significant difference among the groups in the early postoperative period ($P > .05$, Wilcoxon test). A comparison of VAS scores in each group is displayed in Figure 1.

ASES Index Scores

All groups showed marked improvement in ASES scores from preoperatively to postoperatively at 3 months, 6 months, 1 year, and 2 years. The mean ASES score in the SB group increased from 49.986 ± 18.68 preoperatively to 86.185 ± 17.99 at 2 years postoperatively. The mean ASES score in the SP group increased from 49.54 ± 16.86 preoperatively to 87.333 ± 18.15 at 2 years postoperatively. The mean ASES score in the TOG group increased from 49.697 ± 7.84 preoperatively to 86.983 ± 6.20 at 2 years postoperatively. There was no statistically significant difference in mean ASES Index scores among the groups at any time point other than at 3 months. The 3-month ASES Index scores in the SB, SP, and TOG groups were 68.991 ± 18.64, 66.499 ± 17.89, and 67.274 ± 16.99, respectively ($P = .0159$). Further analysis of Wilcoxon testing between groups showed that there was a significant difference between the SB and SP groups ($P = .0155$), as well as between the SB and TOG groups ($P =$

Table 2. Demographic Characteristics of Patients Undergoing Biceps Tenodesis

Characteristic	Subpectoral	Suprapectoral	Top of Groove
Age, mean ± SD, yr	54.56 ± 11.75	54.90 ± 10.58	60.76 ± 9.507 ($P < .001$)*
Sex: M/F/NR, n (%)	535 (60.8)/303 (34.5)/41 (4.7)	196 (55.4)/141 (39.8)/17 (4.8)	416 (60.3)/248 (35.9)/26 (3.8)
Injured shoulder on dominant-hand side: yes/no/NR, n (%)	222 (25.3)/110 (12.5)/547 (62.2)	110 (31.1)/46 (13)/198 (55.9)	216 (31.3)/120 (17.4)/354 (51.3)
Duration of symptoms			
Mean ± SD, mo	13.87 ± 23.29	15.91 ± 32.88	18.61 ± 43.17
No. of respondents	242	211	215

F, female; M, male; NR, not reported; SD, standard deviation.
*Statistically significant.

.0204), but not between the SP and TOG groups ($P > .05$), meaning that at 3 months, there were only differences between the open and arthroscopic techniques and not between the 2 arthroscopic techniques. However, although the mean ASES score reached the level of statistical significance at 3 months, it did not reach the MCID of 13 points for BT.[15] A comparison among groups is displayed in Figure 2.

SANE Scores

All groups showed significant improvement in SANE scores from preoperatively to postoperatively on the 3-month, 6-month, 1-year, and 2-year surveys. The mean SANE score in the SB group increased from 40.664 ± 21.09 preoperatively to 78.276 ± 25.85 at 2 years postoperatively. The mean SANE score in the SP group increased from 38.617 ± 19.54 preoperatively to 78.952 ± 25.69 at 2 years postoperatively. The mean SANE score in the TOG group increased from 38.896 ± 21.09 preoperatively to 79.028 ± 25.99 at 2 years postoperatively. There was no statistically significant difference among any of the groups at any time point ($P > .05$, analysis of variance [Kruskal-Wallis test]). A comparison among groups is displayed in Figure 3.

Discussion

In our analysis, all 3 groups showed statistically significant improvements from before treatment to 2-year follow-up in the VAS, ASES Index, and SANE scores well surpassing the MCID standard for BT.[15] However, there was no statistically significant difference in PROMs that met the MCID among the 3 groups at any time point postoperatively. Although it has been reported in the literature that arthroscopic techniques in the early postoperative period (<3 months) are associated with increased pain, stiffness, and bicipital groove tenderness,[17,18] we were unable to find any difference in VAS scores at 2 and 6 weeks among the groups. Additionally, there was no difference in VAS, ASES, and SANE scores during the early postoperative period at 3 months. Therefore, we found that all BT techniques had similar clinical outcomes, including in the early postoperative period, and none of the 3 procedures was clinically superior to the other procedures. Surgeons may feel confident in their BT technique, taking into consideration their experience and patient factors.

Proponents of each technique tout its distinctly different merits and disadvantages.[19] The open subpectoral technique is a simple, technically easy, reproducible muscle-sparing procedure with an extremely low complication rate, with a reported rate of 2% in the literature.[20,21] It is easy to maintain the biceps muscle length-tension relation, and this technique is not dependent on proximal tendon quality to achieve stable fixation.[21] Biomechanically, the best fixation is achieved in the cortical diaphyseal bone with interference screw fixation.[22-24] Perhaps most important, by removing the diseased tendon and associated synovium, it is thought that this technique may decrease the potential for persistent anterior tunnel pain. Saltzman et al.,[10] in a retrospective study comparing open subpectoral versus arthroscopic tenodeses, reported a higher revision rate when diseased tendon was left within the groove. In an anatomic study, Nasu et al.[25] described an abundance of nociceptive receptors along the entire bicipital groove and transverse ligament from the ascending branch of the anterior axillary nerve. However, in a retrospective series of 1,083 arthroscopic articular margin repairs performed by 7 surgeons, Brady et al.[26] reported a low revision rate of 4.1%, a low rate of residual pain with the VAS score improving from 6.47 to 1.08 postoperatively, and significant improvement in objective shoulder outcome scores.

There is a movement toward less invasive arthroscopic techniques.[4,8,10-12] Advocates of arthroscopic techniques suggest high patient satisfaction, lower wound-healing complication rates especially owing to *Propionibacterium acnes* infection, and avoidance of iatrogenic injuries attendant to open surgery including rare nerve injuries to the musculocutaneous nerve.[12,18,19,21,26-30] Because the fixation is in cancellous metaphyseal bone, there are fewer intraoperative and postoperative fractures by avoiding placing a hole in the diaphyseal bone, creating a potential stress riser.[31]

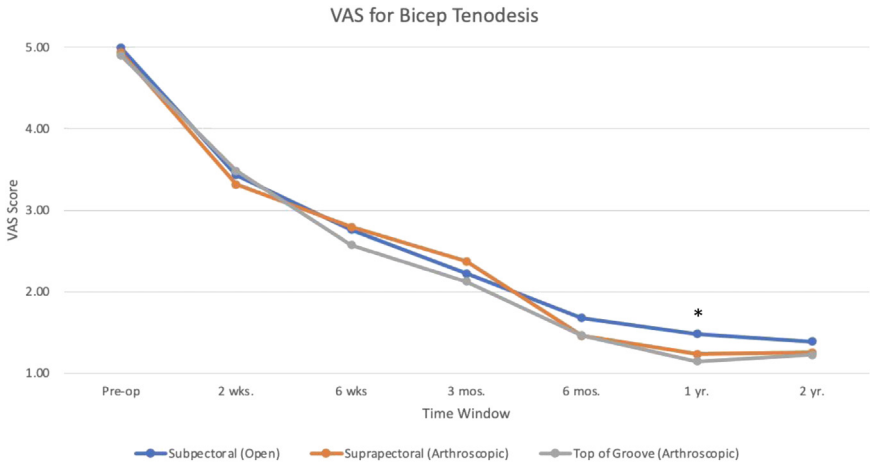

Fig 1. Graph displaying mean visual analog scale (VAS) scores among open subpectoral, arthroscopic low-in-groove suprapectoral, and arthroscopic top-of-groove groups over time. There was no statistically significant difference at any time point other than the difference between the open subpectoral and arthroscopic top-of-groove groups at 1 year (asterisk, $P = .032$, Wilcoxon test); however, the minimal clinically important difference was not reached. (mos, months; Pre-op, preoperatively; wks, weeks; yr, year.)

The biomechanics of fixation is an important consideration as well.[22,24,32-34] Ramos and Coelho,[33] using a sheep model, reported on 3 different fixation techniques: suture anchor, interference screw, and soft-tissue techniques. They reported that mean load to failure was nearly 50% stronger for interference screw fixation, at 152.7 ± 52.7 N as compared with 95 ± 35.3 N for suture anchor fixation and 104.7 ± 23.5 N for the soft-tissue technique.[33] In a matched cadaveric study, Werner et al.[35] compared arthroscopic suprapectoral and open subpectoral interference screw fixation of the biceps long head. They concluded that the arthroscopic technique had a greater tendency to over-tension the biceps length-tension relation, and they reported better interference screw fixation at the subpectoral location owing to better screw purchase in diaphyseal bone. Average load to failure for the arthroscopic procedure was 138.8 ± 29.1 N compared with 197 ± 38.6 N for

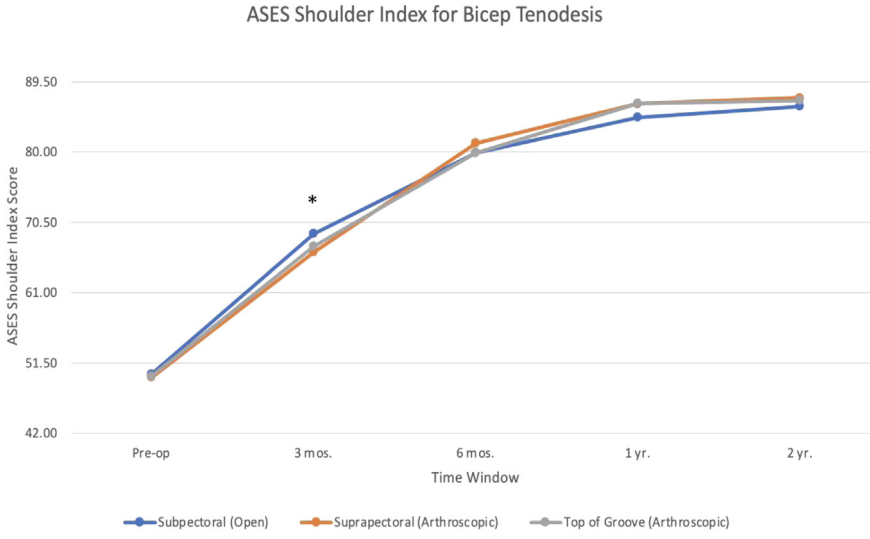

Fig 2. Graph displaying mean American Shoulder and Elbow Surgeons (ASES) Index scores among open subpectoral, arthroscopic low-in-groove suprapectoral, and arthroscopic top-of-groove groups over time. There was no statistically significant difference at any time point other than 3 months (asterisk, $P = .0159$, analysis of variance [Kruskal-Wallis test]); however, the difference did not meet the minimal clinically important difference for biceps tenodesis. (mos, months; Pre-op, preoperatively; yr, year.)

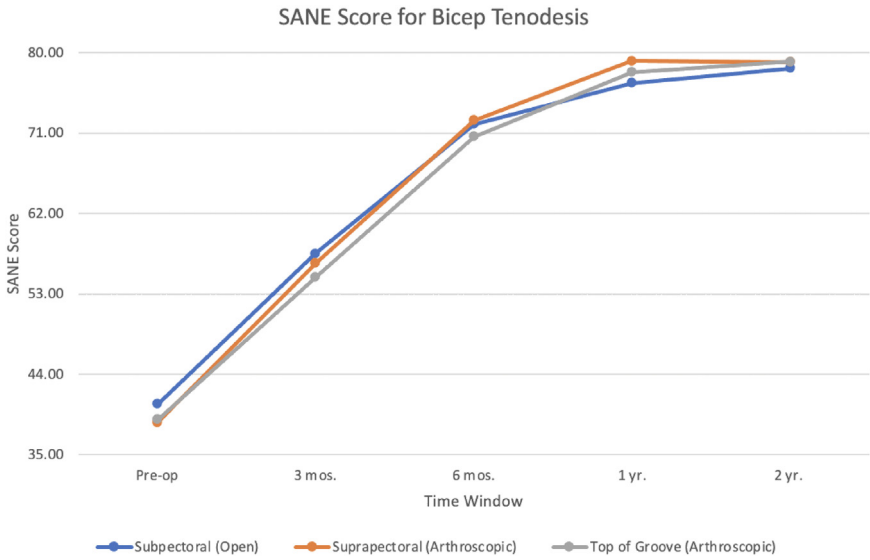

Fig 3. Graph displaying mean Single Assessment Numeric Evaluation (SANE) scores among open subpectoral, arthroscopic low-in-groove suprapectoral, and arthroscopic top-of-groove groups over time. There was no statistically significant difference among the groups at any time point. (mos, months; Pre-op, preoperatively; yr, year.)

the open subpectoral technique. In an effort to determine the true incidence of humeral shaft fractures after subpectoral BT, Overmann et al.[31] reviewed 15,085 cases performed between 2013 and 2016 by use of the US Military Health System Data Repository. The incidence was less than 0.1%, with 11 postoperative humeral fractures and 1 intraoperative humeral fracture, all of which were extra-articular spiral fractures that propagated through the tenodesis site.

There are currently several studies comparing open versus arthroscopic techniques.[5,14,17,18,27,35-44] Tu et al.,[17] in a comparison study of 117 patients, reported that VAS scores, the incidence of postoperative stiffness, and the incidence of persistent bicipital groove tenderness were higher in the arthroscopic group at 3 months; however, they also reported both techniques to be safe and effective with no difference in complication rates. In a single-institution, retrospective series of 1,526 BT procedures, McCrum et al.[40] found no difference in anterior shoulder pain, cramping, deformity, subjective weakness, or complications between tenodeses with a location below the groove and tenodeses in which the tendon was left in the groove. However, soft-tissue tenodesis cases had an increased incidence of new-onset shoulder pain and subjective weakness.[40] Moreover, in a PearlDiver database (Colorado Springs, CO) analysis of 15,257 patients undergoing BT, there was no significant difference in revision rates between arthroscopic and open BT procedures.[42] In the only Level I randomized prospective analysis of open subpectoral versus arthroscopic suprapectoral tenodesis, which included cutting of the transverse humeral ligament, Forsythe et al.[14] reported no differences in PROMs, functional outcomes, or complications. The arthroscopic technique increased surgical time, and one arthroscopic case had to be converted to an open technique because of severe tendon attenuation. More recently, in a systematic review of 8 studies, 1 Level I and 7 Level III, Belk et al.[18] reported similar improvements in clinical outcomes but did find that the arthroscopic technique was associated with an increased incidence of postoperative stiffness in the early postoperative period.

Limitations

One of the limitations of our study is that the global registry queried did not record failure rates for each respective approach; therefore, we are unable to comment on failure rates for the patients involved. Because we queried the database and the inclusion criteria included compliance with a 2-year survey, there may be inherent selection bias. Perhaps patients more satisfied with the procedure were more inclined to fill out the 2-year survey. Moreover, the study may have surgeon selection bias in that certain patient variables may have inclined the surgeon to choose one technique over another. However, in a survey of ASES members, only 38% of surgeons reported choosing their tenodesis technique based on the individual patient and case specifics, with 48% using the same technique in most of their cases.[4] Regarding our sample size, we did eliminate many patients who underwent BT and concomitant procedures to obtain clean data for isolated primary BT procedures, yielding greater than 1,900 participants. Therefore, we are unable to draw conclusions regarding a preferred technique when combined with another

procedure such as rotator cuff repair that is not uncommonly performed concomitantly. The stringent inclusion criteria of isolated tenodesis and 2-year patient compliance with postoperative surveys also explain the seemingly low yield of patients over a period of 9 years with 183 surgeons performing 1,923 isolated tenodesis procedures. Finally, the global registry includes many surgeons with their own specific surgical techniques and fixation methods (interference screw, suture anchor, soft-tissue fixation, and so on), which were not recorded. Accordingly, we are unable to remark on which fixation method affords the best results.

Conclusions

The SB, SP, and TOG BT procedures each resulted in excellent clinical improvement based on PROMs from a global registry. On the basis of the MCID, no technique was clinically superior to the other techniques in terms of VAS, ASES, or SANE scores at any time point up to 2 years.

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