Surgical Treatment of Distal Biceps Tendon Ruptures

An Analysis of Complications in 784 Surgical Repairs

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Background: Distal biceps brachii tendon ruptures lead to substantial deficits in elbow flexion and supination; surgical repair restores muscle strength and endurance.

Purpose: To examine clinical and surgical outcomes for distal biceps tendon repairs in a large, multispecialty, integrated health care system.

Study Design: Cohort study; Level of evidence, 3.

Methods: Retrospective cohort study of distal biceps tendon repairs performed between January 1, 2008, and December 31, 2015. The repair methods were classified as double-incision approach using bone tunnel–suture fixation or anterior single-incision approach. Anterior single incisions were further classified according to the fixation method: cortical button alone, cortical button and interference screw, or suture anchors alone. Patient demographics, surgeon characteristics, range of motion, and complications were analyzed for all repair types.

Results: Of the 784 repairs that met the inclusion criteria, 639 (81.5%) were single-incision approaches. When comparing double-incision and single-incision repairs, there was a significantly higher rate of posterior interosseous nerve palsy (3.4% vs 0.8%, P = .010), heterotopic bone formation (7.6% vs 2.7%, P = .004), and reoperation (8.3% vs 2.3%, $P < .001$). The most common nerve complication encountered was a lateral antebrachial cutaneous nerve palsy (n = 162), which was significantly more common in the single-incision repairs than in the double-incision repairs (24.4% vs 4.1%, $P < .001$). When excluding lateral antebrachial cutaneous nerve palsies, there was no significant difference in the overall nerve palsies between single-incision and double-incision (5.8% vs 6.9%, P = .612). The overall rate of tendon rerupture was 1.9% (single incision, 1.6%; double incision, 2.8%; P = .327). The overall rate of postoperative wound infection was 1.5% (single incision, 1.3%; double incision, 2.8%; P = .182). The average time from surgery to release from medical care was 14.4 weeks (single incision, 14 weeks; double incision, 16 weeks; P = .286). Patients treated with cortical button plus interference screw were released significantly sooner than were patients with other single-incision repair types (13.1 $\pm$ 8.01 weeks, P = .011). There were no significant differences in rates of motor neurapraxia, infection, rerupture, and reoperation with regard to surgeon's years of practice, fellowship training, or case volume.

Conclusion: The surgical repair of distal biceps tendon ruptures has an overall low rate of serious complications, regardless of approach or technique. However, the double-incision technique has a higher rate of posterior interosseous nerve palsy, heterotopic bone formation, and reoperation rate. Surgeon's years of practice, fellowship training, and case volume do not affect the rate of major complications.

Keywords: elbow; muscle injuries; tendinosis

Distal biceps brachii tendon ruptures predominantly affect men in their fourth to sixth decade of life and have an estimated incidence of 2.55 per 100,000 patient-years.[22] With nonoperative management of a complete rupture, patients will lose 21% to 55% of supination strength, 79% of supination endurance, 10% to 40% of flexion strength, and 30% of flexion endurance.[18,35] Surgical repair has been shown to restore strength and endurance in an active, healthy patient population.[‖]

Classically, an anterior single-incision approach was used, but due to high rates of radial nerve palsy, Boyd and Anderson developed the double-incision technique.[8,15]

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The double-incision technique uses anterior and posterior incisions and achieves fixation by passing sutures sewn to the tendon through bone tunnels in the radial tuberosity and tying knots over a bony bridge. The double-incision technique was later modified by Kelly et al[21] to limit subperiosteal dissection and, theoretically, to decrease the risk of heterotopic ossification (HO) formation. Despite the modification, concerns of HO and the potentially devastating sequela of radioulnar synostosis led many surgeons to return to the anterior single-incision approach. A variety of commercially available fixation devices, such as suture anchors, cortical buttons, and cortical buttons with interference screws, have been described.[12,17,24,35]

Despite biomechanical studies showing fixation superiority of some implants over others, the relative rarity of distal biceps tendon ruptures and the multitude of repair techniques available mean the literature lacks enough power to provide strong clinical evidence on the repair method of choice.[1,35] We examined the largest series of captured distal biceps tendon repair patients within an integrated health care system to determine which repair method results in the best patient outcomes with the fewest rates of complications. Our hypothesis was that repairs performed with a cortical button with an interference screw would produce the best patient outcomes with the lowest rates of complications.

We also investigated surgeon factors, such as fellowship training, years in practice, and number of distal biceps procedures performed, for possible correlation with complications.

METHODS

After obtaining institutional review board approval from our institution, we reviewed distal biceps tendon repairs performed between January 1, 2008, and December 31, 2015, by 85 surgeons from 13 hospitals in a multispecialty, integrated health care system. The institutional review board incorporated all 13 hospitals and, given the retrospective study design, individual surgeon approval was not required. Distal biceps tendon repairs were identified by using the following interfacility codes: “arm biceps distal, tendon repair” and “arm biceps, tendon repair.” Inclusion criteria included patients age 18 and older with primary repairs of the distal biceps tendon, postoperative documentation, and at least 6 months of follow-up. Length of follow-up was calculated from date of surgery until time of retrospective chart review. Exclusion criteria included chronic tears requiring tendon reconstruction or interpositional “bridging” grafts. A retrospective chart review was performed of all identified and eligible patients to obtain pre- and postoperative data. Variables recorded included patient demographics (age, sex, occupation, hand dominance), surgeon characteristics (years of practice, case volume, fellowship training), mechanism of injury, time from injury to surgery, surgical approach, repair type/technique, tourniquet time, time to release from medical care (defined as weeks from surgery to last time the patient was seen by the orthopaedic provider), postoperative range of motion, and rates of infection, rerupture, reoperation, HO formation, and nerve complications.

Surgical Techniques

Each surgeon used his or her preferred repair method. All tendons were primarily repaired directly to the bicipital tuberosity, regardless of the chronicity of the tear. The surgical techniques incorporated in the study include (1) double-incision technique using bone tunnel–suture fixation (no implants used), (2) anterior single-incision technique using cortical button fixation alone, (3) anterior single-incision technique using cortical button and interference screw fixation, (4) anterior single-incision technique using suture anchor fixation, and (5) anterior single-incision technique using other fixation devices. In this study, double-incision repairs were classified as the use of both an anterior and posterior incision. We treat double-incision and bone tunnel fixation synonymously, as no implants were used for fixation in the double-incision technique/approach. On occasion, a second more proximal anterior incision was used to aid in the retrieval of retracted tendon stumps. This additional incision was performed per the discretion of the surgeon to decrease the size of the anterior approach.

Postoperative Protocol

Postoperative protocols were variable, were specified by each surgeon, and were carried out by multiple physical therapists. All patients received a period of immobilization followed by repair-specific physical therapy.

Statistical Methods

All data were summarized by the number of incisions used in the surgery; among patients with single-incision operations, additional summarization of data by the type of fixation method (any method, cortical button alone, cortical button plus interference screw, or suture anchor only) is

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TABLE 1
The Most Frequent Mechanisms of Injury

Mechanism of Injury	Frequency (No. of Events)
Lifting	463
Fall	46
Martial arts	34
Baseball/softball	25
Water sports	21
Basketball	18
All others	177

provided. Comparison of measured characteristics by the number of incisions was performed using Pearson chi-square test or the Fisher exact test for categorical variables and independent-samples t test or the nonparametric Wilcoxon ranked-sums test for continuous variables, as appropriate. The parametric assumption was tested using the Shapiro-Wilk test for normality, and all hypothesis tests were 2-sided and considered statistically significant at the 5% type I error rate. All data management and analyses were performed using SAS Enterprise Guide v5.1 (SAS Institute).

RESULTS

There were 784 primary distal biceps tendon repairs performed by 85 surgeons over the study period from January 1, 2008, through December 31, 2015, that met our inclusion criteria. The distal biceps tendon tear was complete in 91.6% of injuries and partial in 8.4%. The dominant extremity was involved in 408 (52%) of tears. The mean patient age was 48 years (range, 20-83 years), with 772 (98.5%) being male; 117 (15%) of patients were active smokers. No patients admitted to active use of anabolic steroids. The most common mechanism of injury was a forceful eccentric extension of a flexed elbow, as in lifting heavy objects (Table 1). Overall, 23 (2.9%) of patients had a documented history of distal biceps tendon rupture in the contralateral extremity. The average time from injury to surgery was 22.9 days (median, 10 days; range, 0-1825 days), and there was no statistically significant difference between single-incision and double-incision repairs (23.3 vs 21.1 days, P = .440). The total number of chronic repairs (>90 days from injury) was 34: double-incision, 6 (3/6 partial ruptures); cortical button alone, 12 (8/12 partial ruptures); cortical button plus interference screw, 11 (4/11 partial ruptures); and suture anchors, 5 (3/5 partial ruptures). The overall average length of follow-up was 49 months (range, 6.6-96.9 months). The mean follow-up for each repair type was as follows: double-incision, 58 months; cortical button alone, 41 months; cortical button plus interference screw, 38 months; and suture anchors, 62 months. There were no significant differences with regard to patient demographics (age, sex, race/ethnicity, or mechanism of injury) between repair types.

An anterior single-incision technique was used in 639 (81.5%) patients, and a double-incision technique was used in 145 (18.5%) (Table 2). Of the single-incision group, 212 (33.2%) were treated with cortical button alone, 211 (33.0%) were treated with cortical button plus interference screw, and 216 (33.8%) were treated with suture anchors (Table 3). There were 8 repairs treated using other fixation devices that were excluded from our study. The histogram of single versus double-incision techniques across the years of the study period is shown in Figure 1; Figure 2 shows the histogram by fixation types across time. Of the cortical buttons used, 82% were BicepsButton (Arthrex), 15% Endobutton (Smith & Nephew), and 3% ToggleLoc (Biomet). A tourniquet was used in 541 (84.6%) of single-incision repairs versus 126 (86.9%) of double-incision repairs. The tourniquet times were significantly shorter for single-incision repairs compared with those for double-incision repairs (56.2 minutes vs 72.5 minutes, $P < .001$).

The mean time from surgery to release from medical care was 14.2 ± 7.97 weeks for single-incision repairs and 16.0 ± 11.51 weeks for double-incision repairs (P = .339). When comparing the single-incision repairs, patients treated with cortical button plus interference screw were released significantly sooner than were patients with other repair types (13.1 ± 8.01 weeks for cortical button plus interference screw, 14.7 ± 7.23 weeks for cortical button alone, and 14.7 ± 8.52 weeks for suture anchors; P = .011). Overall mean postoperative range of motion was 2.4° to 134.7°, with a mean arc of motion of 132.2°. The postoperative range of motion was, on average, 3.5° to 132.9° in the double-incision group and 2.2° to 135.1° in the single-incision group, with the average arc of motion being lower in the double-incision group than in the single-incision group (129.4° vs 132.9°, $P < .001$).

The most common nerve complication encountered was a lateral antebrachial cutaneous nerve (LABCN) palsy (n = 162), which was significantly higher in the single-incision repairs than in the double-incision repairs (24.4% vs 4.1%, $P < .001$). The single-incision approach had significantly higher rates of overall nerve palsy compared with the double-incision approach (30.2% vs 11.0%, $P < .001$). However, when excluding LABCN palsies, there was no significant difference in the overall nerve palsies between single-incision and double-incision repairs (5.8% vs 6.9%, P = .612). No patients required exploration or repair of the LABCN or superficial radial nerve, and at time of last follow-up, no patient had documentation of ongoing sensory nerve palsy. The rate of posterior interosseous nerve palsy was significantly higher in the double-incision repairs than in the single-incision approach (3.4% vs 0.8%, P = .010). There were no significant differences in rates of nerve palsy between the different single-incision repair techniques (P = .522).

The overall rate of postoperative wound infection was 1.5% (single incision, 1.3%; double-incision, 2.8%; P = .182). Three patients (0.4%) required irrigation and debridement for treatment of infection. The overall rate of tendon rerupture was 1.8%. Tendon reruptures occurred in 1.6% of single-incision and 2.8% of double-incision repairs (P = .327). Average time to rerupture was 21 days (range, 5-60 days). There were no significant differences in rates of rerupture between the different single-incision repair types (P = .677).

The overall rate of heterotopic bone formation was 3.6%, with significantly higher rates in patients treated with the double-incision technique (single incision, 2.7%; double-

TABLE 2
Comparison of Single-Incision Versus Double-Incision Distal Biceps Tendon Repairs[a]

	Single-Incision (n = 639, 81.5%)	Double-Incision (n = 145, 18.5%)	Total (N = 784)	*P* Value
Injury characteristics				
Time from injury to surgery, d				.440
Mean (SD)	23.3 (82.96)	21.1 (39.74)	22.9 (76.77)	
Range	0.0-1825.0	0.0-365.0	0.0-1825.0	
Injury severity				.055
Complete	591 (92.5)	127 (87.6)	718 (91.6)	
Partial	48 (7.5)	18 (12.4)	66 (8.4)	
Release from medical care, wk				.339
Mean (SD)	14.2 (7.97)	16.0 (11.51)	14.5 (8.75)	
Range	0.0-60.0	2.0-75.0	0.0-75.0	
Tourniquet time, min				<.001
Mean (SD)	56.2 (21.51)	72.5 (22.06)	59.5 (22.58)	
Range	0.0-155.0	27.0-124.0	0.0-155.0	
Complications				
Infection	8 (1.3)	4 (2.8)	12 (1.5)	.182
Reoperation	15 (2.3)	12 (8.3)	27 (3.4)	<.001
Rerupture of tendon	10 (1.6)	4 (2.8)	14 (1.8)	.327
Heterotopic ossification	17 (2.7)	11 (7.6)	28 (3.6)	.004
Overall nerve palsy	193 (30.2)	16 (11)	209 (26.7)	<.001
Major nerve palsy (no LABCN)	37 (5.8)	10 (6.9)	47 (6)	.612
LABCN palsy	156 (24.4)	6 (4.1)	162 (20.7)	<.001
SRN palsy	30 (4.7)	3 (2.1)	33 (4.2)	.155
PIN palsy	5 (0.8)	5 (3.4)	10 (1.3)	.010

[a]Data are expressed as n (%) unless otherwise noted. LABCN, lateral antebrachial cutaneous nerve; PIN, posterior interosseous nerve; SRN, superficial radial nerve.

TABLE 3
Comparison of Fixation Methods Among Single-Incision Distal Biceps Tendon Repairs[a]

	Fixation Method				
	Button Alone (n = 212, 33.2%)	Button + Screw (n = 211, 33.0%)	Anchor Only (n = 216, 33.8%)	Total (N = 639)	*P* Value
Injury characteristics					
Time from injury to surgery, d					<.001
Mean (SD)	33.8 (134.11)	22.0 (43.72)	14.3 (27.78)	23.3 (82.96)	
Range	1.0-1825.0	1.0-420.0	0.0-272.0	0.0-1825.0	
Injury severity					.614
Complete	193 (91)	197 (93.4)	201 (93.1)	591 (92.5)	
Partial	19 (9)	14 (6.6)	15 (6.9)	48 (7.5)	
Release from medical care, wk					.011
Mean (SD)	14.7 (7.23)	13.1 (8.01)	14.7 (8.52)	14.2 (7.97)	
Range	0.0-47.0	1.0-52.0	1.0-60.0	0.0-60.0	
Tourniquet time, min					.178
Mean (SD)	58.4 (22.50)	56.6 (22.41)	53.8 (19.45)	56.2 (21.51)	
Range	12.0-120.0	0.0-155.0	18.0-120.0	0.0-155.0	
Complications					
Infection	2 (0.9)	5 (2.4)	1 (0.5)	8 (1.3)	.184
Reoperation	6 (2.8)	5 (2.4)	4 (1.9)	15 (2.3)	.800
Rerupture of tendon	4 (1.9)	2 (0.9)	4 (1.9)	10 (1.6)	.677
Heterotopic ossification	10 (4.7)	3 (1.4)	4 (1.9)	17 (2.7)	.072
Overall nerve palsy	62 (29.2)	70 (33.2)	61 (28.2)	193 (30.2)	.504
Major nerve palsy (no LABCN)	9 (4.2)	15 (7.1)	13 (6)	37 (5.8)	.445
LABCN palsy	53 (25)	55 (26.1)	48 (22.2)	156 (24.4)	.633
SRN palsy	7 (3.3)	12 (5.7)	11 (5.1)	30 (4.7)	.482
PIN palsy	1 (0.5)	3 (1.4)	1 (0.5)	5 (0.8)	.436

[a]Data are expressed as n (%) unless otherwise noted. LABCN, lateral antebrachial cutaneous nerve; PIN, posterior interosseous nerve; SRN, superficial radial nerve.

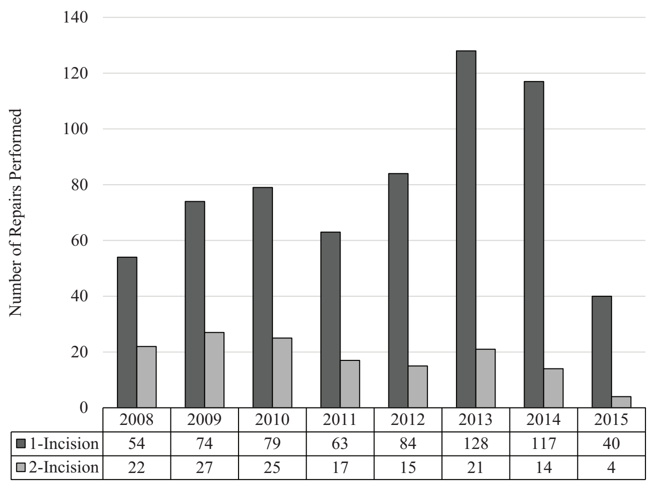

Figure 1. Histogram of distal biceps tendon repairs by number of incisions and year.

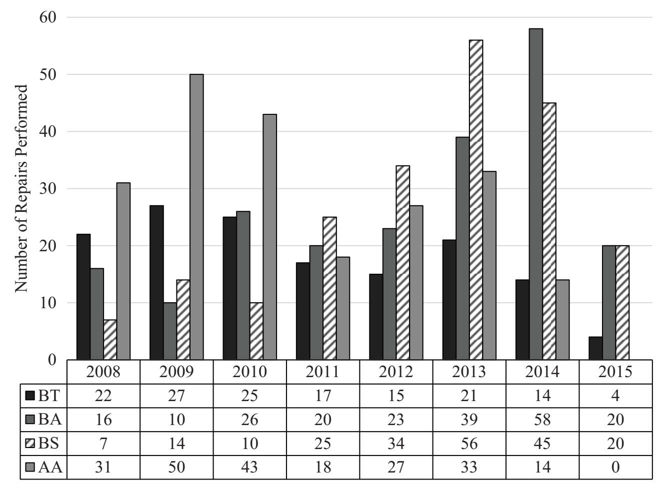

Figure 2. Histogram of distal biceps tendon repairs by repair type and year. AA, suture anchor alone; BA, cortical button alone; BS, cortical button plus interference screw; BT, double-incision bone tunnel.

incision 7.6%; *P* = .004). Among the single-incision repairs, although not statistically significant, cortical button patients had a rate of HO formation that was 3 times higher compared with cortical button plus interference screw repairs (4.7% vs 1.4%, *P* = .072).

Radial neck fracture occurred on 1 occasion (0.12%). The patient underwent a cortical button plus interference screw fixation with an 8-mm tunnel and the fracture occurred as result of a fall at 6 weeks postoperatively (Figure 3). The tunnel placement in this case was too proximal in the radial neck, which may have predisposed it to a fracture. The overall reoperation rate was 3.4%. The indications for reoperation were rerupture (n = 11, 41%), HO excision (n = 7, 26%), infection (n = 3, 11%), misplaced hardware (n = 2, 7%), scar revision (n = 2, 7%) and other (n = 2, 7%). Patients treated with a double-incision technique had a significantly higher incidence of reoperation (single incision, 2.3%; double-incision 8.3%; *P* < .001).

Surgeon characteristics were available for 84 surgeons (one surgeon who performed 1 cortical button case was excluded due to lack of complete surgeon information). The average number of years in practice was 10.2 ± 6.85 years (range, 0-29 years). The average number of cases performed over the study period was 9.7 ± 10.47 cases (range, 1-68 cases); 34 surgeons performed 1 to <5 cases, 16 surgeons performed 5 to <10 cases, 19 surgeons performed 10 to <15 cases, 6 surgeons performed 15 to <20 cases, and 9 surgeons performed >20 cases. Overall, 81% of surgeons were fellowship trained.

Analysis of surgeon characteristics demonstrated that surgeons using the double-incision technique had been in practice longer than were those employing a single-incision repair technique (13.8 ± 6.0 years vs 9.4 ± 6.8 years, *P* < .001). In addition, those surgeons who used a double-incision technique performed a statistically greater total number of cases than did surgeons performing a single-incision approach (21.6 ± 10.9 cases vs 17.7 ± 15.6 cases, *P* < .001) (Table 4). There were no significant differences in the single-incision repair types with regard to years in practice

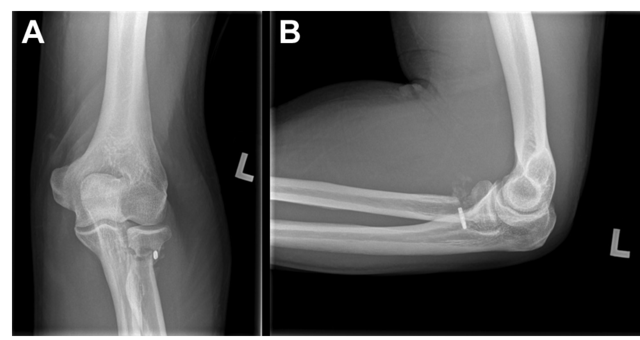

Figure 3. (A) Anteroposterior and (B) lateral radiographs of postoperative radial neck fracture. The tunnel was placed in the radial neck and not the tuberosity, predisposing it to a fracture.

(cortical button alone, 9.1 ± 6.9 years; cortical button plus interference screw, 8.6 ± 5.6 years; suture anchors, 10.5 ± 7.5 years, *P* = .114). When comparing single-incision repair types by total number of cases performed, cortical button and cortical button plus interference screws were used more frequently than were suture anchors in surgeons performing >15 cases (*P* < .001). In addition, cortical button and cortical button plus interference screws were used more frequently than were suture anchors by fellowship-trained surgeons (*P* < .001).

When comparing overall complication rates to surgeon characteristics, there was a significantly higher rate of overall nerve palsies in relation to years in practice, with surgeons with less than 5 years of experience having a 33.2% rate versus a 20.5% rate in surgeons with more than 15 years of experience (*P* = .022) (Table 5). Similarly, the rate of overall nerve palsy was significantly lower when surgeons performed >20 cases (*P* = .019) (Table 6). After eliminating LABCN palsies, there were no significant differences in overall observed nerve palsies with

TABLE 4
Comparison of Fixation Methods for Distal Biceps Tendon Repairs Versus Surgeon Characteristics

	Double Incision (n = 145, 18.5%)	Single Incision: Any Method (n = 638, 81.5%)	Single Incision: Button Alone (n = 211, 27.0%)	Single Incision: Button + Screw (n = 211, 27.0%)	Single Incision: Anchor Only (n = 216, 27.6%)	Total (N = 783)	*P* Value[a]
Surgeon years of experience							<.001
Mean (SD)	13.8 (5.96)	9.4 (6.78)	9.1 (6.94)	8.6 (5.59)	10.5 (7.52)	10.2 (6.85)	
Range	1.0-29.0	1.0-27.0	1.0-27.0	1.0-27.0	1.0-26.0	1.0-29.0	
0 to <5	13 (9)	195 (30.6)	76 (36)	54 (25.6)	65 (30.1)	208 (26.6)	
5 to <10	20 (13.8)	181 (28.4)	60 (28.4)	71 (33.6)	50 (23.1)	201 (25.7)	
10 to <15	38 (26.2)	131 (20.5)	25 (11.8)	72 (34.1)	34 (15.7)	169 (21.6)	
15 years or more	74 (51)	131 (20.5)	50 (23.7)	14 (6.6)	67 (31)	205 (26.2)	
No. of cases performed							<.001
Mean (SD)	21.6 (10.86)	17.7 (15.64)	16.5 (10.67)	25.0 (21.83)	11.7 (7.64)	18.4 (14.94)	
Range	1.0-36.0	1.0-58.0	1.0-58.0	1.0-58.0	1.0-58.0	1.0-58.0	
0 to <5	6 (4.1)	79 (12.4)	18 (8.5)	30 (14.2)	31 (14.4)	85 (10.9)	
5 to <10	21 (14.5)	124 (19.4)	43 (20.4)	30 (14.2)	51 (23.6)	145 (18.5)	
10 to <15	14 (9.7)	194 (30.4)	62 (29.4)	56 (26.5)	76 (35.2)	208 (26.6)	
15 to <20	24 (16.6)	42 (6.6)	18 (8.5)	6 (2.8)	18 (8.3)	66 (8.4)	
20 or more	80 (55.2)	199 (31.2)	70 (33.2)	89 (42.2)	40 (18.5)	279 (35.6)	
Is surgeon fellowship trained?							.984
No	19 (13.1)	84 (13.2)	17 (8.1)	4 (1.9)	63 (29.2)	103 (13.2)	
Yes	126 (86.9)	554 (86.8)	194 (91.9)	207 (98.1)	153 (70.8)	680 (86.8)	

[a]Reported *P* value is for the test of the null hypothesis of no significant difference between single- or double-incision methods' average years of experience of the performing surgeon or for the chi-square test of association between single- and double-incision methods and each categorical characteristic of the surgeon. All continuous variables are reported as mean (SD), and all categorical variables as n (%).

TABLE 5
Comparison of Complications by Surgeon's Years in Practice[a]

	0 to <5 (n = 208, 26.6%)	5 to <10 (n = 201, 25.7%)	10 to <15 (n = 169, 21.6%)	15 or More (n = 205, 26.2%)	Overall (N = 783)	*P* Value
Complications						
Infection	4 (1.9)	3 (1.5)	2 (1.2)	3 (1.5)	12 (1.5)	.949
Reoperation	8 (3.8)	5 (2.5)	4 (2.4)	10 (4.9)	27 (3.4)	.474
Rerupture of tendon	4 (1.9)	3 (1.5)	3 (1.8)	4 (2)	14 (1.8)	.985
Heterotopic ossification	6 (2.9)	8 (4)	1 (0.6)	13 (6.3)	28 (3.6)	.026
Overall nerve palsy	69 (33.2)	57 (28.4)	40 (23.7)	42 (20.5)	208 (26.6)	.022
Major nerve palsy (no LABCN)	15 (7.2)	13 (6.5)	11 (6.5)	8 (3.9)	47 (6)	.513
LABCN palsy	54 (26)	44 (21.9)	29 (17.2)	34 (16.6)	161 (20.6)	.068
SRN palsy	12 (5.8)	10 (5)	6 (3.6)	5 (2.4)	33 (4.2)	.345
PIN palsy	2 (1)	1 (0.5)	4 (2.4)	3 (1.5)	10 (1.3)	.427

[a]Data are expressed as n (%). LABCN, lateral antebrachial cutaneous nerve; PIN, posterior interosseous nerve; SRN, superficial radial nerve.

regard to surgeon years in practice, case volume, or fellowship training (Table 7). In addition, there were no significant differences in rates of infection, rerupture, and reoperation with regard to surgeon years in practice, case volume, or fellowship training.

DISCUSSION

Multiple repair techniques have been described for distal biceps brachii tendon ruptures, with little consensus on which repair method produces the best patient outcomes. Prior studies examining acute distal biceps tendon repairs have been limited by small sample sizes, making comparisons between repair types difficult. We report on the largest series examining the 4 most common distal biceps tendon repairs in the literature to elucidate which surgical repair method produces the fewest complications. In addition, our study is the first to analyze surgeon characteristics (years in practice, case volume, fellowship training) and their associated effects on repair type selection and the subsequent rate of complications. We have found that repair type and surgeon characteristics do not significantly affect functional outcomes (postoperative range of motion or time to release from medical care) or the rate of major complications (permanent nerve injury, infection, or rerupture).

TABLE 6
Comparison of Complications by Surgeon's Number of Cases Performed[a]

	0 to <5 (n = 85, 10.9%)	5 to <10 (n = 145, 18.5%)	10 to <15 (n = 208, 26.6%)	15 to <20 (n = 66, 8.4%)	20 or More (n = 279, 35.6%)	Overall (N = 783)	*P* Value
Complications							
Infection	3 (3.5)	2 (1.4)	1 (0.5)	1 (1.5)	5 (1.8)	12 (1.5)	.417
Reoperation	4 (4.7)	5 (3.4)	2 (1)	4 (6.1)	12 (4.3)	27 (3.4)	.183
Rerupture of tendon	2 (2.4)	3 (2.1)	1 (0.5)	0 (0)	8 (2.9)	14 (1.8)	.258
Heterotopic ossification	3 (3.5)	2 (1.4)	4 (1.9)	7 (10.6)	12 (4.3)	28 (3.6)	.009
Overall nerve palsy	22 (25.9)	46 (31.7)	63 (30.3)	22 (33.3)	55 (19.7)	208 (26.6)	.019
Major nerve palsy (no LABCN)	7 (8.2)	6 (4.1)	18 (8.7)	4 (6.1)	12 (4.3)	47 (6)	.225
LABCN palsy	15 (17.6)	40 (27.6)	45 (21.6)	18 (27.3)	43 (15.4)	161 (20.6)	.023
SRN palsy	6 (7.1)	2 (1.4)	16 (7.7)	2 (3)	7 (2.5)	33 (4.2)	.011
PIN palsy	0 (0)	3 (2.1)	1 (0.5)	2 (3)	4 (1.4)	10 (1.3)	.339

[a]Data are expressed as n (%). LABCN, lateral antebrachial cutaneous nerve; PIN, posterior interosseous nerve; SRN, superficial radial nerve.

TABLE 7
Comparison of Complications by Surgeon's Fellowship Training Status[a]

	Not Fellowship Trained (n = 103, 13.2%)	Fellowship Trained (n = 680, 86.9%)	Overall (N = 783)	*P* Value
Complications				
Infection	2 (1.9)	10 (1.5)	12 (1.5)	.717
Reoperation	5 (4.9)	22 (3.2)	27 (3.4)	.401
Rerupture of tendon	1 (1)	13 (1.9)	14 (1.8)	.502
Heterotopic ossification	7 (6.8)	21 (3.1)	28 (3.6)	.059
Overall nerve palsy	30 (29.1)	178 (26.2)	208 (26.6)	.528
Major nerve palsy (no LABCN)	6 (5.8)	41 (6)	47 (6)	.935
LABCN palsy	24 (23.3)	137 (20.1)	161 (20.6)	.460
SRN palsy	4 (3.9)	29 (4.3)	33 (4.2)	.858
PIN palsy	1 (1)	9 (1.3)	10 (1.3)	.766

[a]Data are expressed as n (%). LABCN, lateral antebrachial cutaneous nerve; PIN, posterior interosseous nerve; SRN, superficial radial nerve.

Our data show that single-incision repairs undergo lower rates of reoperation, posterior interosseous nerve palsy, and HO but experience significantly higher rates of transient sensory nerve palsy compared with a double-incision technique.

Our study of 784 patients, representative of the greater diversity of the Southern California population, is also representative of the patient population that develops distal biceps tendon ruptures.[25] The average age, sex, and mechanism of injury we observed correlate closely with the recent large series by Beks et al[5] and the large systematic reviews conducted by Watson et al[38] and Kodde et al.[23] In addition, the treatment modalities included in this study have been widely compared in the literature. Double-incision bone tunnel–suture fixation, cortical button, suture anchor, and cortical button plus interference screw techniques have all been shown to produce good clinical results. Several studies, including a randomized control trial, have compared repair types with regard to outcomes and rate of complications.[¶] Unfortunately, these studies' statistical analyses have been limited by small sample sizes, and to our knowledge, no previous study has examined more than 100 patients in each group analyzed. For example, the largest published series, by Wang et al,[37] uses the Pearl Diver database and analyzes more than 1400 patients. Unfortunately, due to the PearlDiver database's reliance on Current Procedural Terminology code data, the authors were unable to delineate results by repair type. In contrast, our study analyzed individual patient charts from all clinic and emergency department visits across all specialties and is the first to compare the 4 most common distal biceps tendon rupture treatment modalities, with more than 140 patients in each group.

Distal biceps tendon ruptures occur predominantly in the active working population, but few studies have examined the time to return to work from medical care with regard to repair type. Atanda et al[2] reported on the differences in outcomes between non–workers' compensation and workers compensation patients undergoing distal biceps tendon repairs. They reported that workers' compensation patients returned to full duty at 3.95 months, whereas non–workers' compensation patients returned at 1.35 months. In their series of 40 patients treated with cortical button plus interference screw, Heinzelmann et al[17]

[¶]References 5, 9, 10, 12, 16, 19, 23, 28, 32, 38.

found the average self-reported postoperative time to resume normal activities or return to work was 6.5 weeks. We used time to release from medical care as a gauge of functional outcome, given that it incorporates the surgeon's perceived confidence in the type of repair, patient range of motion milestones, as well as the assumed time to resolution of complications. In our study, patients with single-incision repairs were released sooner than were patients with double-incision repairs, although this did not ultimately reach statistical significance. Among the single-incision repairs, patients treated with cortical button plus interference screw were released from medical care significantly sooner than were patients with any other repair type at 13.1 weeks (P = .011). The addition of an interference screw has been shown to produce a more anatomic placement of the repaired biceps tendon but has not been shown to lead to significant improvement in biomechanical strength compared with button alone.[1,31,33] Further research is warranted to determine if the quicker release from medical care with cortical button plus interference screw observed in our cohort equates to a significantly sooner return to work compared with the other repair methods. The trend in repair techniques as seen in Figures 1 and 2 demonstrates a decline in double-incision repairs and an increase in cortical button alone and cortical button plus interference screw fixation over the course of our study period.

The complications associated with distal biceps tendon repair have been well established in the literature. The most common observed complications include nerve palsy, HO, infection, rerupture, and fracture.[15,35] Given the large sample size of our study, we were able to capture each of these complications. Similar to the findings of the randomized control trial by Grewal et al,[16] the most common complications observed in our patients were transient sensory nerve palsies in patients undergoing anterior single-incision repairs. An LABCN palsy occurred in 20.7% of cases overall. This finding is similar to other studies of single-incision repairs with rates between 3% and 57%.[#] We observed a rate of LABCN palsy that was nearly 5 times lower in the double-incision approach (4.1% vs 24.4%), which agrees with other reports ranging from 0% to 11%.[6,10,16,19,35,38] In our cohort, posterior interosseous nerve palsy occurred more frequently in the double-incision than in the single-incision technique. Our overall rate of posterior interosseous nerve palsy of 1.3% is lower than most previously published rates ranging from 2% to 14%.[**] Nigro et al[27] showed that it takes up to 5 months for posterior interosseous nerve palsies to recover, and in our cohort, all nerve palsies resolved by time of release from medical care.

Despite numerous publications and the widely accepted modifications of the double-incision technique, HO formation remains a common complication for all types of distal biceps tendon repair.[21] In contrast to the review by Cohen,[13] in our cohort, we observed a significantly higher rate of HO formation in the double-incision repairs. The rate of HO formation in our double-incision patients was 7.6%, which is similar to previous reports in which rates range from 2% to 10%.[5,6,32,35] We believe this is likely an underestimation of the overall rate of HO formation given that patients did not routinely receive radiographs past the immediate perioperative period unless they were symptomatic. Revision surgery for HO excision or synostosis takedown was performed in 4.1% of the double-incision patients. In the single-incision repairs, cortical button alone had a higher rate of HO (4.7%) compared with cortical button plus interference screw (1.4%) and suture anchors (1.9%). High rates of HO formation (2%-35%) have also been shown in other studies when only a cortical button is used for fixation.[10,11,24,26,36] We hypothesize that in double-incision and cortical button alone, HO occurs more frequently due to an increased escape of marrow elements postoperatively from the creation of the bony trough and reamer hole. The lower observed rates in the cortical button plus interference screw repairs could potentially be due to the tight seal created between the screw-tendon-bone interface, limiting the escape of HO-forming marrow elements in these patients. This notion is purely theoretical, and we believe further research in this area, as well as HO prophylaxis, is warranted.

The primary purpose of distal biceps tendon repair is to improve the patient's strength and endurance. As such, the rate of rerupture is an important consideration for both surgeon and patient. Previous studies have published a rerupture rate ranging from 0% to 5.6%, with larger studies ($n > 100$) reporting rates near 1.5%.[††] In our cohort, we had a similar overall rerupture rate of 1.8%. Although we observed tendon reruptures in 1.6% of single-incision and 2.8% of double-incision repairs, we did not show a statistically significant difference in the rerupture rate between the 2 methods (P = .327). In the single-incision repairs, the lowest rates of rerupture were in the cortical button plus interference screw group. Hinchey et al[19] reported that reruptures occur within the first 3 weeks entirely because of patient compliance and excessive force across the fresh repair. Our results are similar, with all reruptures occurring in the first 60 days postoperatively (range, 5-60 days).

Surgeon characteristics are an often overlooked component of orthopaedic research but have the potential to affect the generalizability of a study's conclusions. Given the large number of surgeons included in our study, we chose to analyze the distal biceps repair types by surgeon characteristics to determine if differences in outcomes were related to surgeon training and experience. We found that surgeons in the first few years of practice used the single-incision technique more often, which is likely a result of the new advances in single-incision technology and the corresponding marketing of these devices over the last 10 years. In addition, among surgeons who perform the single-incision technique, those without fellowship training were more likely to use suture anchor fixation than a form of cortical button fixation. We postulate this may be due to a lack of exposure in training to the cortical button or a concern for potential complications with cortical button fixation, such as nerve injury

[#]References 2, 4, 5, 7, 9-12, 14, 16, 20, 23, 24, 26, 28, 29, 38.

[**]References 3-5, 10, 11, 14, 15, 19, 23, 24, 26, 27, 34, 35.

[††]References 2, 5, 6, 9, 10, 12, 14-16, 19, 20, 23, 32, 35, 38.

or fracture. In our study, the rate of overall nerve palsy was significantly lower in surgeons with greater than 15 years of experience and with greater than 20 cases performed. When LABCN palsies were excluded, however, there were no differences in nerve complications with regard to surgeon years in practice, cases performed, or fellowship training. Of note, the rate of observed HO was significantly higher in surgeons with more years in practice and with a greater number of cases performed, but this can be attributed to the higher percentage of double-incision surgeons in this group. Furthermore, we found no difference in retear, infection, or reoperation rates in relation to all surgeon characteristics. Similarly, Beks et al[5] showed no difference in surgeon years of experience in patients with or without adverse events. From our data, we conclude that the rate of major complications (motor palsy, retear, reoperation, infection) is not influenced by surgeon characteristics.

The strengths of our study are the large number of subjects analyzed across the 4 most common distal biceps tendon repair techniques over a study period of 8 years. Each repair type was adequately represented and had similar demographic characteristics. The incorporation of 85 different surgeons from an assortment of hospitals, using a variety of implants, adds significant real-world applicability to our results. Compared with previous retrospective studies, our study analyzes patients in an integrated health care system, and thus all patient visits to all specialties were captured and included in our analysis. This provides added reliability that outcomes and complications were captured. In addition, our study analyzes surgeon characteristics and demonstrates that surgeon experience may contribute to repair type used but ultimately does not affect the rate of major complications. The limitations of our study are inherent to its retrospective design, which prohibits randomization and uniform treatment protocols. All pre- and postoperative data were gathered through chart review. We did not analyze the rate of HO prophylaxis. Also, due to the lack of a prospective treatment algorithm, the reporting of standardized functional outcome scores was inconsistent among providers. The inclusion of pre- and postoperative strength, endurance, and pain scores could have potentially added further insight into which repair type is superior.

CONCLUSION

In the largest retrospective cohort study comparing the 4 most common traumatic distal biceps tendon repair types, we found that surgical repair of distal biceps tendon ruptures has an overall low rate of serious complications, regardless of approach or technique. Surgeon experience and training may contribute to the repair type used but ultimately do not affect the rate of major complications. The most common complication overall was an LABCN palsy, most commonly found in anterior single-incision repairs. A double-incision repair using bone tunnel–suture fixation led to statistically higher rates of posterior interosseous nerve palsy, heterotopic bone formation, and reoperation. The cortical button plus interference screw technique had a significantly shorter time to release from medical care compared with other anterior single-incision repair types. These data provide surgeons and patients with an accurate representation of the advantages and disadvantages of each repair type. Further research into the functional outcomes, cost effectiveness, and potential routine use of HO prophylaxis for each repair type is warranted.

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