Intramedullary Cortical Button Fixation of Distal Biceps Tendon Rupture: long-term Patient Outcomes"

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Abstract

Introduction: No consensus exists for optimal distal biceps rupture fixation. Dorsal cortical button (DCB) and dual incision transosseous (DITO) provide the greatest biomechanical load-to-failure, permitting earlier mobilization to prevent arthrofibrosis. Both methods have complications, restricted range of motion (ROM) from heterotopic ossification and proximal radioulnar synostosis for DITO while DCB has increased cutaneous and posterior interosseous nerve (PIN) injuries. The intramedullary cortical button (ICB) fixation limits PIN palsy risk, decreases implant costs and provides strong tendon-bone fixation.

Methods: 21 patients with ICB fixation of chronic and acute distal biceps ruptures at >1 year postoperatively completed a satisfaction survey and Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. ROM, neuropraxia and other complications obtained from chart.

Results: At 4 years average (1.3-7.4) 81% were extremely and 10% very satisfied with their overall outcome. 81% reported no strength or ROM limitations, 76% had pain-free activity, 86% and 81% were extremely satisfied with postoperative elbow ROM and forearm ROM respectively. The mean DASH and sports DASH score were 3.52 and 2.5. 52% had cutaneous deficits, 38% lateral antebrachial cutaneous nerve (LABCN) and 19% superficial radial nerve (SRN). No biceps re-ruptures or PIN palsies were observed.

Conclusion: The ICB technique provides secure distal biceps tendon fixation with excellent long-term patient satisfaction and comparable functional outcomes with restoration of normative DASH scores. The cutaneous nerve complication rate was comparable to other single incision studies and no observed PIN palsies or wound complications while decreasing implant costs.

Keywords: Distal biceps; Tendon repair; Single incision; Endobutton; Intramedullary fixation; Patient reported outcomes

Introduction:

Distal biceps tendon injuries are uncommon with an incidence of 1.2 per 100,000, affecting the dominant arm of males, 86% and 97% respectively, with 98% presenting in their 4th and 5th decades after a forced eccentric elbow extension(7,13,17,29,34,40). Suspected etiologies include a hypovascular zone and mechanical tendon impingement during full pronation(35). Cigarette smoking carries a 7.5x greater risk(29). Non-operative management is possible in low demand patients but anatomic repair restores the strength/endurance loss of 30%/40% for forearm supination and 20%/30% for elbow flexion(1,25,29,30).

Fixation methods include dorsal cortical button (DCB), interference screw (IS) and suture anchor (SA) through a single anterior incision which decreases stiffness risk from heterotopic ossification (HO) and proximal radioulnar synostosis (PRUS) from the second posterior incision necessitated by the dual incision transosseous (DITO) technique developed by Boyd and Anderson (2,4,7). The Morrey modification decreases HO and PRUS risk by dissecting through the extensor carpi ulnaris (ECU) and avoiding ulna exposure. (22,30) DCB had the highest load-to-failure (LTF) in biomechanical studies but to date has not demonstrated clinical superiority over DITO(7,15,23,27,37,39). 30-50% incidence of cutaneous sensory nerve deficits (CSN) and a 1-15% incidence of posterior interosseous nerve (PIN) palsies have been reported with the DCB fixation, attributed to radial retraction at the radial tuberosity plus guide pin and cortical button location(13,40). PIN palsies have been noted after all techniques but are most frequently associated after the DCB(6,16,31). PIN palsies cause significant patient concern and disability despite spontaneous resolution, in a majority of cases, within 3-5 months(6,31). Tendon transfer for a permanent PIN injury has been reported(31). A distally or radially directed guide pin exits within 1-2mm of the PIN with 30% in direct nerve contact(13,26,31).

Nerve injury risk remains despite techniques limiting PIN injury during guide pin advancement by altering pin trajectory to an AP direction with 0-30° ulnar angulation, tapping guide pin through the posterior soft tissues and intraoperative fluoroscopy to assess for soft tissue interposition between the DCB and cortex(6,21,26). In the ICB method, the cortical button is intramedullary, underneath the radial tuberosity as shown in Figure 1 a-b, eliminating PIN injury from the guide pin and cortical button. Two

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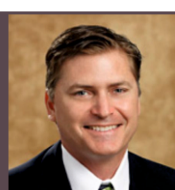
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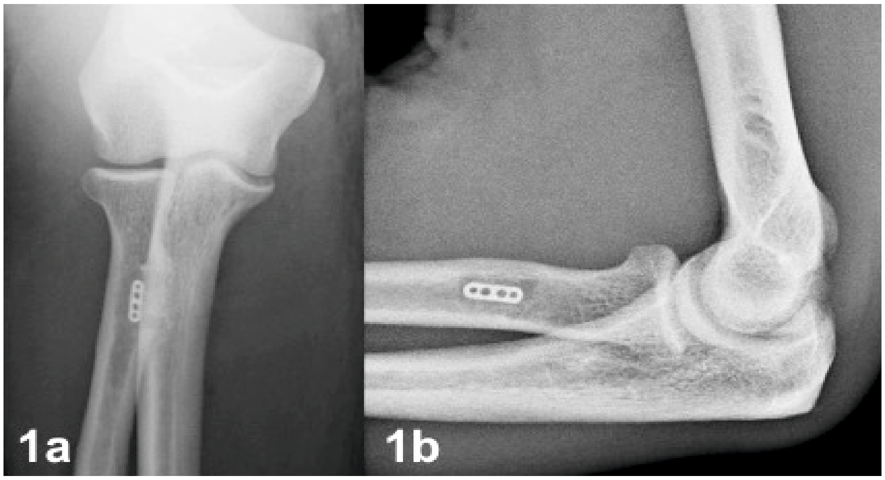

Figure 1 a-b : Postoperative AP and lateral demonstrating intramedullary cortical button technique. The Endobutton™ is positioned against the intramedullary wall underneath the biceps tuberosity footprint. No proximal radioulnar synostosis or heterotopic ossification is noted.

biomechanical studies have validated the load-to-failure strength of this method and a small three patient case series has demonstrated good short-term results(27,39,38). In contrast to the technique by Seibenlist(38), the senior author's ICB technique utilizes a single intramedullary cortical button securing the biceps stump with two high-strength braided sutures. This article demonstrates the long-term clinical outcomes of this novel technique.

Methods

This institution's research ethics board approved of this study. The study was a retrospective case series of consecutive patients undergoing a distal biceps tendon repair by the senior author. Patients were identified by CPT code search from January 2009 through April 2016. The exclusion criteria included minors, prior/current legal action with the author's orthopedic group, and transfer of care in a worker's compensation setting. Inclusion criteria included ICB repair of acute or chronic ruptures without allograft and greater than 1 year follow-up.

A total of 32 distal biceps tendon ruptures were identified in 31 patients. 21 (68%) completed a Disabilities of the Arm Shoulder and Hand (DASH) and sports DASH plus a satisfaction questionnaire. Chart and radiographs were reviewed for ICB location, chronicity of injury, time to surgery, presence of wound complications, motor or sensory nerve deficits with resolution timeframe, ROM, and re-rupture.

Surgical technique and postoperative protocol

The ICB technique utilizes a 4cm transverse anterior incision 2cm distal to the distal antecubital flexion crease with dissection between the brachioradialis and pronator teres. The biceps tendon stump is mobilized as necessary for tendon excursion. The biceps tuberosity is prepared with a curette or high-speed burr creating a clean, bleeding bony surface. A #2 high-strength braided suture is threaded through the toggle hole at both ends of a Smith and Nephew Endobutton™. A needle and suture passes one suture pair into the 4.7mm hole and out the 2mm hole drilled with mild convergence in the distal and proximal tuberosity footprint separated by a 1.5cm bony bridge. This suture pair shuttles the Endobutton™ into the intramedullary canal with both limbs of each suture exiting their respective hole. Figure 2 a-h illustrates the technique. One limb from each suture is whipstitched proximally and back distally. Tensioning the free suture limb exiting the 2mm hole and tying to its free suture pair compresses the biceps stump against the radial tuberosity and secures the Endobutton™ against the intramedullary cortex at the 2mm hole. Finally the free suture limb exiting the 4.7mm hole is tensioned and tied with its

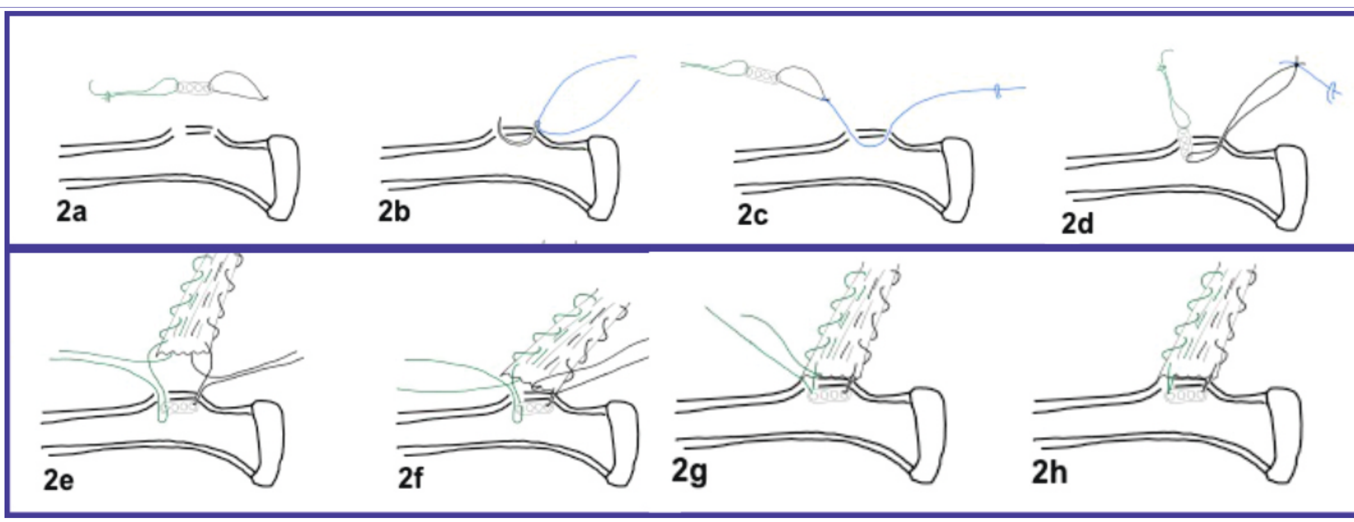

Figure 2 a-h : Illustration of intramedullary cortical button technique. a) #2 high-strength braided suture in each hole at both ends of an Endobutton™ & slightly convergent proximal 2mm and distal 4.7mm drill holes in the biceps tuberosity footprint. b) Pass a shuttling suture with a free needle from proximal to distal. c) Tie the shuttling suture to one braided suture pair loop. d) Shuttle Endobutton™ into intramedullary canal through distal 4.7mm hole. e) Whipstitch one end of each suture proximally and distally. f) Tension free suture from proximal 2 mm hole to compress tendon to bone and secure the Endobutton™ within intramedullary canal. g) Tie proximal sutures limbs together, tension free suture from distal 4.7mm hole. h) Completed repair.

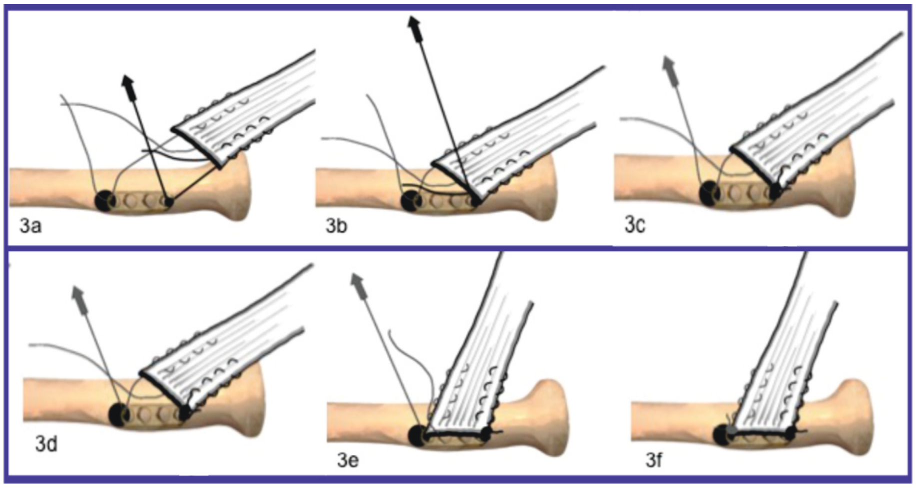

Figure 3 a-e : Illustration of tendon reduction and securing Endobutton™ by a) tensioning the free proximal suture limb b) reduces and compresses the tendon against the proximal tuberosity foot print and secures the Endobutton™ within the intramedullary canal c-d) tensioning the free distal suture limb e) reduces and compresses the remainder of the tendon against the distal tuberosity footprint f) the tendon to bone compressive forces are spread along the entire prepared tuberosity surface.

suture pair limb, evenly distributing the tendon compression over the entire tuberosity footprint. Figure 3 a-e depicts the tendon reduction and fixation.
Intraoperative photographs are shown in Figure 4 a-g.
No postoperative HO prophylaxis is routinely used. Postoperatively, a soft dressing and a posterior long-arm splint with the elbow at 90° flexion and forearm maximally supinated is applied. At 1 week, if a tension free biceps tendon repair was possible without elbow flexion, gentle elbow and forearm motion is permitted in a hinged elbow brace limiting the terminal 30° of extension. If elbow flexion is necessary to achieve a tension-free repair, elbow ROM is delayed for 4 weeks in a long-arm cast at 90° elbow flexion and full supination before transitioning to a hinged elbow brace permitting motion except for the terminal 30° of extension. For all patients, the brace is fully unlocked at 6 weeks, allowing full elbow ROM and the brace is discontinued at 8 weeks. The patient begins formal physical therapy at 8 weeks for ROM and strengthening at 12 weeks. The patient is cleared for full activities at 6 months.

Results
All patients were male, averaging 49 years (30-60) and involved the dominant arm in 52% (15/28). 10% (3/31) had bilateral ruptures, the senior author operated bilaterally in one patient. Former or current smokers comprised 32% (10/31) of patients, including 2 of 3 bilateral ruptures.
There were 2 (6.5%) diabetic patients in this study, one with bilateral rupture of distal biceps tendons.
68% (21/31) completed questionnaires at 4 years on average (range 1.3 to 7.4 years), 71% (15/21) also completed the sports DASH. The mean DASH and sports DASH score was 3.52 and 2.5 respectively. 81% (17/21) were extremely satisfied with their overall outcome and 10% (2/21) very satisfied. The mean DASH and sports DASH scores improved to 0.93 and 1.04 respectively with 93% (14/15) extremely satisfied after excluding WC patients.
81% (17/21) reported no motion or strength activity limitations. 76% (16/21) had no pain with any activity. 86% (18/21) and 81% (17/21) of patients are extremely satisfied with postoperative elbow ROM and forearm ROM respectively. 67% (14/21) of patients are extremely satisfied with elbow flexion and forearm supination strength. See Table 1 for summary of results.

Complications
No incidences of PRUS were noted and only 6.5% (2/31) developed HO. All regained full elbow ROM at 20 weeks average (range 4-40 weeks). 9.5% (2/21) lacked more than 50° and 19% (4/21) lacked more than 20° of total forearm rotation at final clinic follow-up, with the two HO patients losing 20° and 40°. Both regained full forearm rotation at 2 and 4 years during re-examination while completing the questionnaire. The Endobutton™ was located on the intramedullary radial tuberosity footprint in all repairs except 9.5% (2/21) were angled 10-15^0 towards the proximal drill hole. Nerve injuries were noted in 52% (11/21) of patients, consisting of 66% (38% 8/21) LABCN and 36% (19% 4/21) SRN. At the last clinic follow up visit, 19 weeks average, 50% of both (4/8) LABCN and (2/4) SRN deficits spontaneously resolved. At time of study, another 50% had resolved with only minimal deficits remaining in 25% of the initial (2/8) LABCN and (1/4) SRN injuries. No patients in the study re-ruptured their repaired biceps tendon, developed a PIN palsy or experienced a

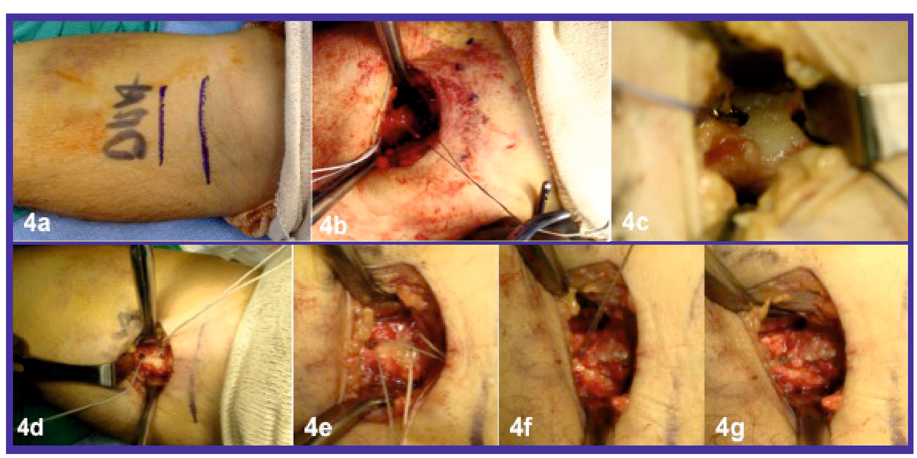

Figure 4 a-g : Intraoperative pictures of intramedullary cortical button technique in the right arm of a supine patient. a) Transverse 4cm incision 2cm distal to the distal elbow flexion crease. b) Shuttling suture passing one braided suture from the distal 4.7mm hole and out the 2mm proximal hole. c) The Endobutton™ entering the distal 4.7mm hole. d) The Endobutton™ seated within the intramedullary canal underneath the biceps footprint with both ends of a braided suture exiting their respective proximal and distal holes. e) One limb of each braided suture whipstitched to the biceps stump. f) The free suture limb from the proximal hole has been tensioned and tied, bringing the biceps stump to the prepared biceps tuberosity. Tensioning the free suture limb from the distal hole brings the remaining biceps tendon down to the tuberosity. g) Completed repair with complete restoration of the biceps tuberosity tendon footprint.

Table 1: Satisfaction, Disabilities of Arm, Shoulder and Hand (DASH) and sports DASH with breakdown of worker's compensation (WC) and private patient outcomes. Satisfaction scale: 5=Extremely Satisfied 4=Very Satisfied 3=Satisfied 2=Somewhat Satisfied 1=Very Dissatisfied

	Elbow ROM	Forearm ROM	Elbow strength	Forearm strength	Residual pain	Overall satisfaction	Avg	DASH	Sports DASH
Total	4.76	4.71	4.29	4.38	4.48	4.71	4.54	3.52	2.5
WC	4.5	4.5	3.5	3.83	4	4.33	4.06	10	8.33
Private	4.87	4.8	4.6	4.67	4.67	4.87	4.73	0.93	1.04

wound infection.

Discussion

No consensus exists regarding the optimal fixation technique for distal biceps tendon, with common techniques utilizing DCB, SA, or IS fixation through a single incision or a DITO repair. Each has advantages and disadvantages with no clear superiority demonstrated consistently in the literature. DCB and DITO fixation have the greatest biomechanical load-to-failure strength but have respective complications of PIN palsy and decreased ROM from HO and PRUS. The ICB technique's rationale is decreased cost in comparison to double SA, minimize PIN injury risk of the DCB by eliminating dorsal radius cortical violation and cortical button placement near the PIN while creating a strong tendon-bone interface to aid biologic healing to prevent recurrent rupture and permit early ROM to prevent arthrofibrosis.

Patients reported high satisfaction rates and comparable DASH scores to studies utilizing different fixation methods. 91% of patients were either extremely (81%) or very satisfied (10%) with their overall outcome. These satisfaction rates were similar those observed by Cohen(9) with 89% either extremely (72%) or very satisfied (16%) and McKee (28) with 81% very satisfied as shown in Table 2. The high overall satisfaction rates were also reflected in the restoration of normative DASH scores equivalent to the general population(18,19).

Our observed mean DASH score of 3.52 was comparable to recent studies, see Table 2, with values ranging from 3.1 to 10.3 and within the minimal clinical important difference (MCID) of 9.6 to 15(1,5,9,14,16,18,28,32,36). Only 4% (1/21) had >50° and 19% (4/21) had >20° loss of total supination/pronation at time of

Table 2: Clinical literature summary of patient reported outcomes and satisfaction. DCB = dorsal cortical button, IS = interference screw, SA = suture anchor, DITO = dual incision transosseous

	# Patients/Fixation	Follow-up %	Mean follow-up	Mean DASH	Satisfaction rate
Caekebeke 2016 (5)	12 DCB+PLLA IS 11 DCB+PEEK IS	1	1 Year	5.4 DCB+PLLA IS 3.1 DCB+PEEK IS	
Shields 2015 (36)	20 DCB 21 DITO	0.52	>1 year	4.47 DCB 5.7 DITO	
Recordon 2015 (33)	19 DCB 27 DITO	0.3	2.1 years		93% Very satisfied
Cohen 2015 (9)	25 DCB 33 DITO	0.38	>2 years	5.91 DCB 6.32 DITO	72% (4/58) Extremely satisfied 17% (10/58) Very satisfied
Giacalone 2015 (14)	21 DITO		22 months	8 DITO	
Olsen 2014 (32)	17 SA 20 DCB		32 months SA 18 months DCB	10.3 SA 4.5 DCB	
Cusick 2014 (10)	170 DCB+IS				
Grewel 2014 (16)	47 SA 43 DITO	0.91	2 years	7.8 SA 5.5 DITO	
Weinstein 2008 (42)	47 DITO	0.7	42 months	4 DITO	
McKee 2005 (28)	53 SA	0.85	29 months (6-89)	8.2 all patients 4.7 w/>12 month follow-up	81% Very satisfied 15% Somewhat satisfied
Greenberg 2003 (15)	14 DCB	1	20 months		

Table 3: Clinical literature rate of heterotopic ossification, synostosis, decreased range of motion, and incidence of peripheral nerve injury. LABCN = lateral antebrachial cutaneous nerve SRN = superficial radial nerve, PIN = posterior interosseous nerve, DCB = dorsal cortical button, IS = interference screw, SA = suture anchor, DITO = dual incision transosseous, ppx = prophylaxis

	Heterotopic ossification	Synostosis	< Range of motion	LABCN	SRN	PIN	Other
Caekebeke 2016 (5)	8% (1/12) DCB+PLLA IS 18% (2/11) DCB+PEEK IS	None		22% (5/23)			
Shields 2015 (36)	9.5% (2/21) Asymptomatic DITO	None	9.5% (2/21) <50° Sup/Pro DITO	Chart DCB 6% (3/54)	20% (4/20) DCB 4.8% (1/21) DITO		5% (1/21) Ulnar palsy DCB
Recordon 2015 (33)	16% (3/19) Asymptomatic DCB 11% (3/27) Asymptomatic DITO 4% (1/27) Symptomatic DITO	None	1 <ROM w HO	30% (14/47)			
Cohen 2015 (9)		6% (2/33) DITO	8% DCB 12% DITO	12% (3/25) DCB			9% (5/58) undefined DITO
Giacalone 2015 (14)	9.5% (2/21) DITO		9.5% (2/21) <30° Sup			5% (1/21) DITO	
Olsen 2014 (32)		None		18% (3/17) SA	6% (1/17) SA 20% (4/21) DCB		6% (1/17) Ulnar palsy SA
Cusick 2014 (10)	0.59% (1/170) Asymptomatic DCB+IS	None	None	10% (17/170) DCB+IS	1.5% (2/170) DCB+IS	2.3% (3/170) DCB+IS	2.3% (3/170) Local
Grewel 2014 (16)	2% (1/47) Asymptomatic w/o ppx SA 2% (1/43) Asymptomatic w/ppx DITO	None	10% > pronation SA	40% (19/47) SA 4.7% (2/43) DITO			2% (1/43) Local DITO
Weinstein 2008 (42)	0% (0/47) DITO	None	None	4% (2/47) SA			
McKee 2005 (28)			None	4% (2/53) SA		2% (1/52) SA	
Greenberg 2003 (15)	26% (5/19) Asymptomatic DCB	None	5% (1/19) DCB	21% (3/14) DCB			

this study at 20 months average. A prospective randomized study of SA versus DITO fixation by Grewal(16) noted no significant difference in patient reported outcomes including DASH, ASES, PREE, and VAS at 2 years postoperatively. The authors did note a significant difference of 10% greater elbow flexion strength in DITO but no difference in ROM was noted with a mean supination of 64° and pronation of 77° for SA fixation.

There were 6 worker's compensation (WC) patients, shown to have worse outcomes overall, included in this study with only half extremely satisfied with worse mean DASH scores of 10 and 8.33(24). Atanda(1) examined WC's effect on distal biceps tendon repair outcomes and noted statistically significant worse mean DASH and sports DASH scores in WC patients of 3.35 and 0.2 versus 0.4 and 0.1 for non-WC patients. Slower return to full duty of 4 months compared to 1.4 months in non-WC patients was also noted. McKee(28) also observed a statistically significant difference in mean DASH scores of 5.5 in non-WC versus 16.9 in WC patients(28). We observed a similar trend with a mean DASH of 10 in WC patients versus 0.93 for non-WC patients. Similarly, the percentage of extremely satisfied patients improved to 93% from 85%.

Besides obtaining good patient outcomes and satisfaction, limiting postoperative complications is important with published studies reporting an increased incidence of CSN deficits after a single anterior incision compared to DITO(16). The most common CSN injury is the LABCN estimated at 5%-57% followed by SRN at 5%-10%(8,11,13,15,16,20,31,33,36,41). Grewel (16) noted a 40% (19/47) incidence of LABCN sensory deficits in SA versus (2/47) 4.3% in DITO. All but 3 had resolved spontaneously by 6 months and 2 remaining at 2 years. Cusick (10) noted complete resolution of all 22 sensory nerve deficits at 8 months including 10% (17/170) LABCN, 1.5% (2/170) SRN, and 2.3% (3/170) local incisional numbness, see Table 3.

Motor nerve palsies have been noted with PIN palsies, occurring in 1%-10% and believed to be more prevalent after DCB fixation but has been observed after all techniques(13,31). Nigro(31) reported a 3.2% incidence of PIN neuropraxias in a literature review. Patients had a good prognosis overall with spontaneous recovery at an average of 86 days in a large majority of patients. Cusick(10) noted a 2.3% (3/170) incidence of PIN neuropraxia with spontaneous recovery after combination DCB and IS fixation.

The PIN is believed to be at greatest risk during DCB fixation as the guide pin exits the dorsal cortex as close as 2mm on average to the PIN nerve with distal and radial direction of the guide pin. A transverse incision in the antecubital flexion crease is cosmetic, but its location ~2cm proximal to the tuberosity will push the guide pin's trajectory distally, therefore increasing PIN injury risk. An anterior-posterior (AP) and ulnarly deviated direction increases the guide pin to PIN distance to 11mm-16mm. (26) However, directing the path too ulnarly risks ulna penetration or ulna-implant impingement in full supination. The ICB technique moves the incision 2cm distally, placing it directly over the biceps tuberosity, allowing AP drilling in the biceps footprint and minimizes PIN nerve injury risk as the dorsal cortex is not violated by the guide pin or Endobutton™. Other sources of PIN injury include placement of retractors radially on the radius and excessive radial soft tissue retraction(13,31).

Many cases of HO are asymptomatic with rates ranging from 0%-25% and found on radiographs while others decrease ROM and, along with PRUS, cause decreased forearm rotation(6,13,40). Studies of the Boyd-Anderson DITO report an incidence of 15% HO and 5% PRUS(12,13). The decrease in incidence of symptomatic HO and PRUS is due to the increasing popularity of single incision fixation, the Morrey modification that dissects through the ECU, avoids interosseous membrane violation and ulna periosteal stripping, see Table 3 (2,22).

We noted no PRUS and 2 cases (9.5%) of HO noted on postoperative radiographs. Both had full elbow ROM but the first had 40° loss of total forearm rotation with 60° of supination at 10 months while the second had 20° of total forearm rotation at 7.5 months. However on re-examination at time of study, both patients had full symmetric bilateral forearm rotation with 85° of supination and 90° pronation. This suggests that patients with limited forearm rotation at up to 10 months can continue to see improvement over time and achieve full ROM.

There were no observed re-ruptures in this study with the reported rate in the literature ranging from 0-5.6%(7,13,16,29,40). However, this study may not have been powered to capture a re-rupture and patients followed a protective postoperative protocol. Grewal(16) noted a 4.4% re-rupture rate in 91 patients treated with either SA or DITO repairs. All 4 occurred during the early postoperative period due to non-compliant activities. Wang(40) reported a 5.4% re-rupture rate, with a non-significant trend towards higher rates in chronic tears. Citak(8) noted a 5.6% re-rupture rate in 54 patients undergoing SA repair with Titan Corkscrew, Super Quick Anchor Plus or DITO. All the ruptures occurred in the Super Quick Anchor Plus suture anchor group.

Reliable tendon-bone healing requires rigid fixation with both high LTF and low cyclical displacement. The highest LTF of common fixation methods in biomechanical testing was the DCB as described by Bain(2,16). In testing by Siebenlist(27), the LTF of ICB not statistically different at 275N compared to 305N for DCB despite a thinner biceps tuberosity cortex but both values were significantly less than the LTF of an intact biceps tendon. In comparison to a double suture anchor fixation method, Siebenlist(38) reported a non-significant trend towards less displacement under cyclical loading of a double ICB construct, which doubles the button/bone contact surface area with identical suture/tendon fixation as a single double loaded ICB

Conclusions

ICB fixation provides biomechanically solid bone-tendon fixation performed through a single anterior incision to minimize symptomatic HO and PRUS risk, yielding comparable cutaneous nerve complications rates to other single anterior incision fixation methods while minimizing the PIN neuropraxia risk observed with DCB fixation. Patient satisfaction rates, DASH scores and ROM are comparable to studies utilizing other fixation methods. Patients with decreased forearm motion at up to 10 months postoperatively can continue to improve their motion and achieve symmetric motion with time.

The paper's strengths includes long-term clinical follow-up, validated patient reported outcome questionnaire, single surgeon with a single technique, and no exclusion for chronic tears or allograft use. The weaknesses include limited patient follow-up leading to selection bias and underestimation of complications and poorer outcomes, low number of objective patient physical examinations, retrospective nature of study, and no cohort comparison with alternative repair method.

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Conflict of Interest:
Jake Ni, MD – NIL
David Auerbach - Consultant: Smith & Nephew, Fastform, Breg, and Integra; Royalties: Hely Weber, Stryker, Top Shelf, Fastform and Wolters Kluwer
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