Primary repair of severely retracted nonchronic distal biceps tendon rupture using 2-incision anterior-approach repair

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\textbf{Background:} Primary repair of a severely retracted distal biceps tendon can pose a technical challenge. We sought to describe the method and clinical outcomes of a surgical technique used as an adjunct to the conventional anterior single-incision repair for severely retracted biceps tendons. This technique involves a second anterior incision proximally to retrieve a severely retracted tendon followed by passing the tendon through a soft-tissue tunnel.

\textbf{Methods:} We identified 30 consecutive patients who had undergone a primary distal biceps tendon repair by an anterior-approach cortical-button technique. A phone survey was conducted for patient-reported outcomes. Patients returned for bilateral forearm supination strength testing in 2 positions (45° of pronation and 45° of supination). Outcomes were compared between patients who required a second incision and high elbow flexion (>60°) because of severe tendon retraction and those who did not require such interventions.

\textbf{Results:} No significant differences in elbow range of motion, supination strength, or patient-reported outcomes were found between the 2 groups of patients (P > .05). Regarding supination strength, the operated side was significantly weaker than the uninjured side in both pronated and supinated positions (P < .05). Both the operated and uninjured sides showed significantly higher torque in a pronated position than in a supinated position (P < .05).

\textbf{Conclusions:} Severely retracted distal biceps tendons can be successfully repaired using a second incision and high elbow flexion without negative effects on the outcomes. Supination strength was decreased following an anterior-approach cortical-button technique, but patient-reported outcomes were not affected negatively.

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Surgical repair of the tendon has been recommended for most cases in young and active patients because a complete rupture of the distal biceps tendon can result in up to a 50% loss of supination strength and 30% loss of elbow flexion strength.\textsuperscript{7,14} Various repair techniques have been described. Although the best repair technique to restore the function and anatomic attachment of the tendon is still being debated, studies seem to agree that the overall clinical outcomes following primary surgical repair of the tendon are satisfactory in most patients.\textsuperscript{6,11,15,16,17,18,25} Managing severely retracted distal biceps tendon ruptures remains challenging. The literature has shown inferior clinical outcomes and higher complication rates following delayed repairs owing to more extensive surgical dissection and more difficult repair from muscle contraction, tendon retraction, and scar tissue adhesion.\textsuperscript{5,11} Many surgeons have believed that if the tendon does not reach the radial tuberosity without significant elbow flexion, a bridging tendon graft should be used.\textsuperscript{5}

It is not uncommon to see patients who present with a complete distal biceps tendon rupture that is significantly retracted proximally to the level of the upper arm after a relatively recent injury. In these patients, the lacertus fibrosus is also completely ruptured, allowing the biceps tendon to retract without a checking mechanism. Locating the proximally retracted tendon in the upper arm, followed by reducing it back to the radial tuberosity, poses a significant technical challenge. It often requires a large extension of the surgical incision, extensive soft-tissue dissection close to the neurovascular structures, and high elbow flexion to enable the tendon to reach the radial tuberosity.

In this study, we sought to describe a surgical technique that can be used as an adjunct to anterior-approach single-incision repair in...
cases with severe tendon retraction. The technique involves making a small second anterior incision proximally at the location of the distal tendon stump to localize the tendon and reducing the tendon to the radial tuberosity through a soft-tissue tunnel, which avoids the need for a large incision and extensive soft-tissue dissection in the antecubital fossa. We also sought to compare the clinical outcomes of this repair technique with those of the conventional anterior single-incision repair technique through a retrospective cohort study. To our knowledge, this particular technique and its clinical outcomes have not been reported. Our hypothesis was that the clinical outcomes would not be significantly different between patients who needed a 2-incision anterior-approach repair and those who underwent a conventional single-incision anterior-approach repair without such interventions.

Material and methods

Study subjects

We performed a retrospective study of patients who underwent a distal biceps tendon repair using a cortical button between 2013 and 2018. The eligible subjects for this study were patients who (1) were 18 years or older, (2) had a unilateral partial or complete distal biceps tendon rupture that was treated with a biceps tendon repair using a cortical button without using a graft, (3) had a minimum clinical follow-up period of 6 months, and (4) were able to provide voluntary written informed consent. A retrospective review of patients’ records was performed to collect data on age, sex, hand dominance, injured side, injury mechanism, time from injury to surgery, extent of proximal retraction (ie, the shortest distance between the radial tuberosity and the tendon stump on sagittal magnetic resonance images in ° of elbow extension and neutral forearm rotation), intraoperative findings (eg, use of a proximal second incision or need for elbow flexion > 60° for tendon reduction to the radial tuberosity), postoperative rehabilitation, complications, and final clinical examination findings (eg, range of motion, pain score, manual strength test, or hook test18). Patients were contacted for a telephone survey on satisfaction with the operated elbow and subjective elbow function using the Mayo Elbow Performance Score (MEPS)16 and Quick Disabilities of the Arm, Elbow and Shoulder Hand (QuickDASH) score. They were then asked to return for additional supination strength testing. At the return visit, bilateral elbow supination strength was measured with the patient standing up and the elbow flexed 90° at his or her side. Isometric supination strength measurement was performed in 2 forearm rotation positions—at 45° of pronation and at 45° of supination—using a Baltimore Therapeutic Equipment (BTE) work simulator with handle number 601 (BTE Technologies, Greenwood Village, CO, USA). Testing was performed twice, and the average of the 2 measurements was used for data analysis.

Surgical technique

In cases with severe proximal tendon retraction, the tendon stump was palpated as a hard, tender subcutaneous mass at the anterior aspect of the upper arm at the level of the biceps muscle belly. The location of the tendon stump was marked beforehand in the preoperative area. A sterile tourniquet was used so that it could be removed intraoperatively for proximal extension of dissection. A 5-cm transverse linear skin incision was made at the anterior elbow approximately 4 cm distal to the main elbow flexion crease (Fig. 1, A). The subcutaneous tissue was carefully dissected while looking out for the lateral anterbrachial cutaneous nerve. Once the nerve was identified, it was left surrounded by the adjacent veins and fat without further dissection to reduce the risk of neurapraxia. The interval between the brachioradialis and pronator teres was developed with blunt dissection. The radial tuberosity is covered by the supinator muscle when approached from the anterior aspect, and forearm supination brings the biceps insertion site at the radial tuberosity anteriorly, closer to the surgical field. Fluoroscopy was used to confirm that the radial tuberosity was correctly located. With the forearm kept in maximum supination, a 3.2-mm drill pin was drilled into the ulnar side of the radial tuberosity. A 7.5-mm cannulated reamer was then drilled over the drill pin to make a unicortical hole.

If the tendon stump could not be reached from the incision because of severe retraction even with a milking maneuver and deflation of the tourniquet, a second skin incision was made at the location of the tendon stump (Fig. 1, A). The second incision was made in a transverse fashion and typically 2 cm long, which was just large enough to pass the index finger. (B) The tendon stump (—) is externalized through the proximal incision.

Figure 1  A 5-cm transverse linear skin incision (—) is made at the anterior elbow approximately 4 cm distal to the main elbow flexion crease (—). If the retracted distal biceps tendon cannot be reached from the incision, a second incision (—) is made proximally at the location of the distal tendon stump. (A) The second incision is made in a transverse fashion and typically 2 cm long, which is just large enough to pass the index finger. (B) The tendon stump (—) is externalized through the proximal incision.
elbow joint. In addition, the lateral antebrachial cutaneous nerve lies lateral and slightly deep to the retracted tendon at this level. The path courses underneath (or deep to) these neurovascular structures at the level of the elbow joint and the radial tuberosity. Flexing the elbow facilitated the reduction of the tendon to the radial tuberosity. When there was a severe proximal tendon retraction, it was often required the elbow to be flexed up to 90º. Once the tendon could reach the radial tuberosity, a cortical button (BicepsButton; Arthrex, Naples, FL, USA) was loaded with the No. 2 suture from the tendon. The button was deployed over the opposite cortex of the radius. The 2 suture ends were gently tugged to make the button lie flat on the opposite cortex, which was confirmed with fluoroscopy. While the elbow was kept flexed, the 2 suture ends were pulled until the distal end of the tendon completely reached the bottom of the unicortical hole (Fig. 5, A). The suture was tied using a knot pusher. Then, a 7-mm × 10-mm polyetheretherketone biceps tenodesis interference screw was inserted into the hole—preferably to the radial side of the hole so that the tendon was pushed to the ulnar-side wall of the tunnel—when additional fixation was desired (Fig. 5, B). All the procedures were performed by a single surgeon. The incisions were closed in layers after irrigation, and a posterior splint was applied for immobilization of the elbow in 90º of flexion and the forearm in 45º of supination.

Postoperative rehabilitation

The posterior splint was switched to a hinged elbow brace locked in 90º of elbow flexion at the first postoperative follow-up visit at 1 week. A supination-stop extension was attached to the distal part of the brace to keep the forearm in neutral rotation. The brace was worn for the following 5 weeks. Exercises for passive and active-assisted flexion and extension of the elbow started at 1 week, but extension was limited to 60º for the first week, then progressively increased by 15º each week. Passive and active-assisted forearm supination and pronation also started at 1 week. Active supination and active elbow flexion were avoided for 6 weeks postoperatively. Strengthening exercises began at 12 weeks. A return to strenuous activities was allowed at 5 months.

Statistical methods

We obtained the ratio of supination strength on the operated side to that on the uninjured side, as well as the ratio of supination strength measured in a 45º supinated position to that measured in a 45º pronated position. To investigate whether requiring a second incision or high elbow flexion (>60º) for tendon repair affected the clinical outcomes, data were compared between the patients who required such interventions and those who did not. A paired t test and the Wilcoxon signed rank test were used for paired comparisons of variables with a normal distribution and those with a non-normal distribution, respectively. An unpaired t test and the Mann-Whitney U test were used for unpaired comparisons of variables with a normal distribution and those with a non-normal distribution, respectively. Normality of data was determined using the Shapiro-Wilk test. Data were presented as mean ± standard deviation. The level of statistical significance was set at P < .05.

Results

Study subjects

Our data review identified a total of 32 patients who had undergone a distal biceps tendon repair during the study period.
Of these patients, 2 underwent revision repairs and were excluded, leaving 30 primary repair patients for the data analysis. The mean clinical follow-up period was $7.2 \pm 8.1$ months (range, 6-48 months). Eight patients had a partial tear, whereas 22 had a complete tear. The mean age of the patients at the time of surgery was $51 \pm 8$ years (range, 38-66 years). There were 29 male patients. The dominant side was involved in 18 patients (60%). Lifting a heavy object was the most common mechanism of injury (19 patients), followed by sudden forceful elbow extension (5 patients). The mean time interval between the injury and surgery was $19 \pm 15$ weeks (range, 3-77 weeks) in patients with a partial tear and $3.8 \pm 14$ weeks (range, 1-12 weeks) in those with a complete tear.

Of the 22 patients with a complete tear, 10 received an acute repair (<10 days from injury), 4 underwent a subacute repair (10-21 days from injury), and 8 received a delayed repair (>21 days from injury) based on the criteria of Kelly et al. The mean proximal tendon retraction distance in this patient group was $6 \pm 3$ cm (range, 2-12 cm), and no statistically significant correlation was found between the timing of the repair and the amount of tendon retraction ($P > .05$). A second anterior incision was required in 12 patients to locate the proximally retracted tendon stump. Of these 12 patients, 10 required high elbow flexion (>60°) to enable the retracted tendon stump to reach the radial tuberosity. The mean proximal tendon retraction distance was $8.4 \pm 2.9$ cm in the 12 patients who needed a second incision vs. $3.9 \pm 3.0$ cm in those who did not need a second incision ($P < .0001$) (Table 1). At the last clinic follow-up visit, all 30 patients, regardless of a second anterior incision or elbow flexion required for tendon reduction, demonstrated full recovery of range of motion of the elbow and forearm rotation on clinical examination. All 30 patients except 1 showed 5 of 5 strength of supination and elbow flexion on manual strength testing. One patient showed 4 of 5 supination strength and was thought to have a recurrent biceps tendon tear based on a positive hook test result during his 5-month follow-up visit. The patient was a 43-year-old manual-type worker with the nondominant side involved. The injury occurred 12 weeks prior to the surgical procedure, and the distal biceps tendon was proximally retracted by 6 cm. He needed a second anterior incision and greater than 60° of elbow flexion for tendon reduction intraoperatively. The patient did not want to pursue further surgery because he was satisfied with his elbow range of motion and function. Other complications included transient neurapraxia of the lateral antebrachial cutaneous nerve in 2 patients and transient partial numbness over the dorsum of the thumb and index finger in 1 patient. These
Comparison between patients with complete tear who required second incision vs. those who did not

| Clinical follow-up (n = 22) | Patients who required second incision (n = 12) | Patients who required no second incision (n = 10) | P value |
|-----------------------------|-----------------------------------------------|-----------------------------------------------|---------|
| Age, yr                     | 49 ± 8                                        | 51 ± 8                                        | .4      |
| Sex                         | All male patients                             | All male patients                             | NA      |
| Time between injury and surgery, wk<sup>c</sup> | 5 ± 15                                       | 2.7 ± 15                                      | .2      |
| Acute                       | 3                                             | 6                                             |        |
| Subacute                    | 3                                             | 0                                             |        |
| Delayed                     | 6                                             | 4                                             |        |
| Proximal retraction of tendon, cm | 8.4 ± 2.9                                   | 3.9 ± 3.0                                     | <.0001  |
| No. of patients requiring high elbow flexion intraoperatively | 10                                            | 0                                             | NA      |
| Complications               | Full/full                                      | Full/full                                      | NA      |
| Phone survey (n = 19)       | NA                                            | NA                                            |        |
| VAS pain score              | 0.4 ± 0.9                                     | 0.7 ± 1.0                                     | .5      |
| MEPS                        | 98.3 ± 6.2                                    | 98.4 ± 6.3                                    | >.99    |
| QuickDASH score             | 4.9 ± 7.3                                     | 6.6 ± 7.3                                     | .3      |
| Satisfaction                | NA                                            | NA                                            |        |
| Very satisfied (%)          | 8 (89)                                        | 10 (100)                                      |        |
| Somewhat satisfied          | 1                                             | 0                                             |        |
| Neutral                     | 0                                             | 0                                             |        |
| Somewhat unsatisfied        | 0                                             | 0                                             |        |
| Very unsatisfied            | 0                                             | 0                                             |        |
| Supination strength test (n = 11) | n = 6                                          | n = 5                                         |        |
| Strength ratio of operated side to uninjured side at 45° of pronation | 0.86                                          | 0.89                                          | .6      |
| Strength ratio of operated side to uninjured side at 45° of supination | 0.69                                          | 0.75                                          | .3      |

NA, not applicable; LABC, lateral antebrachial cutaneous nerve; VAS, visual analog scale; MEPS, Mayo Elbow Performance Score; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand.

* Time between injury and surgery: acute (<10 days from injury), subacute (10-21 days), and delayed (>21 days).

symptoms completely resolved spontaneously within 5 months of surgery. All patients rated their pain none or minimal at their last visit.

**Phone survey results**

Of the 30 patients, 26 (19 with a complete tear and 7 with a partial tear) completed the telephone survey. At the time of the telephone survey, the average time elapsed since surgery was 49 months (range, 11–77 months). The mean visual analog scale (VAS) pain score was 0.6 ± 0.9 (range, 0–3). The mean MEPS was 97 ± 6.2 (range, 83-100). The mean QuickDASH score was 4.7 ± 7.3 (range, 0-22.7). Surgery was rated “very satisfactory” by 23 patients and “somewhat satisfactory” by 3. No patients rated surgery as “neutral,” “somewhat unsatisfactory,” or “very unsatisfactory.” When the patients with a partial tear were compared with those with a complete tear, no significant differences in any of these variables were found between the 2 groups (P > .05). Similarly, when the patients who required a second incision and high elbow flexion intraoperatively were compared with those who did not require such interventions, no significant difference in VAS pain score, MEPS, QuickDASH score, or satisfaction was found (P > .05) (Table I).

**Supination strength and elbow range of motion in 15 patients who returned for study visit**

Of the 26 patients who could be reached by phone, 15 (11 with a complete tear and 4 with a partial tear) returned for a study visit to undergo measurements of supination strength using a BTE work simulator and range of motion using a goniometer. These 15 patients were not significantly different from the 11 patients who did not return for a study visit when the demographic data (eg, age, dominant-side involvement, and length of follow-up) and clinical outcomes (eg, MEPS, QuickDASH score, satisfaction, and complications) were compared (P > .05). The mean age of the 15 patients was 49.5 ± 8.6 years (range, 38-68 years), and they were all men. The dominant-side elbow was involved in 8 patients (53%). A second anterior incision was needed in 6 patients with a complete tear, of whom 5 required high elbow flexion for tendon repair. The average follow-up period was 42 months (range, 12-73 months). Regarding elbow range of motion in these 15 patients, no significant difference was found between the operated side and uninjured side, except for flexion in a supinated position (P = .0001) and extension in a supinated position (P = .0001) (Fig. 7). The magnitude of
Figure 7 Supination strength. The operated side was significantly weaker than the uninjured side both in a 45° pronated position and in a 45° supinated position. The magnitude of difference was significantly larger in a 45° supinated position than in a 45° pronated position. Both the operated and uninjured sides showed significantly higher torque when measured in a 45° supinated position than in a 45° supinated position, and the magnitude of difference was significantly larger on the operated side than on the uninjured side. *P < .01.

difference was significantly larger in a 45° supinated position than in a 45° pronated position (P = .003). In a 45° pronated position, supination torque on the operated side was, on average, 86% of that on the uninjured side, whereas it was, on average, 69% of that on the uninjured side who required a second anterior incision and high elbow flexion intraoperatively because of severe tendon retraction and those whose tendon rupture did not require such interventions. All patients demonstrated full flexion and extension of the operated elbow at their last clinic visit regardless of a second incision or high elbow flexion. When supination strength was measured in 15 patients who returned for strength testing, no significant difference in strength was found between the former and latter groups. Despite the fact that the repaired biceps tendon was under substantial tension initially in those patients who required a second incision and high elbow flexion, a step-wise elbow extension rehabilitation protocol led to a gradual increase in the tendon excursion and, thus, an eventual full recovery of elbow extension. To our knowledge, our study is the first to investigate the clinical outcomes following 2-incision anterior-approach distal biceps tendon repairs using a cortical button in patients with significant proximal retraction of the tendon. A benefit of this technique could be that we were able to avoid a large skin incision and extensive soft-tissue dissection in the antecubital fossa, thus potentially improving cosmesis and minimizing scar contracture across the anterior elbow. In our study, the amount of proximal tendon retraction was closely associated with the intraoperative need for a second incision proximally to locate the retracted tendon stump, as well as high elbow flexion to reduce the tendon to the radial tuberosity; however, it was not necessarily correlated with the time elapsed from injury to repair. Haverstock et al11 used 3 weeks as a reference time point for delayed repair in their study. In our study, 50% of the patients who required a second incision had delayed repairs (>21 days from injury), and 40% of the patients who did not require a second incision had delayed repairs.

This study also found a significant decrease in supination strength following distal biceps tendon repair using a cortical button through an anterior approach. The supination strength decrease was more obvious at terminal supination than at early supination. The supination strength of the operated elbows was, on average, 86% of that of the uninjured elbows in a 45° pronated position, whereas it was only 69% of that of the uninjured elbows in a 45° supinated position. This finding is in agreement with multiple previous studies that have reported decreased supination strength following anterior-approach distal-biceps repair.10,12,20–22,24 Huynh et al14 recently reported that patients’ supination strength was 91% of that of the contralateral uninjured elbows following repair with the anterior single-incision cortical-button technique. Similarly, Greenberg et al15 and Peeters et al16 reported decreased supination strength to 82% and 91% of that of the contralateral uninjured elbows, respectively. The supination strength was measured in neutral forearm rotation in all these studies, which is different from our study. Consistently with previous studies,21–24 our study found that the decrease in supination strength was more obvious in a supinated position than in a pronated position following anterior-approach repair. Schmidt et al24 showed in a cadaveric study that repairing the distal biceps tendon to a location anterior to its anatomic position resulted in a 97% decrease in the biceps supination moment arm with the elbow in 60° of supination and a 27% decrease in the moment arm in a neutral position whereas no significant decrease was found in 60° of pronation.

It is interesting to note that the apparent decrease in supination strength observed in patients did not translate into any noticeable decrease in patient-reported outcomes in our study. The mean VAS pain score was 0.6 ± 0.9, which indicates that our patients were mostly pain free. The mean MEPS was 97 ± 6.2, and the mean QuickDASH score was 4.7 ± 7.3, indicating a very low level of disability of the operated arm. All patients rated their surgery as either very or somewhat satisfactory. In addition, we found no significant correlations between supination strength and those outcome variables. This finding is consistent with previous

\[ \text{Discussion} \]

This study found no significant differences in the clinical outcomes between patients whose distal biceps tendon rupture required a second anterior incision and high elbow flexion...
studies12–23 and suggests that patients feel little hindrance from decreased supination strength during their daily living or recreational activities. This may also suggest that patients can readily adapt to the new lower level of strength by modifying their activities or the way they perform those activities. It may be that supination strength was decreased most at terminal supination and the vast majority of daily living or recreational activities do not require strong supination in that position. Another possible explanation is that the patient-oriented outcome measures do not include enough questions that evaluate the activities that require terminal supination strength and, thus, may not be sensitive enough to detect differences.

As previously shown in the literature,3,17 our study found that forearm supination strength is greater at early supination than at terminal supination in normal elbows. In our study, supination strength in a 45° supinated position was, on average, 67% of that in a 45° pronated position in the uninjured elbows. It is interesting to note that the magnitude of the difference was larger in the operated elbows; supination strength in a 45° supinated position was, on average, 53% of that in a 45° pronated position.

Our study has important limitations. First, this was a retrospective cohort study with its inherent biases and weaknesses. Second, the sample size of the study was small. Although we could obtain clinical examination information for all 30 eligible patients, the phone survey was completed in only 26 patients, and strength testing was completed in only 15 patients. We did not perform post hoc power analysis for every negative statistical test result, but it is possible that some of the negative results—especially the subgroup analysis of supination strength in patients with a second incision vs. those without a second incision—could have been the result of a lack of statistical power. It is not known whether the study findings would have been different if more patients had been included. Third, the integrity of tendon repair was evaluated only with a clinical examination (ie, hook test), without advanced imaging studies. The accuracy of the hook test for repaired distal biceps tendons has not been established, but we believed that palpating a taut, firm tendon in the antecubital fossa when the patients tried to actively supinate was sufficient evidence of tendon integrity.

Conclusion
Distal biceps tendon ruptures with severe proximal tendon retraction could be successfully repaired primarily in a nonchronic setting by using a second incision to locate the tendon and flexing the elbow to reduce the tendon to the radial tuberosity. Making a second incision or flexing the elbow for reduction of the tendon did not negatively affect the final clinical outcome including elbow motion or strength. Supination strength was significantly decreased following distal biceps repair using an anterior-approach cortical-button technique, and the strength decrease was more obvious toward terminal supination than at early supination. Despite the objective decrease in supination strength, patient-reported outcomes were not affected negatively.

Disclaimer
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