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Early success of the arthroscopic-assisted locked loop suprapectoral biceps tenodesis

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Background: There is wide variability in surgical technique for biceps tenodesis. Prior biomechanical studies have demonstrated superior ultimate and fatigue strength with a Krakow-type locked loop when compared with simple suture and lasso-loop configurations; however, this had not yet been clinically studied. The purpose of this study was to assess the short-term results an arthroscopic-assisted locked loop (ALL) suprapectoral biceps tenodesis technique.

Methods: All patients who underwent an ALL suprapectoral biceps tenodesis by a single surgeon from 2012 and 2019 with a minimum of 12-month follow-up were analyzed. Data collected included demographics, surgical indications, concomitant operative procedures, and postoperative complications of anterior shoulder "groove" pain, "Popeye deformity," biceps muscle cramping pain, and need for revision surgery.

Results: Forty patients who underwent an ALL suprapectoral biceps tenodesis met inclusion criteria. Patients were 55.6 ± 8.6 years of age, consisting of 28 men (57%) and 21 women (43%). The median follow-up was 19.3 months. At the latest follow-up, 1 (2%) patient had anterior shoulder "groove" pain, and no patients had a Popeye deformity or biceps muscle cramping. There were no revision biceps tenodesis procedures.

Conclusion: The ALL suprapectoral biceps tenodesis technique results in a low incidence of postoperative complications. At a short-term follow-up of 1 year, no patients had reoperations or revisions for failed biceps tenodesis. Groove pain was nearly absent in this series of patients.

Long head of biceps tendon (LHBT) pathology is a common source of pain and dysfunction related to shoulder pain.[2,14,15,37] Nonoperative options such as anti-inflammatories, physical therapy, and injections exist for mild symptoms and should be attempted in all patients. However, for patients who fail nonoperative treatment, surgical treatment has been shown to be widely effective.[5,6,8,9,16,22,27,31,32] Despite considerable research, the surgical treatment of LHBT pathology remains controversial, as literature supports both tenotomy and tenodesis.[17,22] Tenodesis involves excising the long-head biceps tendon from its insertion on the labrum and anchoring it into the humerus to prevent retraction of the tendon that would result in a cosmetic (Popeye) biceps deformity, cramping, and weakness. Associated complications with a biceps tenodesis include persistent groove pain, muscle cramping, and loss of fixation.[33] Tenotomy involves excising the long-head biceps tendon from its insertion allowing it to retract without any fixation. A recent randomized controlled trial comparing tenotomy and tenodesis identified a 3 times greater rate of Popeye deformity and decreased forearm supination power in the tenotomy group.[29] Because of these complications associated

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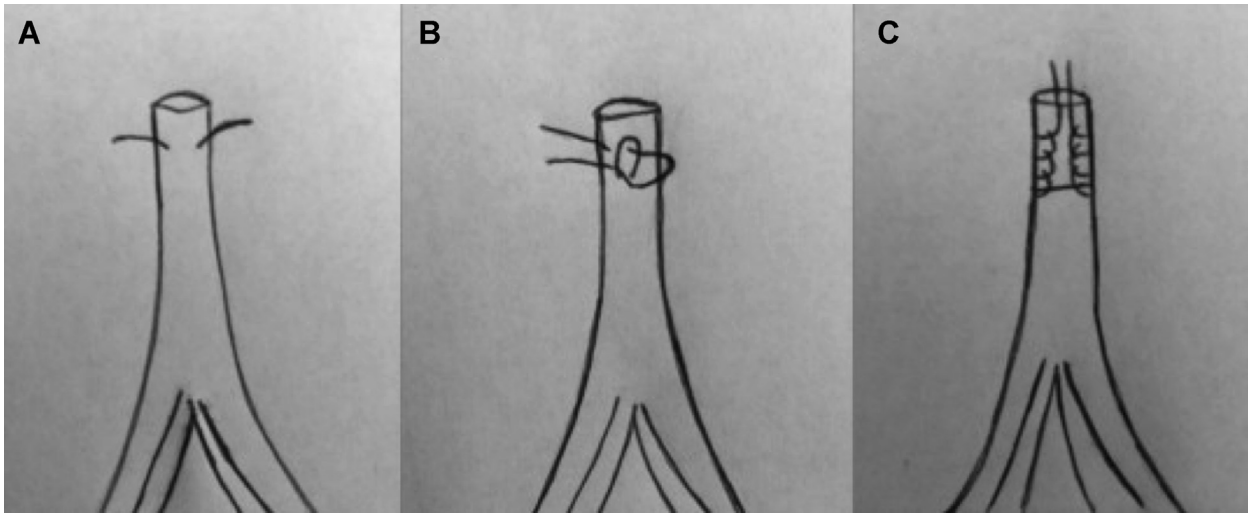

Figure 1 Three methods of biceps suture fixation: (**A**) simple suture, (**B**) lasso loop, and (**C**) Locked Loop or Krakow stitch. Prior studies have demonstrated increased biomechanical strength with the locked loop or Krakow stich as shown in (**C**).

with tenotomy, more authors have begun advocating for biceps tenodesis in younger individuals, manual laborers, those concerned about cosmetic appearance, or for those who participate in high demand activities.[1,13,17,21,22,43]

Tenodesis techniques vary based on location (suprapectoral or subpectoral), open or arthroscopic, fixation method (anchor or screw), interosseous or extraosseous, and tendon-suture interface configuration (lasso loop, Krakow, or simple stitch) (Fig. 1). However, even among those who advocate for biceps tenodesis, there is no consensus on the tenodesis technique, and there is varying evidence supporting open and arthroscopic, suprapectoral and subpectoral, and fixations techniques.[4,34,42] Proponents of the subpectoral technique have cited a high incidence of groove pain in the suprapectoral technique; however, these techniques can use larger drill holes in the groove (7-9 mm) and interference screw techniques. A previous biomechanical study identified the Krakow tendon-suture interface configuration (or a locked-looped suture) as providing superior ultimate and fatigue strength when compared with simple suture and lasso-loop configurations.[25] These findings have led to the development of an arthroscopic-assisted locked loop (ALL) suprapectoral biceps tenodesis technique.

The purpose of this study is to investigate complication rates in patients who have undergone ALL suprapectoral biceps tenodesis, including rates of reported bicipital groove pain, appearance of Popeye deformity, biceps muscle cramping, revision biceps tenodesis, and any ipsilateral revision shoulder surgery.

Materials and methods

Institutional review board approval was obtained for this study. A retrospective review of a single surgeon's case log (TB) was conducted using the electronic medical record to identify patients with the Current Procedural Terminology code of 29828 between 2012 and 2019. Inclusion criteria included shoulder arthroscopy with a biceps tenodesis and age older than 18 years.

Operative reports were then reviewed to confirm that an ALL suprapectoral biceps tenodesis had been performed. Data collected included patient demographics, surgical indications, and associated number and type of concomitant shoulder procedures. Outpatient follow-up notes were reviewed to determine rates of bicipital groove pain, appearance of Popeye deformity, biceps muscle cramping, revision biceps tenodesis, and any ipsilateral revision shoulder surgery. Patients with less than 12-month follow-up were excluded. All data were collected in a follow-up clinic visit, and patients were specifically asked about cramping and groove pain. Descriptive statistics were used to determine frequency of indications, number and types of concomitant procedures, and rates of complications. All statistical analysis was performed using Stata 13.1 (StataCorp, College Station, TX, USA).

Surgical technique

The patient is placed in a beach-chair position, and after appropriate prepping and draping, a standard posterior arthroscopic portal is placed (Fig. 2). A standard diagnostic arthroscopy is performed. An accessory anterolateral working portal is placed directly over the biceps tendon through the rotator cuff interval using outside-in needle localization. The superior labrum and long head of the biceps are then probed. If there is degenerative tearing of the superior labrum, tendinosis of the long head of the biceps, or subluxation of the long head of the biceps owing to a subscapularis tear or incompetence of the biceps pulley, the decision is then made to perform a biceps tenodesis.

A Kelly clamp is introduced through this anterolateral working portal to control the biceps tendon, and a biceps tenotomy is performed at its proximal insertion. The biceps is then pulled to maximal excursion outside the skin and held in place with a Kelly clamp. An extracorporeal locked-loop stitch is begun at the point the biceps tendon is past the skin, with at least 3 passes placed proximally to distally along the tendon and then at least 3 passes placed proximally to return to the starting point. The locked-loop stitch is then loaded through a 4.75-mm Swivelock anchor (Arthrex, Naples, FL, USA) which is placed in the superior aspect of the bicipital groove just lateral to the articular cartilage.

Results

A total of 49 patients who underwent an ALL suprapectoral biceps tenodesis met inclusion criteria in this study. Patient demographics are shown in Table I. Patients were 55.6 ± 8.6 years of age, consisting of 28 men (57%) and 21 women (43%). The median follow-up was 19.3 months.

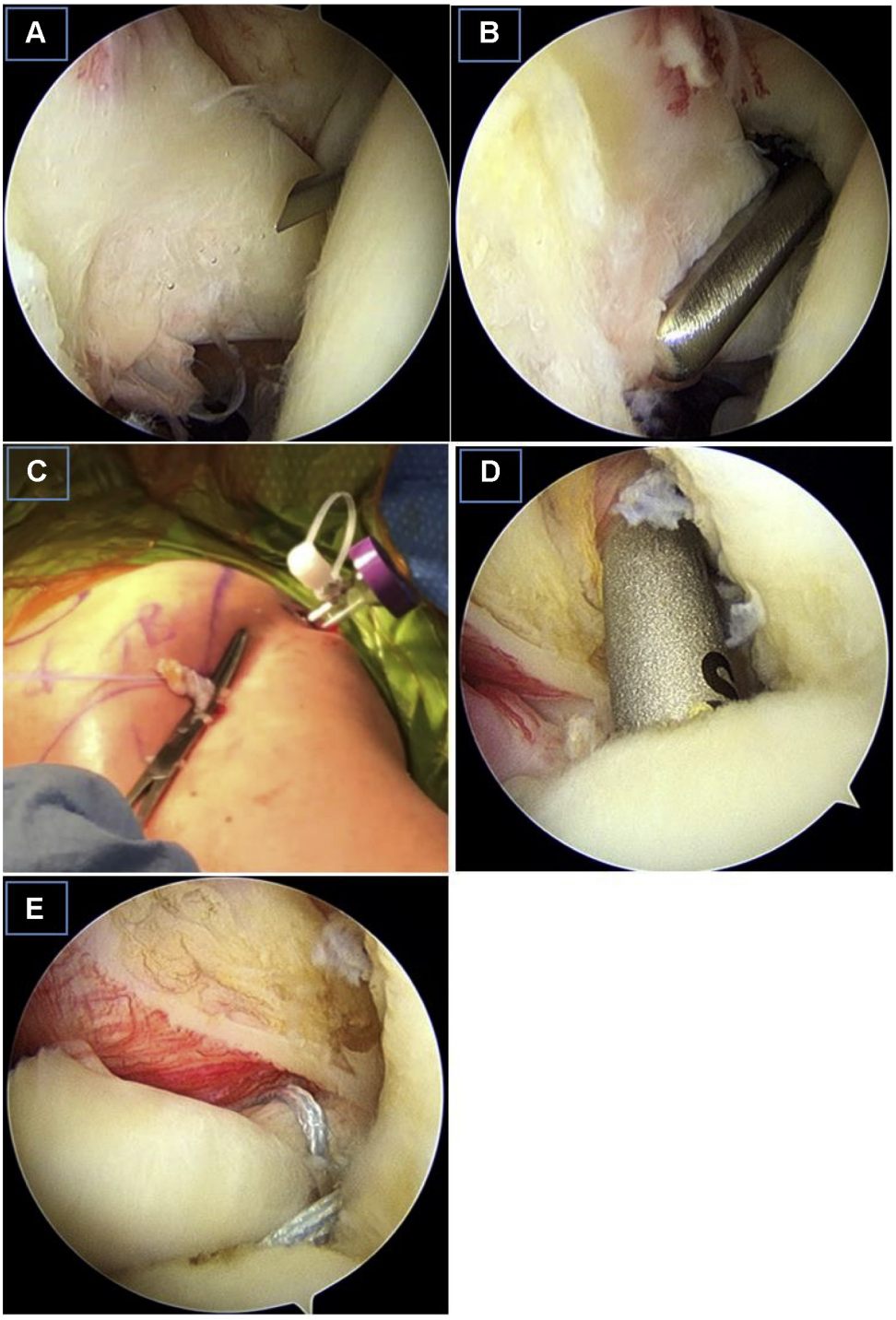

Figure 2 Arthroscopic images demonstrating the arthroscopic-assisted locked loop (ALL) suprapectoral biceps tenodesis technique. (**A**) Outside-in needle location directly over the biceps tendon through the rotator cuff interval for an accesory anterolateral working portal, (**B**) a Kelly clamp introduced through the anterolateral portal to control the biceps tendon upon tenotomy, (**C**) locked-loop stitch extracorpeal via the anterolateral portal with a Kelly clamp holding tension on biceps tendon, (**D**) anchor preparation at the superior bicipital groove, and (**E**) completion of the ALL suprapectoral biceps tenodesis in the suprapectoral position within the biceps groove.

Table I
Patient demographics.

Number	n = 49
Average age (mean ± SD)	55.6 ± 8.6 yr
Male gender	57% (n = 28)
Workers compensation	23% (n = 11)
Follow-up (median, IQR)	19.3 (13.0-34.7) mo

Intraoperative indications for biceps tenodesis are shown in Table II. Intraoperative indications for performing the ALL suprapectoral biceps tenodesis included 26 (53%) tendinosis, 14 (29%) partial tears, 6 (12%) LHBT subluxations, 2 (4%) SLAP tears, and 1 (2%) unretracted LHBT rupture.

No patients had an isolated biceps tenodesis. The number of concomitant procedures is shown in Table III. In total, 14 (29%)

Table II
Intraoperative indications for biceps tenodesis.

Biceps tendinosis	53% (n= 26)
Partial tear	29% (n = 14)
LHBT subluxation	12% (n = 6)
SLAP Tears	4% (n = 2)
Unretracted LHBT rupture	2% (n = 1)

LHBT, long-head biceps tendon.

Table III
Concomitant procedures.

Number of concomitant procedures	
>4	29% (n = 14)
4	23% (n = 11)
3	43% (n = 21)
2	4% (n = 2)
1	2% (n = 1)
Type of concomitant procedures	
Subacromial decompression	98% (n = 48)
Rotator cuff repair	82% (n = 40)
Distal clavicle resection	43% (n = 21)
Subscapularis repair	31% (n = 15)
Labral repair	16% (n = 8)
SLAP repair	10% (n = 25)
Superior capsule reconstruction	6% (n = 3)

Table IV
Follow-up data.

Anterior shoulder groove pain	2% (n = 1)
Popeye deformity	0%
Biceps muscle cramping	0%
Revision biceps tenodesis	0%
Ipsilateral shoulder surgery	8% (n = 4)

underwent more than 4 concomitant procedures, while 11 (23%) underwent 4 procedures, 21 (43%) underwent 3 procedures, 2 (4%) underwent 2 procedures, and 2% (1) underwent 1 additional concomitant procedure. Subacromial decompression with acromioplasty (98%, 48) and rotator cuff repair (82%, 40) were the most common concomitant procedures. Distal clavicle resection (21; 43%), subscapularis repairs (15; 31%), SLAP tear repairs (25, 10%), labral repair (8, 16%), and superior capsular reconstruction (3, 6%) were also concurrently performed.

Follow-up symptoms are shown in Table IV. At the latest follow-up, 1 (2%) patient had anterior shoulder “groove” pain, and no patients had a Popeye deformity or biceps muscle cramping. In the 1 patient with anterior shoulder pain, subsequent ultrasound of the biceps tendon demonstrated intact proximal tendon over the tenodesis site. There were no revision biceps tenodesis procedures. In total, 4 (8%) patients had subsequent ipsilateral shoulder surgery. Two of those surgeries were latissimus dorsi transfers, 1 was a revision rotator cuff repair and 1 was a shoulder arthroplasty. These subsequent procedures were performed for other indications and none were performed principally to address the biceps tendon.

Discussion

There remains little consensus on the appropriate surgical treatment for LHBT pathology. The 2 main treatment options are commonly used in practice can be divided into tenotomy and tenodesis. Furthermore, there are numerous different surgical techniques used to perform a biceps tenodesis,[7,11,12,18,27,30,39,40] making it even more difficult to interpret the outcomes of this procedure. This study focuses solely on the technique and early outcomes associated with the ALL suprapectoral biceps tenodesis method to treat LHBT pathology.

For some surgeons, biceps tenotomy is a preferred method to treat LHBT pathology owing to its low technical demand, shorter operative times than tenodesis, and decreased postoperative restrictions.[35] Tenotomy and tenodesis have been shown to have similar rates of success, complication rates, and patient outcomes[7,10,17,22,26,28,41]; however, tenotomy has been shown to result in more postoperative biceps cramping and muscle belly deformity.[11,26]

Biceps tenodesis can be performed via several different described techniques, resulting in substantial variation in how the procedure is performed. It can be performed arthroscopically or open, suprapectorally or subpectorally, with multiple suture-tendon interface configurations (lasso loop, Krakow, or simple stitch) and fixation methods (to adjacent soft tissue or to the bicipital groove), and with multiple different devices (sutures alone, suture anchor, suture button, or screw). Such a degree of variability makes interpreting the collective results of biceps tenodesis procedures rather difficult.

For open biceps tenodesis, a systematic review by *Abraham et al*[1] showed no differences compared with arthroscopic biceps tenodesis; however, there were substantial variations among the techniques used for both open and arthroscopic procedures. Both open and arthroscopic tenodesis were found to have failure rates resulting in muscle belly deformities of 0.7% and 1.5%, respectively. All of the tenodesis failures were from tenodesis procedures that involved soft-tissue fixation.[1,11] Persistent pain was noted in 1.1% of open procedures and 1.0% of arthroscopic procedures.[1] Of note, the authors found that the open procedure had additional complications that did not result from the arthroscopic technique such as superficial infections (1.1%) and transient brachial plexopathies (0.7%).[1] When comparing previously described methods of open subpectoral biceps tenodesis[31] and arthroscopic suprapectoral biceps tenodesis with Krakow stitching and bioabsorbable interference screw fixation,[30] *Gombera et al*[19] noticed no differences between the 2 groups with no instances of cramping or biceps muscle belly deformity. However, open tenodesis was found to have a 4.3% occurrence of superficial infection and a 4.3% occurrence of transient brachial plexopathy, while none of these complications were noted in the arthroscopic tenodesis group.

Some authors prefer open subpectoral techniques, citing a high incidence of groove pain for the suprapectoral technique. Mazzocca et al[31] performed a single standardized technique of open subpectoral biceps tenodesis using a locking stitch with bioabsorbable interference screw fixation in bone and found all patients were pain free with only 2.4% of patients resulting in failure of tenodesis fixation and subsequent biceps muscle belly deformity. Other authors report similar open tenodesis failure rates resulting in muscle belly deformity, 0.57%[33] and 3.4%.[20]

As mentioned previously, arthroscopic biceps tenodesis can have wide variability in technique,[7,11,12,18,27,30,39,40] making the interpretation and extrapolation of findings amongst multiple studies difficult. We advocate for the ALL technique because it can be performed with fewer incisions than a subpectoral technique while also still being able to use a biomechanically superior locked loop or Krakow stitch. Our study examined the early results of a single technique, arthroscopic suprapectoral biceps tenodesis using a locked-loop stitch that is secured in the bicipital groove with a suture anchor. With a minimum follow-up of 1 year and a median follow-up 19 months, we found no occurrences of biceps muscle belly deformity, tenodesis failure, biceps muscle cramping, and a low (<2%) incidence of bicipital groove pain.

Other studies report higher rates of fixation failure resulting in muscle belly deformity; however, there are differences in the type of fixation or suture technique used. *Boileau et al*[7] looked at 43 patients who had arthroscopic suprapectoral biceps tenodesis with a tendon whip stitch fixed to bone with an interference screw, finding all patients to be pain free at the bicipital groove and 4.7% of patients to have failure of fixation resulting in muscle belly deformity. The main differences in technique were the running baseball whip stitch and the use of an interference screw used in their study compared with the use of a locked-loop stitch and a suture anchor used in our study.[7]

Lutton et al[30] looked at 17 patients who had arthroscopic suprapectoral biceps tenodesis with Krakow stitch fixed to bone via a bioabsorbable interference screw, finding no patients had fixation failure resulting in muscle belly deformity. Interestingly, the authors also looked at the location of fixation within the bicipital groove, reporting 2 of 5 (40%) patients with fixation proximally in the groove had persistent bicipital groove pain, while all 12 (100%) of the patients with fixation distally in the groove were pain free.[30] Some authors advocate for a more distal biceps tenodesis fixation because it leaves less diseased biceps tendon behind to serve as a pain generator.[24,30,36,38] There may be merit to this hypothesis; however, higher-powered studies evaluating the location of fixation within the bicipital groove compared with postoperative bicipital groove pain are needed.

Delle Rose et al[11] examined 56 patients who had arthroscopic suprapectoral biceps tenodesis with soft-tissue suture fixation in the bicipital groove and noted 3 of 56 (5.4%) patients had failure of fixation resulting in muscle belly deformity, 2 of 56 (3.6%) patients had painless medial subluxation of the biceps tendon identified on ultrasound, and no patients had biceps cramping. Compared to the technique performed in our study, *Delle Rose et al*[11] performed a soft-tissue tenodesis with no bony fixation. The reason behind the increased rate of failure seen in their study with soft tissue fixation is unclear. A recent meta-analysis of cadaveric biomechanical studies performed on biceps tenodesis fixation constructs found that suture anchor fixation required less force to reach ultimate failure load compared with both interference screw fixation and soft-tissue fixation, with interference screw fixation performing the best.[3] These findings are limited by the fact that there was significant variability among studies analyzed in the meta-analysis, such as different loading protocols and stitching patterns. Other studies do not seem to corroborate all the findings in the aforementioned meta-analysis, suggesting that suture anchors[39] and interference screws[23] are superior to soft-tissue fixation. There may be a role for the type of stitch pattern used for the tendon-suture interface, as the Krakow stitch has been shown to be superior, failing by suture breakage as opposed to pull out from the tendon when compared with both the simple stitch and lasso-loop stitch.[25]

There are several limitations of this study. The major limitation of this study is its retrospective nature. In addition, biceps tenodesis was not performed as an isolated procedure. It was performed alongside several different procedures, which could serve as confounders and impact outcomes, in particular patient-reported outcomes such as perceived pain. Furthermore, this study does not report on the long-term clinical outcomes. There may be differences in fatigue and failure of different implant-tissue interfaces that require extended periods of cyclical loading to fatigue, which would not be captured in the present study. Having follow-up data multiple years with clinical outcomes scores after the index procedure would give better insight into long-term outcomes, but that was not the objective of this study, which aimed to the evaluate early outcomes of this procedure.

Conclusion

This study evaluates the early results of a large series of patients who underwent a biceps tenodesis by an ALL suprapectoral biceps tenodesis technique. At short-term follow-up, we report a low incidence of postoperative complications with a low incidence of groove pain and no reoperations or revisions for failed biceps tenodesis. Additional study is warranted to evaluate long-term clinical follow-up.

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Conflicts of interest

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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