J Shoulder Elbow Surg (2020) 29, 1548–1553

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Chronic distal biceps avulsion treated with suture button

Craig A. Zeman, MD[a], Joseph D. Mueller, DO[b,*], Brent R. Sanderson, DO[b], Joshua S. Gluck, MD[a]

[a]*Ventura Orthopedics, Clinical Faculty at Community Memorial Health System Orthopedic Residency, Ventura, CA, USA*
[b]*Department of Orthopedic Surgery, Community Memorial Health System, Ventura, CA, USA*

Background: Distal biceps tendon avulsions account for 3%-10% of all biceps ruptures. Treated nonoperatively, these injuries lead to a loss of endurance, supination strength, and flexion strength compared with operative repair or reconstruction. Operative management of chronic injury has classically been with graft tissue to augment the contracted muscle. We present our results for chronic distal biceps avulsions secured with suture button through a single transverse incision in high flexion without the need for allograft augmentation.

Materials and Methods: This was a retrospective review of 20 patients with 21 injuries who underwent primary surgical repair of chronic distal biceps tendon avulsions at an average of 10 weeks (range 4-42 weeks). All patients were treated with a single transverse incision with a suture button armed with nonabsorbable no. 2 core sutures. Postoperatively patients were found to have 50°-90° flexion contracture. All patients were placed in a simple sling postoperatively with gentle extension to gravity as tolerated immediately and no formal physical therapy. Patients were surveyed regarding pre- and postoperative American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score, visual analog scale (VAS) score, Mayo Elbow Performance Score (MEPS), Oxford Elbow Score (OES), and overall satisfaction. Range of motion (ROM), flexion, and supination strength compared to the contralateral uninjured extremity were evaluated at final follow-up.

Results: Mean clinical follow-up was 26 months. All patients regained full ROM and 5/5 flexion and supination strength at final follow-up. MEPSs were 100 for all responding patients compared with an average 47.5 preoperatively ($P < .0001$). The mean postoperative ASES score was 97.2 compared with 41.9 preoperatively ($P < .0001$). Mean OESs pre- and postoperatively were 24.2 and 48, respectively ($P < .0001$). The mean VAS score was 4.4 preoperatively and was reported as 0 by all patients at final follow-up ($P < .0001$). Two patients had transient sensory radial nerve neuropathy, and 1 patient has persistent palsy. No synostoses occurred. Four patients reported supination fatigue postoperatively compared with the uninjured extremity.

Conclusion: Given these results, we feel that chronic distal biceps tendon ruptures can be repaired successfully with a single incision using suture button technique without the use of a graft. Though the flexion contracture is significant postoperatively, all patients regained full ROM and had excellent postoperative functional outcome scores.

Level of Evidence: Level IV; Case Series; Treatment Study

Keywords: Chronic; distal; bicep; button; flexion; rupture; avulsion; EndoButton

Distal biceps tendon avulsions are a relatively rare injury of the upper extremity, accounting for between 3%-10% of all biceps ruptures.[13,28,30,36] These injuries typically occur during the eccentric phase of isokinetic exercise in weightlifters or as a result of a rapid eccentric load placed on the biceps brachii. The location of these avulsion

Community Memorial Health System Institutional Review Board approval was obtained (CMHS IRB Study Number: 2018-HSR017).

*Reprint requests: Joseph D. Mueller, DO, 147 N. Brent St., Ventura, CA 93003, USA.

E-mail address: josephmueller@live.com (J.D. Mueller).

1058-2746/$ - see front matter © 2020 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
https://doi.org/10.1016/j.jse.2020.01.103

injuries tend to occur at the tendon insertion on the bicipital tuberosity of the radius.[34,38]

The treatment of distal biceps tendon avulsions is dependent on many variables, including time from injury, patient comorbidities, baseline functional status, cosmesis, expectations, and surgeon experience. Studies have shown that these injuries treated nonoperatively are well tolerated in low-functioning individuals; however, previous studies demonstrated that nonoperative treatment leads to a loss of endurance, loss of 40%-50% of supination strength, and loss of 30% of flexion strength compared with operative repair or reconstruction.[2,6,7,12,18,22,23,26,28,30,33,35,42] A more recent study did demonstrate that patients were able to regain 63% of supination strength and 93% of flexion strength compared with the contralateral uninjured side.[12] In addition to the loss of function, patients may complain of persistent discomfort, muscle spasm, and ''Popeye'' deformity.

Acute injuries are treated with early anatomic surgical reattachment via a single- or a dual-incision approach with the use of suture button technology, interference screw, suture anchor, transosseous fixation, or some combination of surgical methods. Surgical techniques and approaches continue to be debated among surgeons, with each technique carrying its own unique advantages and complications.[1,3,4,5,10,11,17,20,25,29,39,40] A 2014 systematic review of the different techniques used to repair distal biceps tendons found that the cortical button technique had the lowest complications rate.[41] Multiple biomechanical studies have also evaluated various reattachment techniques, and the suture button construct has reproducibly demonstrated the greatest load to failure.[14,27]

Treatment of chronic injuries has been well described in the literature as well and includes the use of allograft tendon tissue to account for tendon retraction, larger or multiple incisions to aid in tendon identification and clearance of soft tissue adhesions, and nonanatomic tenodesis.[8,15,16,19,21,24,31,35,37,43] The use of allograft tendon brings about additional concerns such as disease transmission, immunologic reaction, poor biologic incorporation, appropriate graft tensioning, and up to a 10-fold increase in implant cost. Nonanatomic tenodesis of the biceps tendon to the brachialis or brachioradialis may improve flexion strength but does not reliably improve supination weakness.

It has been our clinical experience that chronic distal biceps tendon avulsions can safely be directly repaired to the anatomic insertion site through a single incision without the need for allograft tissue. Postoperatively, no additional precautions are necessary, regardless of the final elbow flexed positioning following repair and skin closure. There is a currently a paucity of literature to support a similar protocol of treatment with direct repair of chronic ruptures without the use of supplementary allograft tissue.[9,32,37,41] This retrospective case series is a presentation of the clinical results of a single upper extremity surgeon treating chronic distal biceps injuries using a single transverse incision, primary repair in significant flexion.

Materials and methods

Patients

This study is a retrospective case series with some prospectively collected data points. Patients with chronic ruptures were included in the study. Based on an extensive review of the related literature, we defined *chronic* as 4 weeks' time.[9,32,37] Our average time from injury to treatment was 10 weeks, with a range of 4-42 weeks. Patients were identified using a search of the electronic medical record using CPT code 24342. Charts were reviewed for confirmation of time from injury to surgery, length of follow-up, and strength and range of motion at the time of final follow-up visit, and any perioperative complications. Data were collected for completion of both preoperative and postoperative American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form scoring, Mayo Elbow Performance Score, Oxford Elbow Score, and visual analog scale for pain at either final follow-up in the office or via telephone survey.

Statistical analysis

The Student t test was used to analyze the data given the parametric results. The 95% confidence level ($P < .05$) was chosen to represent statistical significance. Minimal clinically important difference values were chosen based on a review of the current available literature for each individual test performed (Table I).

Surgical technique

All patients in this chronic repair group were repaired using a single transverse incision technique with the retracted tendon secured using a single suture button, EndoButton (Smith & Nephew, Andover, MA, USA), armed with nonabsorbable no. 2 core sutures. After general anesthesia is initiated, the operative extremity is prepped and draped in a sterile fashion taking care to expose as far proximally as possible. Sterile tourniquet is available on the field for application. The transverse incision is made just distal to the elbow crease, and dissection is carefully carried to the bicipital tuberosity.

Finger dissection is then carried proximally in the prior anatomic pathway of the biceps tendon until the retracted tendon stump is identified. In many cases, the tendon is significantly retracted proximally and is scarred into the surrounding tissue, making identification of the tendon stump difficult. To aid with exposure, it is recommended that the subcutaneous tissue proximal to the incision be undermined using blunt finger dissection as far as the surgeon can reach. This allows the incision to become a mobile window that can be then elevated with an Army-Navy retractor, giving the surgeon improved visualization as well as the ability to explore further proximally for the retracted tendon. Although not necessary, a headlamp also can be useful at this point to better visualize under the elevated tissue. After this subcutaneous tissue is freed, bending the elbow to relax the tension on the skin and surrounding soft tissue will also aid in proximal exploration. Once identified, it is important to spend time circumferentially releasing all scar tissue and adhesions from the tendon stump and as far proximally along the bicep as possible. This will facilitate passage of the tendon and help reduce the angle of the elbow required for the tendon to reach the tuberosity. The quality and length of the remaining tendon are then

Table I Minimal clinically important differences for outcome measures

Test	MCID
American Shoulder and Elbow Surgeons	20.9
Mayo Elbow Performance Score	15
Oxford Elbow Score	8.2
Visual analog scale	1.4

MCID, minimal clinically important difference.

evaluated, and nonviable tissue is débrided. For all patients in the study undergoing repair, the use of allograft tissue was not required. After débridement of nonviable tissue, 2 no. 2 nonabsorbable sutures are used in a running/locking configuration and passed through a single suture button.

Attention is then returned to the biceps tuberosity, taking care to avoid excessive retraction. A surgical clamp is placed under direct visualization at the tuberosity and its location is confirmed to be appropriate with the use of fluoroscopy. A cannulated 4.0-mm drill is then used to create a bicortical path for the suture button to pass. A larger, unicortical tunnel is created with a burr based on the diameter of the residual tendon. The residual tendon is then passed deep to the antecubital vessels in its prior anatomic pseudo-sheath. The suture button is deployed followed by tendon reduction into the re-created insertion site. A free needle is then used to pass a locking stitch into the base of the reduced tendon. This can be a difficult step with the elbow in significant flexion, emphasizing the importance of liberating the tendon from adhesions when the stump is found to decrease the amount of flexion required. At this point in the procedure, the incision will be mobile enough to provide exposure directly over the tuberosity. The subcutaneous tissue is closed with 3 or 4 no. 3-0 Vicryl sutures to minimize reactivity to the suture, and the skin is closed with surgical staples. This eliminates the difficulty of passing a subcuticular or running-type suture with the elbow in high flexion.

Postoperative care

Postoperatively, patients' elbows were wrapped in a soft dressing and placed into a standard sling. All patients were allowed to remove the sling when in the sitting position to allow the elbow to gently extend with gravity. Patients were encouraged to perform gravity-assisted extension stretching several times per day. Follow-up visits were scheduled at 1 and 2 weeks to monitor elbow range of motion, including progression of elbow extension. None of our patients underwent physical therapy for motion as we feel that it is safer to let the patient monitor the safe extent of motion and prevent iatrogenic rupture by an overzealous therapist. Patients were then seen at the 6-week and 3-month postoperative follow-ups, with strength training allowed after 3 months. If patients had fully regained motion at 3 months, they were allowed to return to clinic on an as-needed basis.

Results

Between August 2007 and August 2016, the senior author (C.Z.) performed 26 consecutive repairs of distal biceps tendon avulsions using a single-incision technique secured with a suture button construct. Of these, 21 repairs were chronic avulsions performed on 20 patients. The 5 acute repairs were not included in the study. Chronic patients were treated at an average 10 weeks (range 4-42 weeks) from the time of injury. None of the patients in our series required a second, more proximal retrieval incision or augmentation with allograft tissue. There were no cases of partial tear included in this study, and although the presence of an intact lacertus fibrosis was not specifically tracked, in the majority of cases this was also torn. Patient demographic characteristics and follow-up data are shown in Table II. All of the patients were male, with a mean age of 52 years at the time of repair (range 37-63 years). The mean length of final follow-up was 26 months, with no patients lost to follow-up.

In all 21 cases, equivalent strength and range of motion was obtained based on evaluation of the contralateral extremity. At the termination of each procedure, the final elbow position was between 50°-90° after fixation of the tendon stump. This was not individually measured or tracked during each case. The average final elbow range of motion was 3° (range 0°-10°) of extension, 132° (range 125°-150°) of flexion, 64° (range 55°-80°) of pronation, and 71° (range 60°-90°) of supination.

The mean American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form scores pre- and postoperatively were 42 and 97, respectively, and were found to be statistically and clinically significant ($P < .0001$, t test). Mean Mayo Elbow Performance Score preoperatively was 48 and postoperatively was 100, which were found to be both statistically and clinically significant ($P < .0001$, t test). Oxford Elbow Scores preoperatively and postoperatively were 24 and 48, respectively, which were both statistically and clinically significant ($P < .0001$, t test). Finally, mean visual analog scale scores preoperatively and postoperatively were 4.5 and 0, respectively, which were statistically and clinically significant ($P < .0001$, t test).

Complications

Complications in our cohort of patients included 2 transient lateral antebrachial cutaneous neuropathies and 1 that was persistent. One patient presented with subjective radial forearm numbness prior to surgery and continued to have persistent lateral antebrachial cutaneous neuropathy. This accounts for a 14% incidence of neuropathy in these cases. Because of this, we feel it is of utmost importance to counsel patients about this possibility before surgery. The 2 patients who presented postoperatively with transient lateral antebrachial cutaneous nerve paresthesias noted complete resolution of symptoms at the 3-month postoperative appointment. We did not encounter any cases of elbow stiffness that required any formal treatment. We also did not experience any reruptures, contractures, synostoses,

Table II Patient characteristics, range of motion at final clinical follow-up, and outcome measures

Patient No.	Sex	Laterality	Age, yr	Time to surgery, weeks	Follow-up, mo	Final ROM		Pre MEPS	Post MEPS	Pre ASES	Post ASES	Pre OES	Post OES	Pre VAS	Post VAS
						Range	Pronation/supination								
1	M	Right	48	4	117	0°-140°	80°/80°	75	100	63.3	96.6	28	48	0	0
2	M	Left	52	12	98	0°-135°	60°/90°	25	100	23.3	98.3	24	48	8	0
3	M	Left	37	7	6	0°-135°	60°/90°	55	100	51.6	98.3	28	48	3	0
4	M	Left	52	11	6	5°-130°	70°/60°	75	100	63.3	96.6	28	48	0	0
5	M	Right	63	7	60	10°-125°	60°/55°	40	100	21.6	96.6	19	48	6	0
5	M	Left	63	6	60	10°-125°	35°/50°	40	100	21.6	96.6	19	48	6	0
6	M	Left	62	5	22	5°-135°	60°/50°	25	100	18.3	96.6	17	48	8	0
7	M	Left	51	4	31	0°-130°	55°/60°	50	100	43.3	98.3	30	48	6	0
8	M	Right	60	8	6	0°-135°	70°/90°	25	100	18.3	98.3	24	48	8	0
9	M	Right	45	16	26	0°-135°	60°/65°	75	100	78.3	96.6	28	48	0	0
10	M	Left	47	7	5	5°-135°	60°/90°	75	100	74.9	96.6	32	48	0	0
11	M	Left	55	20	16	0°-130°	60°/60°	55	100	55	98.3	22	48	3	0
12	M	Right	53	4	5	5°-130°	70°/80°	25	100	18.3	96.6	25	48	8	0
13	M	Left	38	6	13	0°-140°	60°/80°	40	100	41.6	96.6	21	48	6	0
14	M	Right	42	12	5	5°-125°	70°/70°	40	100	21.6	98.3	19	48	6	0
15	M	Left	60	4	13	0°-130°	60°/70°	40	100	41.6	96.6	21	48	6	0
16	M	Right	62	4	9	10°-135°	65°/60°	40	100	36.6	98.3	21	48	6	0
17	M	Right	38	4	5	0°-130°	80°/80°	55	100	58.3	98.3	24	48	3	0
18	M	Left	44	6	3	0°-150°	80°/75°	75	100	63.3	98.3	28	48	0	0
19	M	Left	58	24	25	5°-125°	60°/70°	25	100	18.3	96.6	24	48	8	0
20	M	Right	58	42	24	0°-125°	70°/70°	50	100	43.3	96.6	24	48	4	0

M, male; *ROM*, range of motion; *Pre*, preoperative; *MEPS*, Mayo Elbow Performance Score; *Post*, postoperative; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *OES*, Oxford Elbow Score; *VAS*, visual analog scale.

infections, or motor nerve palsies in any of our patients, though these potential issues must always be considered as possibilities.

Discussion

Repair of distal bicep tendon ruptures with the use of suture button technology has been repeatedly documented as an excellent option for surgical management with the greatest load to failure. Although this technology has been available for years, there continues to be a lack of literature on the amount of motion and function that can be regained after primary repair with a significantly flexed final elbow position.[19] This has led to the development of many different grafting and reconstruction techniques, including augmentation with the use of fascia lata, semitendinosus, flexor carpi radialis, palmaris, Achilles, and other synthetics.[8,15,16,19,21,24,31,37,43] Each of these options carries its own inherent potential for complications.

Multiple studies have evaluated the load to failure of several fixation methods in the treatment of distal biceps injuries. In a cadaveric study in 2003, Greenberg et al[14] evaluated the pullout strength of the EndoButton, suture anchor, and bone bridge techniques. Their results demonstrated a pullout strength of 584, 253, and 177 N, respectively. They also reported on the average distance of cortical button to the posterior interosseous nerve being 9.3 mm, highlighting the importance of understanding the local anatomy and ensuring the tendon be placed at its footprint at the level of the tuberosity. In a larger cadaveric study in 2007, Mazzocca et al[27] evaluated the tendon displacement of 4 different fixation methods after cyclic loading and then reported the ultimate loads to failure. Although they found no significant difference in displacement, the loads to failure of the EndoButton (440 N), suture anchor (381 N), bone tunnel (310 N), and interference screw (232 N) were significantly different.

In 2014, Morrey et al[32] reported on their results of 23 retracted distal bicep tendon ruptures treated in greater than 60° of flexion via a 2-incision technique and a tendon docking technique. Their study demonstrated that contracted distal biceps tendons may be reliably reattached to their anatomic insertion with up to 90° of elbow flexion. Our study echoes their results: primary repair in flexed position allows patients to regain motion and obtain an excellent outcome. In their cohort, Morrey and colleagues had one patient who required use of an Achilles allograft augmentation secondary to a partial tear in the myotendinous junction. In contrast, our cohort of patients did not require the use of allograft augmentation. Their study highlights the importance of assessing residual tendon quality and having allograft backup available when performing these chronic cases.

There are several limitations of this study that must be taken into consideration. One is the retrospective nature of the project, though much of the data were collected in a prospective manner throughout the treatment of these patients. Another limitation is the potential bias of the examiner in evaluating strength during clinical examination. Additionally, there was no power analysis performed to determine the number of patients needed to make this study generalizable to the population. This may contribute to the lack of patients in our cohort requiring allograft, though the primary purpose of this project is to demonstrate that patients will regain their motion regardless of the high flexion that they may be repaired in. Future studies may consider the addition of MRI to determine if there is a correlation of tendon retraction to the need for allograft tissue augmentation.

Strengths of this study include the consistency in the surgical technique with a single surgeon as well as a constant protocol postoperatively. The study also has an extensive follow-up on its patients, which helps narrow the potential for missed or unappreciated late complications.

Conclusion

Chronic distal biceps tendon ruptures can be treated safely without allograft tissue augmentation through a single incision with suture button technology despite being left in a position of high flexion. These patients obtain excellent postoperative functional outcome scores with a low complication rate and will regain their range of motion with time and self-directed stretching. Although our patient cohort did not require allograft tissue, one must always be prepared to augment their repair in the case of inadequate tendon for fixation.

Disclaimer

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.

References

1. Bain GI, Prem H, Heptinstall RJ, Verhellen R, Paix D. Repair of distal biceps tendon rupture: a new technique using the Endobutton. J Shoulder Elbow Surg 2000;9:120-6.
2. Baker BE, Bierwagen D. Rupture of the distal tendon of the biceps brachii. Operative versus non-operative treatment. J Bone Joint Surg Am 1985;67:414-7.
3. Barnes SJ, Coleman SG, Gilpin D. Repair of avulsed insertion of biceps. J Bone Joint Surg Br 1993;75:938-9.
4. Bosman HA, Fincher M, Saw N. Anatomic direct repair of chronic distal biceps brachii tendon rupture without interposition graft. J Shoulder Elbow Surg 2012;21:1342-7. https://doi.org/10.1016/j.jse.2012.01.012
5. Boyd HB, Anderson LD. A method for reinsertion of the distal biceps brachii tendon. J Bone Joint Surg Am 1961;43:1041-3.
6. Chillemi C, Marinelli M, De Cupis V. Rupture of the distal biceps brachii tendon: conservative treatment versus anatomic reinsertion—clinical and radiological evaluation after 2 years. Arch Orthop Trauma Surg 2007;127:705-8. https://doi.org/10.1007/s00402-007-0326-7
7. D'Alessandro DF, Shields CL Jr, Tibone JE, Chandler RW. Repair of distal biceps tendon ruptures in athletes. Am J Sports Med 1993;21:114-9.
8. Darlis NA, Sotereanos DG. Distal biceps tendon reconstruction in chronic ruptures. J Shoulder Elbow Surg 2006;15:614-9. https://doi.org/10.1016/j.jse.2005.10.004
9. Dillon MT, Bollier MJ, King JC. Repair of acute and chronic distal biceps tendon ruptures using the EndoButton. Hand (N Y) 2011;6:39-46. https://doi.org/10.1007/s11552-010-9286-4
10. El-Hawary R, Macdermid JC, Faber KJ, Patterson SD, King GJ. Distal biceps tendon repair: comparison of surgical techniques. J Hand Surg Am 2003;28:496-502. https://doi.org/10.1053/jhsu.2003.50081
11. Failla JM, Amadio PC, Morrey BF, Beckenbaugh RD. Proximal radioulnar synostosis after repair of distal biceps brachii rupture by the two-incision technique. Report of four cases. Clin Orthop Relat Res 1990:133-6.
12. Freeman CR, McCormick KR, Mahoney D, Baratz M, Lubahn JD. Nonoperative treatment of distal biceps tendon ruptures compared with a historical control group. J Bone Joint Surg Am 2009;91:2329-34. https://doi.org/10.2106/JBJS.H.01150
13. Gilchreest EL. The common syndrome of rupture, dislocation and elongation of the long head of the biceps brachii: an analysis of one hundred cases. Surg Gynecol Obstet 1943;58:322-40.
14. Greenberg JA, Fernandez JJ, Wang T, Turner C. EndoButton assisted repair of distal biceps tendon ruptures. J Shoulder Elbow Surg 2003;12:484-90. https://doi.org/10.1016/s1058-2746(03)00173-3. Erratum in: J Shoulder Elbow Surg 2005;14:231.
15. Hallam P, Bain GI. Repair of chronic distal biceps tendon ruptures using autologous hamstring graft and the Endobutton. J Shoulder Elbow Surg 2004;13:648-51. https://doi.org/10.1016/j.jse.2004.01.032
16. Hang DW, Bach BR Jr, Bojchuk J. Repair of chronic distal biceps brachii tendon rupture using free autogenous semitendinosus tendon. Clin Orthop Relat Res 1996;323:188-91.
17. Hartman MW, Merten SM, Steinmann SP. Mini-open 2-incision technique for repair of distal biceps tendon ruptures. J Shoulder Elbow Surg 2007;16:616-20. https://doi.org/10.1016/j.jse.2006.10.021
18. Hetsroni I, Pilz-Burstein R, Nyska M, Back Z, Barchilon V, Mann G. Avulsion of the distal biceps brachii tendon in middle-aged population: is surgical repair advisable? A comparative study of 22 patients treated with either nonoperative management or early anatomical repair. Injury 2008;39:753-60. https://doi.org/10.1016/j.injury.2007.11.287
19. Hovelius L, Josefsson G. Rupture of the distal biceps tendon. Report of five cases. Acta Orthop Scand 1977;48:280-2.
20. John CK, Field LD, Weiss KS, Savoie FH 3rd. Single-incision repair of acute distal biceps ruptures by use of suture anchors. J Shoulder Elbow Surg 2007;16:78-83. https://doi.org/10.1016/j.jse.2006.03.002
21. Kaplan FT, Rokito A, Birdzell MG, Zuckerman JD. Reconstruction of chronic distal biceps tendon rupture with use of fascia lata combined with a ligament augmentation device: a report of 3 cases. J Shoulder Elbow Surg 2002;11:633-6. https://doi.org/10.1067/mse.2002.126102
22. Klonz A, Loitz D, Wöhler P, Reilmann H. Rupture of the distal biceps brachii tendon: isokinetic power analysis and complications after anatomic reinsertion compared with fixation to the brachialis muscle. J Shoulder Elbow Surg 2003;12:607-11. https://doi.org/10.1016/s1058-2746(03)00212-x
23. Leighton MM, Bush-Joseph CA, Bach BR Jr. Distal biceps brachii repair. Results in dominant and nondominant extremities. Clin Orthop Relat Res 1995;317:114-21.
24. Levy HJ, Mashoof AA, Morgan D. Repair of chronic ruptures of the distal biceps tendon using flexor carpi radialis tendon graft. Am J Sports Med 2000;28:538-40.

25. Lintner S, Fischer T. Repair of the distal biceps tendon using suture anchors and an anterior approach. Clin Orthop Relat Res 1996:116-9.
26. Mariani EM, Cofield RH, Askew LJ, Li G, Chao EYS. Rupture of the tendon of the long head of the biceps brachii: surgical versus nonsurgical treatment. Clin Orthop 1988;228:233-9.
27. Mazzocca AD, Burton KJ, Romeo AA, Santangelo S, Adams DA, Arciero RA. Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. Am J Sports Med 2007;35:252-8. https://doi.org/10.1177/0363546506294854
28. McDonald LS, Dewing CB, Shupe PG, Provencher MT. Disorders of the proximal and distal aspects of the biceps muscle. J Bone Joint Surg Am 2013;95:1235-45. https://doi.org/10.2106/JBJS.L.00221
29. Meherin JM, Kilgore ES. The treatment of ruptures of the distal biceps brachii tendon. Am J Surg 1954;88:657-9.
30. Morrey BF, Askew LJ, An KN, Dobyns JH. Rupture of the distal tendon of the biceps brachii. A biomechanical study. J Bone Joint Surg Am 1985;67:418-21.
31. Morrey BF. Tendon injuries about the elbow. In: Morrey BF, editor. The Elbow and Its Disorders. Philadelphia: Saunders; 2000. p. 468-84.
32. Morrey ME, Abdel MP, Sanchez-Sotelo J, Morrey BF. Primary repair of retracted distal biceps tendon ruptures in extreme flexion. J Shoulder Elbow Surg 2014;23:679-85. https://doi.org/10.1016/j.jse.2013.12.030
33. Nesterenko S, Domire ZJ, Morrey BF, Sanchez-Sotelo J. Elbow strength and endurance in patients with a ruptured distal biceps tendon. J Shoulder Elbow Surg 2010;19:184-9. https://doi.org/10.1016/j.jse.2009.06.001
34. Quach T, Jazayeri R, Sherman OH, Rosen JE. Distal biceps tendon injuries—current treatment options. Bull NYU Hosp Jt Dis 2010;68:103-11.
35. Rantanen J, Orava S. Rupture of the distal biceps tendon: a report of 19 patients treated with anatomic reinsertion, and a meta-analysis of 147 cases found in the literature. Am J Sports Med 1999;27:128-32.
36. Safran MR, Graham SM. Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. Clin Orthop Relat Res 2002;404:275-83.
37. Sanchez-Sotelo J, Morrey BF, Adams RA, O'Driscoll SW. Reconstruction of chronic ruptures of the distal biceps tendon with use of an Achilles tendon allograft. J Bone Joint Surg Am 2002;84:999-1005. https://doi.org/10.2106/00004623-200206000-00015
38. Seiler JG 3rd, Parker LM, Chamberland PD, Sherbourne GM, Carpenter WA. The distal biceps tendon. Two potential mechanisms involved in its rupture: arterial supply and mechanical impingement. J Shoulder Elbow Surg 1995;4:149-56.
39. Sotereanos DG, Pierce TD, Varitimidis SE. A simplified method for repair of distal biceps tendon ruptures. J Shoulder Elbow Surg 2000;9:227-33.
40. Taylor CJ, Bansal R, Pimpalnerkar A. Acute distal biceps tendon rupture—a new surgical technique using a de-tensioning suture to brachialis. Injury 2006;37:838-42. https://doi.org/10.1016/j.injury.2006.02.016
41. Watson JN, Moretti VM, Schwindel L, Hutchinson MR. Repair techniques for acute distal biceps tendon ruptures: a systematic review. J Bone Joint Surg Am 2014;96:2086-90. https://doi.org/10.2106/JBJS.M.00481
42. Weinstein DM, Ciccone WJ, Buckler MC, Balthrop PM, Busey TD, Elias JJ. Elbow function after repair of the distal biceps brachii tendon with a two-incision approach. J Shoulder Elbow Surg 2008;17:82S-6S. https://doi.org/10.1016/j.jse.2007.07.006
43. Wiley WB, Noble JS, Dulaney TD, Bell RH, Noble DD. Late reconstruction of chronic distal biceps tendon ruptures with a semitendinosus autograft technique. J Shoulder Elbow Surg 2006;15:440-4. https://doi.org/10.1016/j.jse.2005.08.018