Original Article

# An Expedited Sling Immobilization Protocol After Isolated Biceps Tenodesis Results in Clinical and Patient-Reported Postoperative Outcomes Equivalent to a Standard Rehabilitation Protocol

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**Purpose:** To characterize clinical and patient-reported outcomes for patients after isolated biceps tenodesis (BT) who underwent either standard or expedited sling immobilization protocols following surgery. **Methods:** This retrospective cohort study compared patients who were assigned to use a sling for either 4 to 6 weeks (standard) or 0 to 2 weeks (expedited) following an isolated BT. Primary endpoint included rate of re-rupture, surgical revision, loss of fixation, and Popeye deformity. Secondary endpoints included shoulder range of motion (ROM) as well as pre- and postoperative patient-reported outcomes (PROs) of pain and function. Missing data were managed via multiple imputation with chained equations. Complication prevalence 95% confidence intervals were calculated using the Clopper Pearson method and a series of hierarchical mixed effects linear regressions were performed to assess differences between sling interventions in PROs and ROM. **Results:** The average age of the standard cohort (n = 66) was 49 years (±14 years), and the average age of the expedited cohort (n = 69) was 47 years (±14 years). The expedited and standardized cohorts demonstrated 0.4 and 0.3 complications per 10,000 exposure days, respectively, with no significant difference between groups (1.4 [95% confidence interval 0.2-10.0], $P = .727$). There was no demonstrated difference in forward flexion, abduction, or external ROM. The expedited group had less improvement in visual analog scale for pain scores that was not clinically significant and there were no differences in PROs of function. **Conclusions:** No statistically significant difference in the rate of re-rupture, surgical revision, loss of fixation, or Popeye deformity was noted between protocols after isolated BT. Furthermore, there were no clinically significant differences in ROM or PROs identified between protocols after isolated BT. This study suggests that patients who have undergone isolated BT may safely discontinue sling use within 2 weeks after surgery. **Level of Evidence:** Level III, retrospective comparative study.

Biceps tenodesis (BT) is a common orthopaedic procedure that is indicated for interstitial tears, instability, or tenosynovitis of the long head of the biceps tendon, as well as for primary or secondary treatment of superior labrum anterior and posterior lesions.[1-5] This procedure can be done with multiple techniques, including either a supra- or subpectoral approach, both of which show similar outcomes.[6-8] Postoperative rehabilitation protocols vary considerably in both sling immobilization duration and timing of initiation of physical therapy.[9-12]

Generally, the use of a sling is part of the rehabilitation protocol after BT, which is intended to protect the fixation of the long head of the biceps.[13,14] However, the use of a sling can increase patients' risk for falls, limit their ability to drive, and cause discomfort or inconvenience during activities of daily living (ADLs).[15-17] If the length of sling immobilization after surgery can be safely reduced, unnecessary limitations on patients' ADLs can be minimized. In contrast to the

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robust data surrounding immobilization periods following rotator cuff repair, there is paucity of literature evaluating expedited sling protocols after isolated BT.[6,18-21]

The purpose of this study was to characterize clinical and patient-reported outcomes (PROs) for patients after isolated BT who were treated with either standard or expedited sling immobilization protocols following surgery. It was hypothesized that expedited sling immobilization and standard sling immobilization durations following BT would show no clinically relevant differences in the collected outcomes.

## Methods

### Study Design

After institutional review board approval (#00068529), a retrospective review of consecutively enrolled patients who underwent an isolated BT surgery from January 2018 to January 2022 at a single institution was conducted in line with Strengthening the Reporting of Observational Studies in Epidemiology guidelines (Fig 1).[22] Inclusion criteria required patients to have undergone an isolated BT surgery. Patients were excluded if they underwent concomitant reconstructive procedures, such as rotator cuff or labral repair, where the postoperative rehabilitation course was dictated by the concomitant procedures. Distal clavicle excision, superior labral or rotator cuff debridement, and/or subacromial decompression were permitted. They also were excluded if they were younger than 18 years of age or if they did not have a documented sling rehabilitation protocol, as characterization of their postoperative course would not be possible retrospectively. Race, sex, age, laterality, limb dominance, body mass index (BMI) at surgery, fixation site, fixation type, and surgical approach were documented for each group.

All operations were performed by 1 of 3 sports medicine fellowship-trained orthopaedic surgeons, including authors B.R.W. and N.A.T., via arthroscopic or combined arthroscopic and open approach for fixation of the long head of the biceps tendon. Patients who underwent surgery before December 2019 were treated with the standard protocol, whereas patients who underwent surgery after December 2019 were phased into treatment with the expedited protocol. The standard protocol called for 4 to 6 weeks of sling immobilization at all times besides hygiene and exercise, with PT initiation after 2 weeks. The expedited protocol called for 0 to 2 weeks of sling immobilization, with PT initiation within 2 weeks. Both protocols prohibited resisted elbow flexion/supination or lifting greater than 5 pounds for 6 weeks.

### Data Collection

All data collection was performed via review of the electronic medical record, and all PRO data were collected via Surgical Outcomes System (SOS; Arthrex, Naples, FL). Primary outcomes were the rate of re-rupture, surgical revision, loss-of-fixation, and Popeye deformity. Popeye deformity was evaluated via the documented physical examination in the electronic medical record visits by either the operative surgeon or an orthopaedic sports medicine—trained physician assistant. This is routinely collected as a part of the existing template for assessment at all pre- and postoperative time points. Secondary outcomes included range of motion (ROM) and PROs. Abduction, external rotation, and forward flexion range of motion were collected preoperatively, as well as 2, 6, 12, and 24 weeks' postoperatively. PROs data collected included visual analog scale for pain (VAS), American Shoulder and Elbow Surgeons (ASES), Single Assessment Numeric Evaluation (SANE), the shortened Disabilities of the Arm, Shoulder and Hand questionnaire (QuickDASH), and the Patient-Reported Outcomes Measurement Information System (PROMIS-10) preoperatively as well as 6 months' and 1 and 2 years' postoperatively.[23-33]

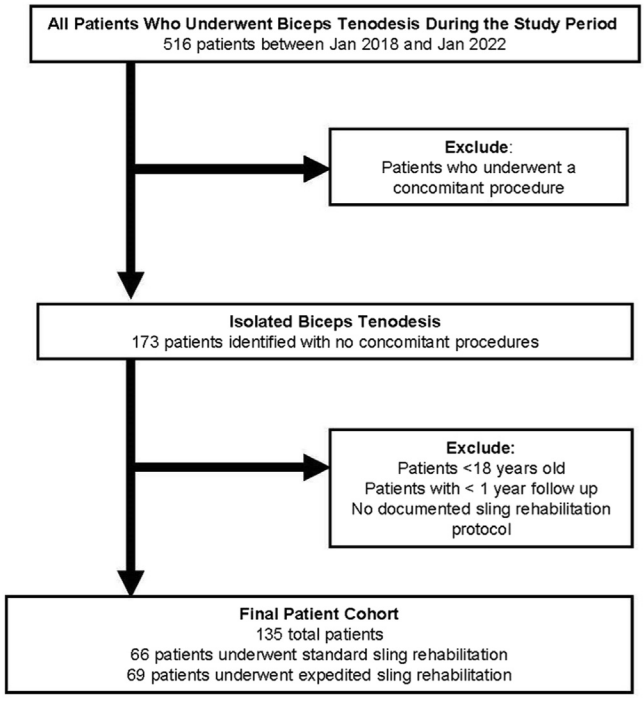


**Fig 1.** Patient cohort selection for standard sling rehabilitation (n = 66) and expedited sling rehabilitation (n = 69) for patients enrolled in this study consistent with the STROBE guidelines.

### Statistical Analyses

Patient characteristics were analyzed using the $\chi^2$ test. A priori statistical significance was defined as $P \geq .05$. Before analyses, missing data were assessed. Missing data prevalence was 73% and varied between variables (age: 0%, sex: 0%, BMI: 0%, days of follow up: 0%, preoperative external range of motion: 84%, 24-week external range of motion: 86%, preoperative VAS: 53%, 2-year VAS: 84%; Appendix Table 1, available at www.arthroscopyjournal.org). No patients were lost to follow-up; as a result, no right censor issues were present. No missing data differences in either sling intervention were observed, nor were differences in preoperative or end of follow-up PROs or ROM differences observed. The missing data mechanism was missing at random and to control for missing data, multiple imputation with chained equations were performed with 70 iterations. Variables for imputation included age, BMI, sling intervention, preoperative and follow-up times for range of motion (flexion, abduction, and external rotation), PROs (VAS, ASES, Quick DASH, and PROMIS), complications, and follow-up time. Rubin's rules of imputation iteration aggregation were performed for all analyses.

Complication prevalence 95% confidence intervals (95% CIs) were calculated using the Clopper Pearson method. Complication rates were calculated per 10,000 exposure days. Rate ratios were performed to compare complication rates and sling intervention. To assess potential differences between sling interventions and ROM and PROs, a series of hierarchical mixed effects linear regressions were performed. Hierarchical random effects were at the individual patient and surgeon level. Fixed effects controlled for an interaction of sling intervention and time of follow-up. All analyses were performed in R 4.1.2 (Core Team [2021]. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org/). The *naniar* package was used for missing data analyses, the *mice* package for multiple imputation, the *GenBinomApps* package for Clopper Pearson prevalence measures, the *fmsb* package for rate ratio analyses, the *lme4* package for mixed effects analyses, the *broom.mixed* package for Rubin's rule aggregation with multiple imputation, and the *ggeffects* package for mixed effects model visualization.

## Results

The average age of the standard cohort (n = 66) was 49 years (±14 years), and the average age of the expedited cohort (n = 69) was 47 years (±14 years) (Table 1). Average follow-up time for the standard group was 3.09 (±1.04) years, which was on average longer than that for the expedited group at 2.09 years (± 0.77 years) ($P < .001$). There were no significant differences in the ratios of gender and race as well as the BMI for this cohort (Table 1).

### Complications

A total of 52,649 exposure days were collected for the expedited sling cohort and 74,478 exposure days for the standard sling cohort. Complications for the purpose of this study include re-rupture, surgical revision, loss-of-fixation, and Popeye deformity. Overall complication prevalence for the expedited sling cohort was 3% (95% CI 0-10) and the standard sling cohort was 3% (95% CI 0-11) (Table 2). Complication rates for the expedited cohort were 0.4 complications per 10,000 exposure days and for the standard cohort were 0.3 complications per 10,000 exposure days, with no differences in rates of complications between cohorts (1.4 [95% CI 0.2-10.0], $P = 0.727$).

### Patient-Reported Outcomes

The standard sling cohort reported −0.8 (95% CI −1.2 to −0.30) lower pain, measured by VAS, over the follow-up period compared with the expedited sling cohort (Figure 2). There were no differences in in PROs between the 2 treatment groups over the follow-up period for the ASES Functional Score (0.14 [95% CI −3.54 to 3.52]), ASES Index Score (5.3 [95% CI −26.3 to 36.9]), SANE (5.7 [95% CI −31.9 to 43.3]), Quick DASH (−0.2 [95% CI −28.6 to 28.2]), PROMIS Physical Component Score (−0.2 [95% CI −28.6 to 28.2]), nor

**Table 1.** Demographics for Patients in the Standard and Expedited Sling Rehabilitation Cohorts

| Variable | Standard (n = 66) | Expedited (n = 69) | *P* Value |
|---|---|---|---|
| Age | 49 ± 14 | 47 ± 14 | .341 |
| Sex (male/female) | 34/32 | 33/36 | .671 |
| BMI | 30 ± 6 | 31 ± 7 | .636 |
| Follow-up, y | 3.09 ± 1.04 | 2.09 ± 0.77 | .001* |
| Race (White/Black/other) | 55/9/2 | 57/11/1 | .777 |
| Laterality of surgery (dominant/nondominant/unknown dominance arm) | 24/28/14 | 26/21/22 | .2478 |
| Surgical approach (arthroscopic) | 28/38 | 47/22 | .0033* |
| Fixation site (suprapectoral/subpectoral) | 28/38 | 47/22 | .0033* |
| Fixation type (suture anchor/interference screw/button) | 28/36/1 | 41/28/0 | .0699 |

NOTE. Values are shown as mean ± standard deviation.
*Statistically significant.

**Table 2.** Prevalence of Primary Outcomes of Loss of Fixation, Re-Rupture, Revision Rate, and Popeye Deformity for Patients in the Standard and Expedited Group

| Variable (%) | Standard | Expedited | *P* Value |
|---|---|---|---|
| Popeye deformity | 2% (n = 1) | 3% (n = 2) | .5857 |
| Loss of fixation | 0% (n = 0) | 0% (n = 0) | .999 |
| Revision rate | 2% (n = 1) | 0% (n = 0) | .3048 |
| Re-rupture rate | 1% (n = 1) | 1% (n = 1) | .9747 |

the PROMIS Mental Component Score (−0.2 [95% CI −28.6 to 28.2]).

### Range of Motion

There was no difference in range of motion between both sling interventions in forward flexion (−5.7 [95% CI −69.0 to 55.6]), abduction (−4.3 [95% CI] −93.3 to 88.7]), or external rotation (−6.8 [95% CI −38.6 to 25.0]) during the duration of follow-up (24 weeks) (Figs 3-5).

## Discussion

The most important finding of this study was that, for patients who underwent an isolated BT, there was no clinically significant difference in overall complication rates, ROM, or PROs between the standard and expedited sling cohorts, which supported our hypothesis. The only observed difference was a greater improvement in pain by 0.8 points on the VAS scale among the standard protocol group. However, this difference in pain did not meet the threshold of minimum clinically important difference for the VAS pain scale and is likely not clinically significant.[34] Otherwise, there was no difference observed in risk of Popeye deformity, loss of fixation, or re-rupture, and there was no difference in PROs as quantified by SANE, VAS, ASES, QuickDASH, PROMIS-10 Physical, and PROMIS-10 Mental subscores. In patients undergoing isolated BT, expedited sling protocol may be a safe option without notable increased risk of adverse events.

These results suggest that patients who have undergone BT may safely discontinue sling use within 2 weeks after surgery. Early sling discontinuation allows patients to perform ADLs sooner, which may offer improved balance and earlier initiation of physical therapy.[15-17] Conservative rehabilitation measures have been driven by concern that tendon healing requires prolonged immobilization; however, our study suggests that expedited mobility does not impact risk of surgical failure, ROM, or functional PROs.[35,36] Other clinical studies investigating rehabilitation after BT have shown that early mobilization is as safe as the standard 4 to 6 weeks of immobilization, although no others examined isolated BT with both subpectoral and suprapectoral approaches.[6] In 2018, Liechti et al.[37] showed that patients who underwent mini-open subpectoral BT and were given no postoperative restrictions had failures requiring revision at rates comparable with rates published by others, at 2.2%, but had no comparison group.[38] Similarly, our study found no differences between expedited and standard sling cohorts. Further, a cohort study done by Keeling et al.[38] in 2021 compared 21 patients with sling use for comfort only with 44 patients with 4 weeks of sling use, and found no differences in ASES, SANE, or ROM at 6 months, consistent with the findings of our study. However, their study included both isolated BT and BT with concomitant rotator cuff repair, and patients with concomitant rotator cuff repair were given different restrictions.

This study included heterogenous surgical approaches, fixation sites, and types of fixation. However, based on recent comparative studies, type and site of fixation are equivocal in terms of clinical outcomes. A metanalysis in 2020 by Dekker et al.[39] indicated that there was no difference in load to failure or cyclic displacement in a cadaveric model between either suprapectoral or subpectoral tenodesis location or

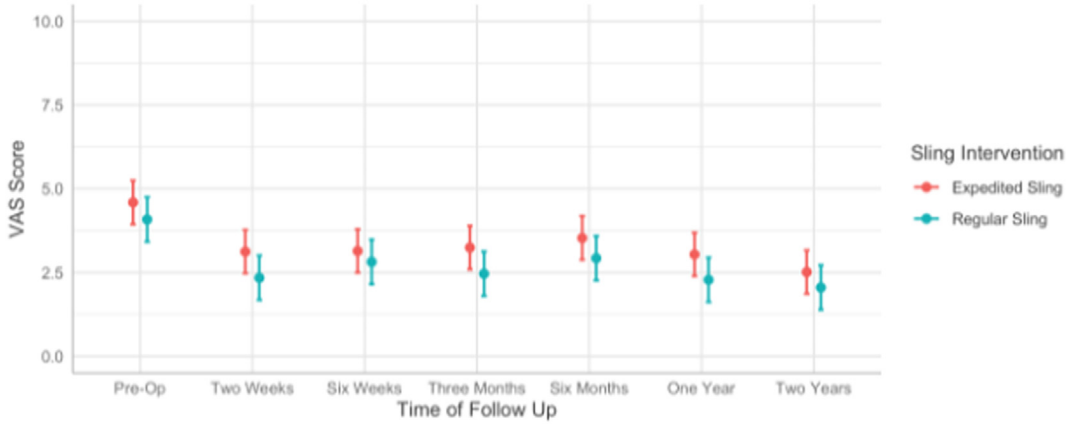


**Fig 2.** Visual analog scale for pain (VAS) for patients in the sling (green) and expedited (red) cohorts preoperatively, 2 and 6 weeks, as well as 3, 6, 12, and 24 months' postoperatively.

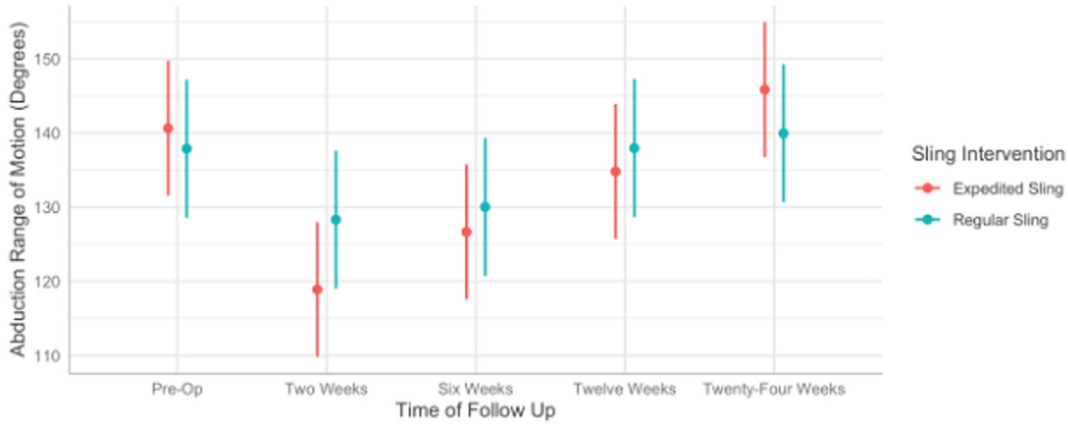


**Fig 3.** Abduction range of motion for the standard (green) and expedited (red) cohorts preoperatively, as well as 2, 6, 12, and 24 months' postoperatively.

between the following types of fixation: cortical button, interference screw, and suture anchor. Furthermore, Diaz et al.[40] in 2020 found that in a comparison of 6 methods of fixation (interference screw, cortical button, double-loaded anchor, single-loaded anchor, and soft-tissue tenodesis), that the tendon—suture interface was the main site of failure, rather than the fixation site. They also found that there was no significant difference in fixation type, concluding that the most important factor dictating that tendon quality and suture parameters were the most important factors in determining failure load rather than fixation type.[40] In human research, Forsythe et al.[6] found no difference in PROs or complication rates between open subpectoral and arthroscopic suprapectoral BT. As such, the heterogeneity of this sample likely does not impact the results of this study.

Particularly when coupled with persistent symptoms, a Popeye deformity is a major difference in outcome between BT and biceps tenotomy.[41] In the current practice, the latter is reserved for pathology of the long head of the biceps in elderly, low-demand patients, and/or patients with morbid obesity. This study evaluated for Popeye deformity via retrospective review of documented patient reports and formal physical examination. However, no formal radiographic correlation, with ultrasound or advanced imaging was performed. As such, this can lead to an underestimation of a Popeye deformity.[41,42] A recent meta-analysis of Level I randomized controlled trials comparing BT with tenotomy demonstrated Popeye deformity occurred in 6.8% of tenodesis patients and 23.3% of the tenotomy group.[5] Although it is possible the prevalence of a Popeye deformity was underestimated in this study, the prevalence identified is consistent with reported values in literature.[43,44] Patients with more subtle findings may have been detected with ultrasound or magnetic resonance imaging. However, due to the primarily

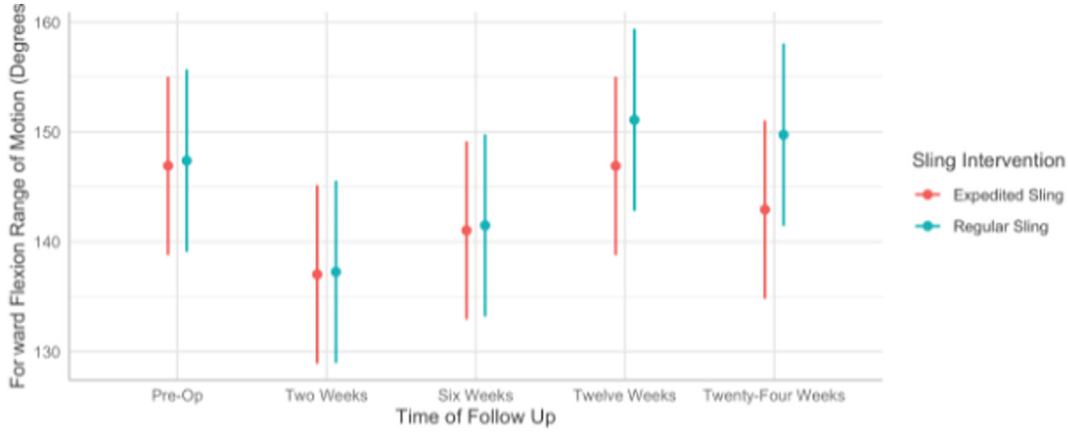


**Fig 4.** Forward flexion range of motion for the standard (green) and expedited (red) cohorts preoperatively, as well as 2, 6, 12, and 24 -months' postoperatively.

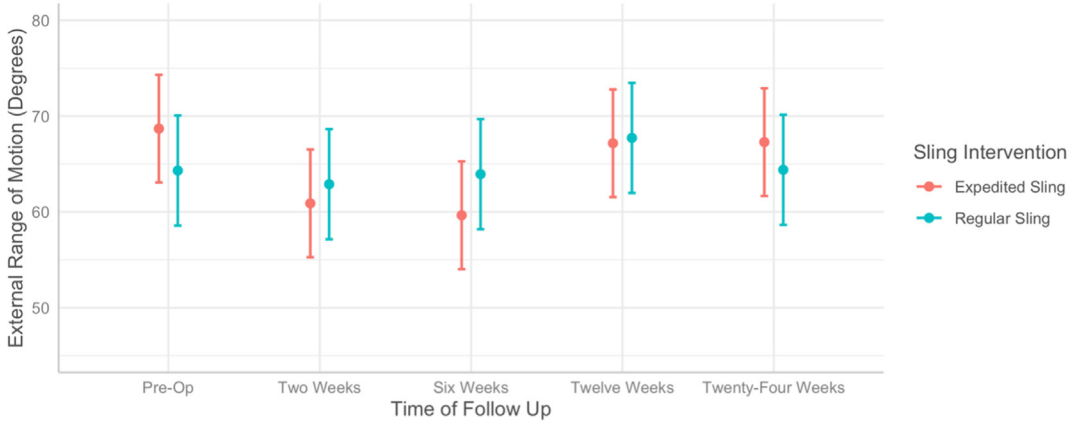


**Fig 5.** External range of motion for the standard (green) and expedited (red) cohorts preoperatively, as well as 2, 6, 12, and 24 months' postoperatively.

cosmetic nature of Popeye deformity, the increased patient burden of additional imaging to detect subtle deformity was not justified for this study.

BT is a safe procedure that provides significant clinical benefit and high patient satisfaction.[45-47] As BT remains a common operation, standard postoperative rehabilitation is essential in formulating safe, evidence-based guidelines for that minimize unnecessary restrictions and secondary loss of motion to patients.[48] Given the results of this study, physicians may safely elect to pursue early discontinuation of sling use with expedited mobilization, though further multi-centered randomized trials are necessary to solidify these findings.

### Limitations

This study is not without limitations. First, all patients were treated by 1 of 3 surgeons at a tertiary referral center, which may limit the generalizability of this study. Second, characteristics that influenced surgeon choice in rehabilitation protocol, such as handedness or occupation, were not analyzed and may impact patients' comfort and ability to undergo an expedited sling protocol. Future studies can prospectively collect this information to better qualify their results. Third, given the modest sample size of this cohort and the retrospective nature of data collection, the results and demographics in this study would, again, benefit from a prospective randomized control or cohort design. Lastly, the standard cohort had a significantly longer follow-up time than the expedited group, which was due to fact that most patients who had surgery before December 2019 also underwent the standard sling protocol. Shortened characterization of surgical outcomes for the expedited group is possible as a result of this incongruency.

## Conclusions

No statistically significant difference in the rate of re-rupture, surgical revision, loss-of-fixation, or Popeye deformity was noted between protocols after isolated BT. Furthermore, there were no clinically significant differences in ROM or PROs identified between protocols after isolated BT. This study suggests that patients who have undergone isolated BT may safely discontinue sling use within 2 weeks after surgery.

## Disclosure

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: B.R.W. reports publishing royalties from *Arthroscopy* and Elsevier; consulting fees from DePuy and FH Ortho; paid presenter for Arthrex and Vericel; board member for American Academy of Orthopaedic Surgeons, American Orthopaedic Society for Sports Medicine, American Shoulder and Elbow Surgeons, *Arthroscopy*, and AANA and editorial or governing board for *Video Journal of Sports Medicine*; stock options from Kaliber AI, Sparta, and Vivorté; and other financial or material support from the Musculoskeletal Transplant Foundation and Smith & Nephew. All other authors (M.A.G., A.R., A.J.R., E.C.B., G.S.B., N.A.T.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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## References

1. Vellios EE, Nazemi AK, Yeranosian MG, et al. Demographic trends in arthroscopic and open biceps tenodesis across the United States. *J Shoulder Elbow Surg* 2015;24:e279-e285.

2. Creech MJ, Yeung M, Denkers M, Simunovic N, Athwal GS, Ayeni OR. Surgical indications for long head biceps tenodesis: A systematic review. *Knee Surg Sports Traumatol Arthrosc* 2016;24:2156-2166.
3. Recker AJ, Waters TL, Bullock G, et al. Biceps tenodesis has greater expected value than repair for isolated type II SLAP tears: A meta-analysis and expected-value decision analysis. *Arthroscopy* 2022;38:2887-2896.e4.
4. Hong IS, Meade JD, Young BL, et al. Trends in repair vs. biceps tenodesis for superior labrum from anterior to posterior (SLAP) tear: An epidemiological study. *Cureus* 2022;14:e27096.
5. Belk JW, Kraeutler MJ, Houck DA, Chrisman AN, Scillia AJ, McCarty EC. Biceps tenodesis versus tenotomy: A systematic review and meta-analysis of level I randomized controlled trials. *J Shoulder Elbow Surg* 2021;30:951-960.
6. Forsythe B, Zuke WA, Agarwalla A, et al. Arthroscopic suprapectoral and open subpectoral biceps tenodeses produce similar outcomes: A randomized prospective analysis. *Arthroscopy* 2020;36:23-32.
7. Gombera MM, Kahlenberg CA, Nair R, Saltzman MD, Terry MA. All-arthroscopic suprapectoral versus open subpectoral tenodesis of the long head of the biceps brachii. *Am J Sports Med* 2015;43:1077-1083.
8. Duchman KR, DeMik DE, Uribe B, Wolf BR, Bollier M. Open versus arthroscopic biceps tenodesis: A comparison of functional outcomes. *Iowa Orthop J* 2016;36:79-87.
9. Mazzocca AD, Cote MP, Arciero CL, Romeo AA, Arciero RA. Clinical outcomes after subpectoral biceps tenodesis with an interference screw. *Am J Sports Med* 2008;36:1922-1929.
10. Civan O, Bilsel K, Kapicioglu M, Ozenci AM. Repair versus biceps tenodesis for the slap tears: A systematic review. *J Orthop Surg (Hong Kong)* 2021;29:23094990211004794.
11. Werner BC, Evans CL, Holzgrefe RE, et al. Arthroscopic suprapectoral and open subpectoral biceps tenodesis: a comparison of minimum 2-year clinical outcomes. *Am J Sports Med* 2014;42:2583-2590.
12. Waugh CA, Havenhand T, Jain N. Open subpectoral tenodesis for isolated traumatic long head of biceps tendon rupture provides excellent functional outcomes in active male patients. *Cureus* 2022;14:e31553.
13. Kim H, Lee K, Jang IT, Shin DC. Arthroscopic suprapectoral biceps tenodesis: The "double secure loop technique" using an all-suture anchor and an arthroscopic suture passer. *Arthrosc Tech* 2019;8:e1511-e1515.
14. Carvalho FF, Nolte PC, Pinheiro J, Guehring T, Egenolf M, Chatterjee T. Improvement in long head of biceps function and lower rate of biceps deformities after subpectoral tenodesis with cortical button and interference screw vs. arthroscopic tenotomy: A 4-year follow-up. *JSES Int* 2022;6:820-827.
15. Sonoda Y, Nishioka T, Nakajima R, Imai S, Vigers P, Kawasaki T. Use of a shoulder abduction brace after arthroscopic rotator cuff repair: A study on gait performance and falls. *Prosthet Orthot Int* 2018;42:136-143.
16. Rossi MJ, Brand JC, Lubowitz JH. Return to driving after arthroscopic and related surgery: Before patients start, how do we know they can stop? *Arthroscopy* 2018;34:1745-1747.
17. Hatta T, Yamamoto N, Sano H, Itoi E. Comfort and acceptability of various immobilization positions using a shoulder external rotation and abduction brace. *J Orthop Sci* 2017;22:285-288.
18. Shen C, Tang ZH, Hu JZ, Zou GY, Xiao RC, Yan DX. Does immobilization after arthroscopic rotator cuff repair increase tendon healing? A systematic review and meta-analysis. *Arch Orthop Trauma Surg* 2014;134:1279-1285.
19. Cuff DJ, Pupello DR. Prospective randomized study of arthroscopic rotator cuff repair using an early versus delayed postoperative physical therapy protocol. *J Shoulder Elbow Surg* 2012;21:1450-1455.
20. Lee BG, Cho NS, Rhee YG. Effect of two rehabilitation protocols on range of motion and healing rates after arthroscopic rotator cuff repair: Aggressive versus limited early passive exercises. *Arthroscopy* 2012;28:34-42.
21. Gottschalk MB, Karas SG, Ghattas TN, Burdette R. Subpectoral biceps tenodesis for the treatment of type II and IV superior labral anterior and posterior lesions. *Am J Sports Med* 2014;42:2128-2135.
22. International Olympic Committee Injury and Illness Epidemiology Consensus Group, Bahr R, Clarsen B, Derman W, et al. International Olympic Committee Consensus Statement: Methods for Recording and Reporting of Epidemiological Data on Injury and Illness in Sports 2020 (Including the STROBE Extension for Sports Injury and Illness Surveillance (STROBE-SIIS)). *Orthop J Sports Med* 2020;8:2325967120902908.
23. Celik D. Comparison of the outcomes of two different exercise programs on frozen shoulder. *Acta Orthop Traumatol Turc* 2010;44:285-292.
24. Tashjian RZ, Hung M, Keener JD, et al. Determining the minimal clinically important difference for the American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and visual analog scale (VAS) measuring pain after shoulder arthroplasty. *J Shoulder Elbow Surg* 2017;26:144-148.
25. Roy JS, MacDermid JC, Woodhouse LJ. Measuring shoulder function: a systematic review of four questionnaires. *Arthritis Rheum* 2009;61:623-632.
26. Kolade O, Ghosh N, Luthringer TA, et al. Correlation of Patient-Reported Outcome Measurement Information System (PROMIS) with American Shoulder and Elbow Surgeons (ASES), and Constant (CS) scores in idiopathic adhesive capsulitis. *J Shoulder Elbow Surg* 2021;30:554-560.
27. Ashton ML, Savage-Elliott I, Granruth C, O'Brien MJ. What are we measuring? A systematic review of outcome measurements used in shoulder surgery. *Arthrosc Sports Med Rehabil* 2020;2:e429-e434.
28. Örgel M, Graulich T, Liodakis E. Single Assessment Numeric Evaluation (SANE)—a promising and valid measuring tool related to patient-reported outcome measures (PROM). *Orthopade* 2022;51:333-336 [in German].
29. Nazari G, MacDermid JC, Bobos P, Furtado R. Psychometric properties of the Single Assessment Numeric Evaluation (SANE) in patients with shoulder conditions. A systematic review. *Physiotherapy* 2020;109:33-42.

30. Budtz CR, Andersen JH, de Vos Andersen NB, Christiansen DH. Responsiveness and minimal important change for the quick-DASH in patients with shoulder disorders. *Health Qual Life Outcomes* 2018;16:226.
31. Gordon D, Pines Y, Ben-Ari E, et al. Minimal clinically important difference, substantial clinical benefit, and patient acceptable symptom state of PROMIS upper extremity after total shoulder arthroplasty. *JSES Int* 2021;5:894-899.
32. Overbeek CL, Nota SP, Jayakumar P, Hageman MG, Ring D. The PROMIS physical function correlates with the QuickDASH in patients with upper extremity illness. *Clin Orthop Relat Res* 2015;473:311-317.
33. Kazmers NH, Hung M, Rane AA, Bounsanga J, Weng C, Tyser AR. Association of physical function, anxiety, and pain interference in nonshoulder upper extremity patients using the PROMIS platform. *J Hand Surg Am* 2017;42:781-787.
34. Lu Y, Beletsky A, Chahla J, et al. How can we define clinically important improvement in pain scores after biceps tenodesis? *J Shoulder Elbow Surg* 2021;30:430-438.
35. Gimbel JA, Van Kleunen JP, Williams GR, Thomopoulos S, Soslowsky LJ. Long durations of immobilization in the rat result in enhanced mechanical properties of the healing supraspinatus tendon insertion site. *J Biomech Eng* 2007;129:400-404.
36. Wada A, Kubota H, Miyanishi K, Hatanaka H, Miura H, Iwamoto Y. Comparison of postoperative early active mobilization and immobilization in vivo utilising a four-strand flexor tendon repair. *J Hand Surg Br* 2001;26:301-306.
37. Liechti DJ, Mitchell JJ, Menge TJ, Hackett TR. Immediate physical therapy without postoperative restrictions following open subpectoral biceps tenodesis: Low failure rates and improved outcomes at a minimum 2-year follow-up. *J Shoulder Elbow Surg* 2018;27:1891-1897.
38. Keeling LE, Looney AM, Curley AJ, et al. Early versus delayed active range of motion after open subpectoral biceps tenodesis. *Orthop J Sports Med* 2021;9:23259671211026619.
39. Dekker TJ, Peebles LA, Preuss FR, Goldenberg BT, Dornan GJ, Provencher MT. A systematic review and meta-analysis of biceps tenodesis fixation strengths: fixation type and location are biomechanically equivalent. *Arthroscopy* 2020;36:3081-3091.
40. Diaz M, Shi BY, Baker MC, Binkley MT, Belkoff SM, Srikumaran U. Open biceps tenodesis: A Biomechanical comparison of 6 fixation techniques. *Orthopedics* 2020;43:e102-e108.
41. Hartland AW, Islam R, Teoh KH, Rashid MS. Clinical effectiveness of tenotomy versus tenodesis for long head of biceps pathology: A systematic review and meta-analysis. *BMJ Open* 2022;12:e061954.
42. Yanke AB, Huddleston HP, Forlenza EM, et al. Two-year clinical outcomes and survivorship after isolated biceps tenodesis. *Arthroscopy* 2022;38:1834-1842.
43. Lee HJ, Jeong JY, Kim CK, Kim YS. Surgical treatment of lesions of the long head of the biceps brachii tendon with rotator cuff tear: A prospective randomized clinical trial comparing the clinical results of tenotomy and tenodesis. *J Shoulder Elbow Surg* 2016;25:1107-1114.
44. Zhang Q, Zhou J, Ge H, Cheng B. Tenotomy or tenodesis for long head biceps lesions in shoulders with reparable rotator cuff tears: A prospective randomised trial. *Knee Surg Sports Traumatol Arthrosc* 2015;23:464-469.
45. Almeida A, Gobbi LF, de Almeida NC, Agostini AP, Garcia AF. Prevalence of Popeye deformity after long head biceps tenotomy and tenodesis. *Acta Ortop Bras* 2019;27:265-268.
46. Lu Y, Agarwalla A, Lavoie-Gagne O, et al. How long does it take to achieve clinically significant outcomes after isolated biceps tenodesis? *Orthop J Sports Med* 2022;10:23259671221070857.
47. Agarwalla A, Gowd AK, Liu JN, et al. Predicting patient satisfaction with maximal outcome improvement after biceps tenodesis. *Orthopedic* 2021;44:e359-e366.
48. Werner BC, Brockmeier SF, Gwathmey FW. Trends in long head biceps tenodesis. *Am J Sports Med* 2015;43:570-578.