



Acute complete and partial distal biceps tendon ruptures: what have we learned? A review

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- Acute distal biceps tendon (DBT) pathology includes bicipitoradial bursitis, tendinosis, partial and complete tears.
- Diagnosis of complete DBT tears is mainly clinical, whereas in partial tears medical imaging is a valuable addition to the clinical diagnosis.
- New insights in clinical and medical imaging of partial tears may reduce time to diagnosis and may guide the treatment plan.
- Most complete tears are best treated with primary repair using either a single-incision or double-incision approach with good clinical outcome.
- The double-incision technique has a higher risk of heterotopic ossification, whereas a single-incision technique carries a higher risk of nerve-related complications.
- Intramedullary fixation may be a viable solution to negate the risk of posterior interosseus nerve lesions in single-incision repairs.
- DBT endoscopy can be used to treat low-grade partial tears and tendinosis.

Keywords: complete; distal biceps tendon; elbow; intramedullary; partial; review; rupture; test

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Introduction

Although our knowledge of distal biceps tendon (DBT) pathology has evolved significantly over the last few years, some elements of diagnosis and treatment still remain controversial. Most studies focus on biomechanical and clinical outcomes of older techniques. Only a few report on innovation. The purpose of this article is to provide an up-to-date review of the literature with an emphasis on new concepts in diagnosis and treatment of acute complete and partial DBT ruptures. This starts with an understanding of the relevant anatomy, epidemiology

and pathophysiology as this will dictate further improvements in diagnosis and treatment.

Anatomy of the distal biceps tendon

The biceps muscle consists of two distinct muscle heads and is innervated by the musculocutaneous nerve. Distally, the biceps inserts with a tendon and the lacertus fibrosus. The tendon has long been described as one single structure, but Eames et al clearly showed the distinction between the long and short heads at the distal insertion (Fig. 1).¹ Both tendons attach to the posterior aspect of the radial tuberosity.² At the level of the musculotendinous junction the short head lies medial to long head. The tendon externally rotates 90° while it traverses the bicipital tunnel. This rotation positions the short head distal to the long head. The tendon of the long head inserts proximal and posterior on the bicipital tuberosity of the radius. This location dictates a contribution mostly to a supination moment of the forearm. The tendon of the short head inserts more distal on the radial tuberosity giving it a greater elbow flexion moment.³ The radial tuberosity has a protuberance just anterior to the distal

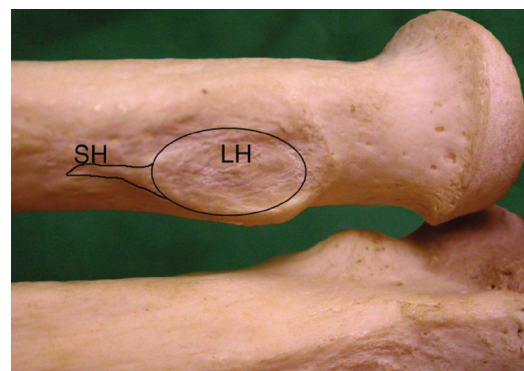


Fig. 1 The short and long head of the distal biceps tendon have distinct insertion areas.

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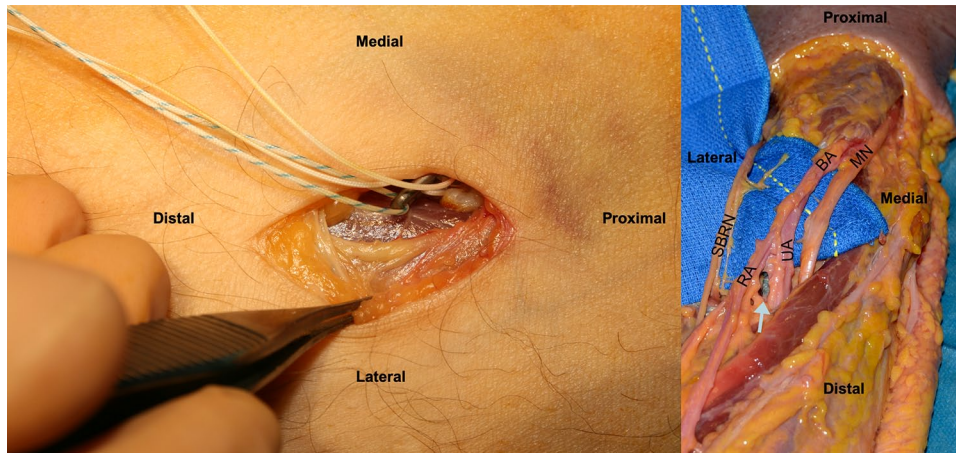


Fig. 2 Localization of the lateral antebrachial cutaneous nerve (LACN), the superficial branch of radial nerve (SBRN), the median nerve (MN), the ulnar artery (UA), radial and recurrent radial arteries (RA), and their bifurcation. Biceps flagged with white arrow. Note. Copyright MoRe Foundation.

biceps insertion which acts as a cam increasing the supination force.^{4,5}

The lacertus fibrosus originates at the level of the musculotendinous junction and consists of three distinct layers, enveloping the forearm flexors and serving as a stabilizer to the distal biceps tendon.⁶ A tense lacertus fibrosus secondary to contraction of the forearm flexors may contribute to tendon rupture due to a medial pull at the time of injury.⁷ The preservation of the lacertus at the time of surgery remains controversial.⁸

The vascularity of the distal biceps tendon can be categorized into a proximal, middle and distal zone. The proximal zone is comprised of the musculotendinous junction and the proximal tendon. It is supplied by branches of the brachial artery which continue in the paratenon. The distal zone is supplied by the posterior interosseous recurrent artery. The middle zone is a hypovascular zone which averages 2.14 cm in length and is supplied by the two beforementioned arteries, although only through its thin extratendinous paratenon cover.⁹ The radial recurrent artery branch of the radial artery lies superficial to the distal biceps tendon and is often accompanied by two to four venous structures. Variations in number and branches of the artery have been described.¹⁰

Several nerves run across the forearm. Two are of special interest as they are at risk during surgical repair. Anteriorly, the lateral antebrachial cutaneous nerve (LACN) is a terminal sensory branch of the musculocutaneous nerve. It bifurcates into two branches that supply the volar-radial portion of the wrist, portions of the thumb and the distal two-thirds of the dorsolateral forearm. It has been shown to run at the lateral aspect of the distal biceps tendon, often with the cephalic vein (Fig. 2). Posteriorly, the posterior interosseous nerve (PIN) is the terminal motor branch of the radial nerve. It supplies

hand and wrist extensors. It runs in close contact with the radius, circling the bone from anterior to posterior. The exact position with regard to the distal biceps tendon and radial tuberosity depends on the position of the forearm in supination or pronation (Fig. 3).

Epidemiology of distal biceps tendon ruptures

We found no clear record of the exact incidence of partial distal biceps tears. This is mainly due to the fact that certainly not all patients with partial ruptures seek medical care. Kelly and colleagues reported an incidence of complete distal biceps tendon tears of 2.55 cases per 100,000 patients in a large population database.¹¹ Because they only evaluated surgically treated patients, the actual incidence will likely be higher. The vast majority of complete distal biceps tendon ruptures occurs in men between 40 and 60 years of age.^{11,12} The dominant limb is involved in 52% of cases. Interestingly, an 8% cumulative incidence of bilateral biceps tendon ruptures has been reported.¹³ Besides the lower incidence in women, an evaluation of distal biceps tendon ruptures in women described a more gradual onset of symptoms and higher incidence of partial tears.¹⁴

Pathophysiology of distal biceps tendon injury

The mechanism of injury is typically an eccentric force applied to a flexed and supinated elbow. Pre-existing inflammatory or degenerative changes involving the distal biceps tendon, relative hypovascularity and anatomic factors such as a tuberosity spur, might explain why distal biceps tendon ruptures occur. Other predisposing factors

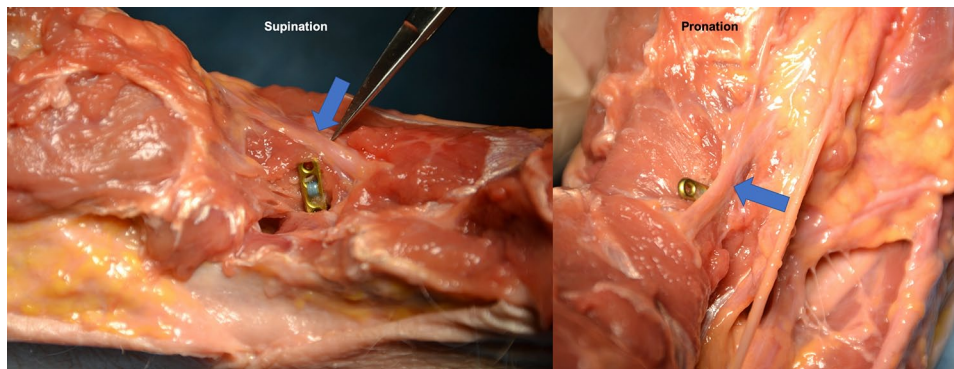


Fig. 3 The posterior interosseous nerve runs in close contact with the radius, circling the bone from anterior to posterior. The exact position with regard to the distal biceps tendon and radial tuberosity depends on the position of the forearm in supination or pronation. Position shown in relation to a bicortical button.

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include an elevated body mass index (BMI), smoking and steroid use. Elevated BMI, possibly secondary to greater muscle mass, would increase the load on the tendon and may predispose to rupture. Furthermore, obesity has been shown to decrease immune response to acute tendon injury.¹⁵ Of patients with a distal biceps tendon rupture, 36–66% have reported to be obese.^{11,12} The exact incidence of smoking in patients with distal biceps tendon ruptures is unknown, but it is widely accepted that smoking is a predisposing factor in tendon injuries. A possible effect of smoking involves an increased zone of hypovascularity in the tendon between the proximal and distal blood supply.⁹ Anabolic steroid use combined with exercise may lead to dysplasia of collagen fibrils, which can decrease the tensile strength of the tendon. Changes in tendon's crimp morphology have been shown to occur as well, which again may alter the tensile strength of the tendon.¹⁶

There may also be a biomechanical reason for distal biceps tendon rupture. The dynamics of the distal biceps tendon in its excursion from supination to pronation at different flexion angles may result in abrasion and damage to the tendon against the margin of the radial tuberosity, especially as it passes deeper to insert into a more posterior surface of the radius in the pronated position. As shown by computed tomography, the narrow passage between the lateral ulnar border and the radial tuberosity was found to decrease by roughly 50% in pronation when compared with supination. In a study of forearm motion, Ray et al¹⁷ demonstrated that during pronation not only does the radius rotate over the ulna, but the distal ulna actually moves laterally in its relationship to the radius. This 'ulnar abduction' may account for the significant decrease in the proximal radioulnar canal space. Bony irregularities bordering this osseous canal or inflammation in the biceps tendon could further compromise this narrow inlet, leading to impingement of the biceps

tendon as it is rotated through pronation and supination.⁹ Although some authors contest this statement,¹⁸ a recent study warns that mechanical impingement might explain complications after anatomical reinsertion.¹⁹

Diagnosis of distal biceps tendon injury

Clinical diagnosis

In complete distal biceps tendon ruptures, patients commonly report a history of a sudden eccentric load on a flexed elbow. Patients often report a traumatic 'pop'. They may present with acute pain and ecchymosis in the antecubital fossa, although the pain may subside quite rapidly. Clinically they present with local tenderness, weakened supination and flexion strength, although the weakness may be difficult to demonstrate, especially in stronger patients. A palpable defect is often appreciated. If the lacertus fibrosus is also torn, the biceps muscle belly is seen to retract proximally, which is often referred to as a reverse Popeye sign (Fig. 4). Several clinical tests have been described to confirm the diagnosis. In complete tears, the

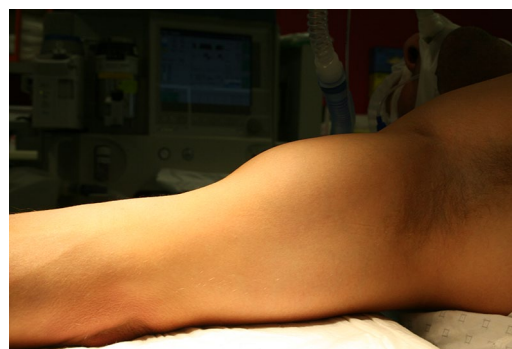


Fig. 4 A reverse Popeye sign can be seen in complete distal biceps tendon ruptures.

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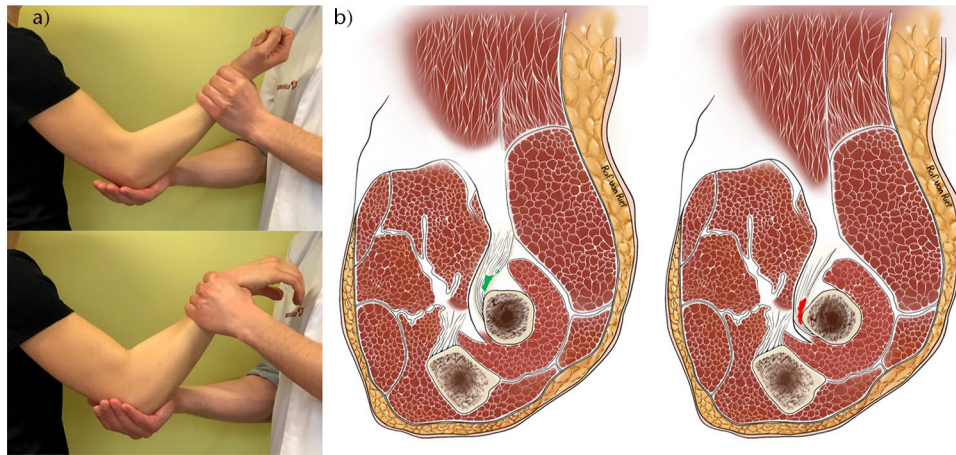


Fig. 5 (A) The biceps provocation test is a two-part test. The patient is standing, with the elbow supported by the examiner and flexed to 70 degrees. The examiner's hands are placed on the patient's forearm and the patient is asked to flex the elbow against resistance with the forearm supinated (ABTs). The forearm is then pronated, and the test is repeated (ABTp). Care is taken not to place the hands on the hand or wrist, as resisted wrist flexion or extension might elicit pain in other elbow pathologies. (B) On the left, the position of the biceps tendon with the forearm supinated (tear in green). On the right, the position of the biceps tendon with the forearm pronated (tear in red). As the distal biceps tendon wraps around the radial tuberosity when the arm is pronated, the tendon is stretched and compressed when the biceps is activated.

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cordlike tendon cannot be palpated and, sometimes, the biceps stump can be found proximal to the elbow crease. The hook test, described by O'Driscoll, is based on the fact that an attached distal tendon feels like a tight cord in isometric resisted supination.²⁰ To perform this test the patient is asked to abduct the shoulder, actively flex the elbow to 90° and to supinate the forearm. The examiner then uses the index finger to hook the lateral edge of the biceps tendon. With an intact tendon, a finger can be inserted approximately 1 cm beneath the tendon. The test is reported to be 100% sensitive and 100% specific in detecting complete distal biceps tendon ruptures.²⁰ Other tests include the biceps squeeze test, passive rotation test and the biceps crease interval test. Squeezing the muscle belly simulates contraction and in case of an intact tendon the arm will supinate passively.²¹ Alternatively, passively rotating the forearm with an intact tendon would cause the muscle belly to move proximally with pronation and distally with passive supination. With the crease interval test, the hypothesis is that complete distal biceps tendon ruptures result in an objectively measurable anatomic landmark (the distance between the antecubital crease of the elbow and the cusp of distal descent of the biceps muscle, or the biceps crease interval), as a result of proximal retraction of the musculotendinous complex. Using a diagnostic threshold of a biceps crease interval greater than 6.0 cm or biceps crease ratio greater than 1.2, the biceps crease interval test had a sensitivity of 96% and a diagnostic accuracy of 93% for complete tears.²² Musculotendinous junction tears, albeit extremely rare, can also

present with antecubital pain, ecchymosis, swelling or weakness with elbow flexion and supination.²³

The clinical findings associated with partial distal biceps tendon ruptures, tendinitis or bicipital bursitis typically include antecubital pain with activity, leading to minor weakness to resisted flexion and supination. Diagnosis is often delayed or may be missed altogether. The two-part biceps provocation test can be used to diagnose distal biceps tendon pathology, other than a complete tear. The elbow is flexed to 70° with the forearm supinated. Resisted elbow flexion will elicit pain. The forearm is then rotated, and the test is repeated. In a positive test, resisted flexion whilst the forearm is pronated is more painful than with the forearm supinated. This can be explained as the abraded tendon is compressed against the bone as it wraps around the radius in pronation (Fig. 5).²⁴

Imaging studies

If doubt still remains, an elbow ultrasound (US) or magnetic resonance imaging (MRI) can aid in the diagnosis. The accuracy of MRI and US was 86.4% and 45.5% in diagnosis of complete distal biceps tendon rupture, respectively. These findings suggest that MRI is a more accurate imaging modality at correctly identifying distal biceps tendon tears, although US is more cost-effective.²⁵ The sensitivity and specificity of an MRI for complete tears are reported to be 100% and 82.8%, respectively.²⁶ The sensitivity for partial tears or other distal biceps tendon pathology is significantly lower (sensitivity 59.1% and specificity 100%).^{26–29} In 2004, Giuffrè et al suggested a

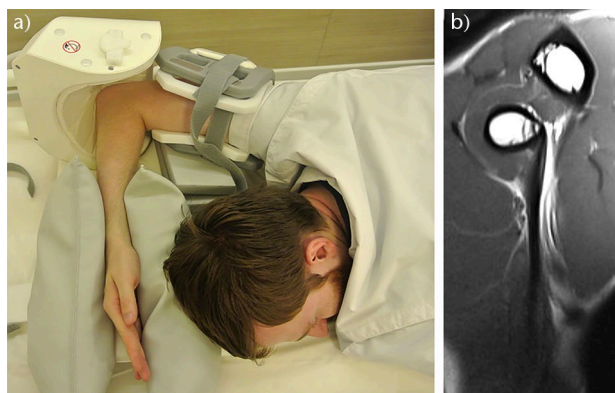


Fig. 6 (A) Flexion-abduction-supination view positioning with shoulder abduction and elbow flexion-supination. (B) Flexion-abduction-supination magnetic resonance imaging view (three-dimensional double-echo steady state with water excitation) showing normal distal biceps tendon. The entire tendon can be viewed from the insertion to the musculotendinous junction on a single image.

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new flexion abduction supination view (FABS) to optimally view the distal biceps tendon from the musculotendinous junction to its insertion, usually on a single image (in one or, at most, two sections).³⁰ To obtain this view, the patient is positioned prone on an MRI table with the shoulder in abduction, the elbow flexed and the forearm supinated. Although similar in sensitivity and specificity compared to standard MRI views, Schenkels et al showed that the interrater reliability was higher with FABS views, and FABS views were significantly more accurate in grading the extent of the pathology when compared to surgical findings (Fig. 6).³¹

Treatment of distal biceps tendon injury

Acute complete tears

Although patients do not always report a subjective loss of strength,³² a number of biomechanical studies clearly showed a loss in strength and endurance of conservative treatment when compared to surgical repair. Conservative treatment can lead to problems with repetitive and forceful supination activities such as turning a screwdriver.^{33,34} Mechanical testing showed a 40% loss of supination strength, 79% loss of supination endurance, 30% loss of flexion strength and 30% loss of flexion endurance.³⁵ Therefore, non-surgical treatment may be considered in low-demand patients with concerns regarding anaesthesia and surgery after discussion of previous mentioned aspects with the patient. Both costs³⁶ and complications are higher when the surgical repair is performed at later stages.³⁷ Early surgical repair is therefore preferred.

Approach

Surgical repair of the DBT can be performed through a single or double-incision approach. Both approaches have been extensively described and evaluated. Both provide good clinical results, and each has its own advantages and disadvantages. The two-incision technique is performed through a relatively small anterior incision through which the tendon is retrieved, prepared and passed posteriorly to a larger posterior approach. This second approach is used for tendon reinsertion at the anatomical footprint at the radial tuberosity. Most surgeons adopting the two-incision approach use either bone tunnels or suture anchors. The biggest advantage of the two-incision is the anatomical reinsertion. A reinsertion at the native reinsertion site has been shown to yield superior supination strength and endurance compared to a non-anatomical reinsertion.^{4,5,38} Separate anatomical insertion of the short and long head has shown no added benefit compared reinsertion as a single tendon.³⁹ The two-incision technique has been shown to have less LACN neuropraxia compared to the single-incision technique. Heterotopic ossification (HO), however, remains the major complication of the two-incision technique. It was postulated that the bone formation might result from damaging the periosteum while lifting the anconeus from the ulna and possibly the interosseous membrane.^{40,41} To prevent symptomatic HO, some authors have recommend splitting the extensor carpi ulnaris (ECU) or the extensor digitorum communis (EDC) instead of elevating the anconeus. Care should be taken to remove all bone debris created through burring.^{40,41} However, this did not completely avoid symptomatic HO using the two-incision technique.⁴² Supination strength may also be influenced by the two-incision repair, as the damage to the supinator muscle due to the posterior incision may decrease postoperative supination strength.⁴³

In the single anterior approach, a 2–3 cm incision is made anteriorly through which the tendon is retrieved, prepared and reinserted. This approach decreases the risk of HO. Multiple fixation methods can be used with the single-incision approach. Options include bone tunnels, suture anchors, cortical buttons, interference screws or a combination of interference screws with a cortical button. The use of the bicortical button construct prohibits an anatomical reinsertion. The technique of placing a button at the far cortex of the radius endangers the PIN. Therefore, a non-anatomical reinsertion is advised. Even with non-anatomical reinsertion, the distance between the button and the PIN is 11.6 mm (Fig. 3).⁴⁴ This distance decreases when the tunnel is placed anatomically.

A randomized controlled trial comparing both approaches showed similar results regarding pain, the American Shoulder and Elbow Surgeons (ASES) elbow scores, the disabilities of the Arm, Shoulder and Hand (DASH) score,

patient-rated elbow evaluation (PREE) score and isometric extension, pronation and supination strength. The double-incision approach resulted in higher elbow flexion strength when compared to the single-incision approach (104% vs. 94%, respectively).⁴⁵ A recent systematic review of complications showed an overall complication rate of 25%.³⁷ This is similar to the results of a systematic review by Watson et al, who showed an overall complication rate of 23.9% of the single-incision approach and 25.7% of the double-incision approach. The major complication rate was 4.6% and included a 1.6% rate of posterior interosseous nerve injury; 0.3% median nerve injury; 1.4% re-rupture and 0.1% ($n = 4$), synostosis. Synostosis occurred only with the double-incision approach. Minor complications included stiffness (1.8% in the single incision and 5.7% in the double incision), LACN neuropraxia (11.6% in the single incision and 5.8% in the double incision) (Table 1, Table 3, Table 3).⁴⁶

Tendon fixation

Multiple fixation methods have been proposed since the transosseous suture technique described by Morrey et al.³⁵ Biomechanical evidence showed a significantly

stronger initial fixation strength of the cortical button and the cortical button/interference screw construct compared to suture anchor and the interference screw alone (Table 4).^{47,48} Initial fixation strength allows early active motion and loading. This is believed to improve outcome. These studies have also shown a possible problem of gap formation using suture anchors which was not seen with techniques using a bone socket. The addition of an interference screw to the cortical button construct has not resulted in an improved clinical outcome.^{49,50} Furthermore, radial osteolysis may pose a problem as this may lead to radial fracture and possible disastrous outcome. Owing to the smaller size of the proximal radius, the risk of fracture through the surgically created bone tunnel for distal biceps tendon repair could be a potential problem.

In recent years, the lack of anatomical reinsertion options with the single-incision technique sparked the interest for alternative fixation methods. Siebenlist and colleagues proposed a double intramedullar button fixation device.^{51–53} A recent publication from our institution biomechanically evaluated a single intramedullar button that allows an in-bone fixation of the tendon (Fig. 7).⁵⁴ The biomechanical results of this intramedullar button are comparable to other currently used techniques.^{47,55} Both load to failure (356 N) and stiffness (61 N/mm) are similar to the excellent results of the bicortical button technique.^{47,55} The mean load of failure was 332 ± 44 N which is similar to previous reported results of bicortical fixation. The load to failure of this technique and our described results are higher than the native tendon as described.⁴⁸ These techniques rarely fail due to their high initial fixation strength.⁵⁶ The new button provides the same initial fixation strength as most other techniques.^{47,48,55} Intramedullar placement of the button allows reinsertion of the distal biceps tendon at its anatomical footprint through a single anterior approach without the risk of PIN injury. An added benefit of the anatomical reinsertion is restoration of the native cam effect of the bicipital tuberosity. The strong initial fixation allows early active motion. From a patient's perspective, the proposed benefit of this technique includes the restoration of supination strength using a single incision.

Table 1. Clinical and functional outcomes^{43,45}

	Single-incision	Double-incision
Flexion	134.5 ± 6.9	131.8 ± 9.1
Extension	3.0 ± 4.3	1.9 ± 4.6
Pronation	76.7 ± 8.2	72.4 ± 12.6
Supination	63.9 ± 12.5	59.5 ± 11.5
ASES pain score	4.6 ± 8.0	4.4 ± 8.5
ASES function score	32.6 ± 5.2	34.6 ± 3.7
DASH score	7.8 ± 12.9	5.5 ± 11.8
PREE score	6.1 ± 14.6	4.9 ± 13.0
Supination strength	Non-anatomical reinsertion	Anatomical reinsertion
Strength: 60 pronation	101.2% ± 19.5%	94.0% ± 12.0%
Strength: 0 neutral	89.6% ± 21.9%	92.2% ± 6.9%
Strength: 60 supination	66.9% ± 18.3%	81.3% ± 16.4%

Note. ASES, American Shoulder and Elbow Surgeons score; DASH, Disabilities of the Arm, Shoulder and Hand score; PREE, patient-rated elbow evaluation score.

Table 2. Complications after biceps tendon repair separated by fixation method and approach^{37,46}

	Suture anchors	Cortical button	Interference screw	Button and screw	Bone tunnels	Single-incision	Double-incision
Major							
PIN palsy	1.7%	3.3%	2.9%	0.9%	1.7%	4.6%	1.6%
R-U synostosis	0.0%	0.0%	0.0%	0.0%	1.4%	0.0%	2.3%
Rerupture	1.7%	0.8%	1.5%	0.9%	1.2%	1.8%	1.2%
Minor							
LACN paresthesia	7.7%	18.6%	13.0%	8.0%	5.9%	11.6%	5.8%
SRN paresthesia	4.2%	3.3%	1.5%	4.9%	0.5%	0.6%	0.0%
HO	5.4%	6.1%	5.8%	1.5%	4.9%	3.1%	7.0%
Stiffness	1.7%	0.6%	0.0%	0%	0.9%	1.8%	5.7%
Total	22.4%	32.8%	24.6%	16.4%	16%	23.9%	25.7%

Note. HO, heterotopic ossification; LACN, lateral antebrachial cutaneous nerve; PIN, posterior interosseous nerve; R-U, radioulnar; SRN, superficial radial nerve.

Table 3. Indications for reoperation³⁷

Indication	%
Heterotopic ossification	43.8
Deep infections	9.4
Re-rupture	31.2
Nerve explorations	15.6
Total	100

rest and avoidance of aggravating activity. They are sometimes combined with brace therapy and steroid injection.^{59–61} A recent paper by Bauer and colleagues showed that up to 55.7% of patients who tried a non-operative treatment ultimately underwent surgery. Furthermore, high-need patients as defined by occupation were more likely to report that they recovered better if they underwent

Table 4. Biomechanical evaluation of fixation methods for distal biceps tendon repair

		Intact tendon	Suture anchors	Transosseous bone tunnels	Interference screw	Bicortical button	Double intramedullary button	Single custom intramedullary button
Mazzocca et al ⁴⁷	Load to failure (N)	/	381	310	232	440	/	/
	Stiffness (N/mm)	/	/	/	/	/	/	/
Idler et al ⁴⁸	Load to failure (N)	204.3 ± 76.9	/	124.9 ± 22.8	178.0 ± 54.5	/	/	/
	Stiffness (N/mm)	30.1 ± 12.4	/	15.9 ± 5.6	30.4 ± 9.5	/	/	/
Siebenlist et al ⁵¹	Load to failure (N)	/	200 ± 120	/	/	/	312 ± 76	/
	Stiffness (N/mm)	/	55.9 ± 21.3	/	/	/	67.1 ± 11.7	/
Caekebeke et al ⁵⁴	Load to failure (N)	/	/	/	/	296 ± 97	/	356 ± 37
	Stiffness (N/mm)	/	/	/	/	58.2 ± 9.2	/	61.1 ± 9.7



Fig. 7 Image of the intramedullary button. The pedals of the button span over the radial tuberosity with a fixation on the strong anterior cortex.

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Gap formation has been shown to be a problem in patients with persistent radial-sided forearm pain and weakness on provocative testing after distal biceps repair with a seemingly intact repair. When gapping is confirmed on FABS MRI a revision repair with an in-bone technique can lead to good results. Considering these findings, an intramedullary fixation device allowing an in-bone technique may be preferred. The effect of an anatomical reinsertion on the radioulnar space still has to be evaluated and considered when deciding where to reinsert the tendon.^{19,57}

Partial tears and bicipital bursitis

Partial biceps tendon ruptures were initially treated either conservatively⁵⁸ or operatively.⁵⁹ Conservative treatment options are generally tried first and consist of a period of

surgery as compared with patients who did not undergo surgery.⁶² Schmidt and colleagues noted that a significant decrease of supination strength was present when the tear was larger than 75% of the footprint.⁶³ The initial surgical option was a complete release of the tendon with formal reinsertion.^{59,64} This technique had similar outcomes to the treatment of complete distal biceps tendon ruptures.⁶⁰ As the tendon cannot be inspected through an open technique, minimal tears which do not react to conservative therapy have to be released and formally reinserted, which may be overshooting as a therapy. With the popularization of endoscopic techniques this was also applied to partial distal biceps tendon ruptures.^{65–68} The biggest advantage is the ability to evaluate the degree of the tears (Fig. 8).⁶⁵ Thus, minimal tears can be treated differently to tears that are more progressed.⁶⁶ FABS view MRI can indicate the possibility for endoscopic treatment but decisions on which treatment are made upon endoscopic visualization.³¹ Minimal tears and bicipital bursitis can be treated with debridement under endoscopic visualization. Slightly larger tears can be reinforced with anchor fixation of the torn part of the tendon. There seems to be a tendency to treat tears affecting more than 50% of the tendon with release of the tendon and formal reinsertion. Recent articles seem to confirm the safety of biceps endoscopy and showed the feasibility through a single anterior incision.^{69,70}

Conclusion

A multitude of research papers have discussed the DBT in recent years. Most of them discuss biomechanical and clinical outcomes of long-standing techniques. However, there are also those which look into innovation of current

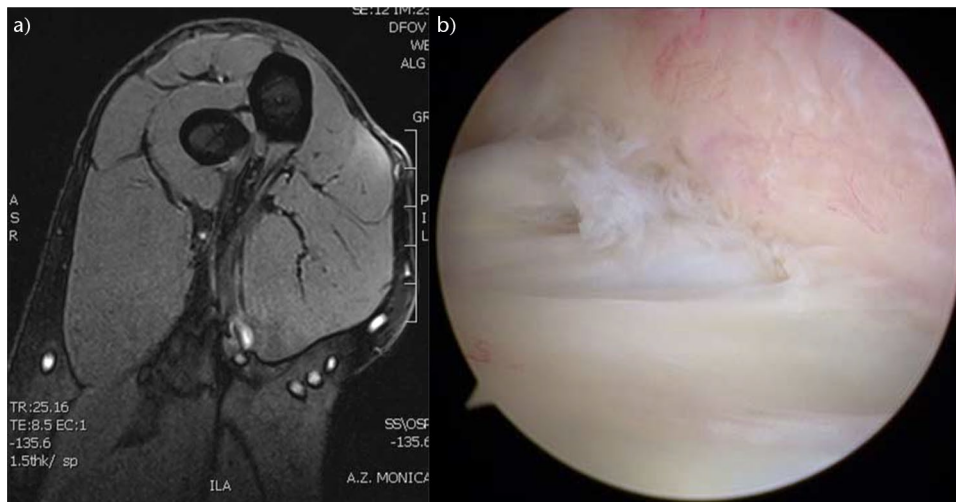


Fig. 8 (A) Flexion abduction supination view of a partial distal biceps tendon tear. (B) Endoscopic view of the same distal biceps tendon insertion. Endoscopic debridement is a viable solution for low-grade partial tears.

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diagnostic tools and treatment options. These include new insights into possible pathophysiological factors which can teach us about possible avoidable complications. Furthermore, new developments in both clinical and technological diagnostic tools might help with timely and accurate diagnosis of partial ruptures and bicipital bursitis. Finally, better insight into the complications of current techniques seem to lead to new surgical treatment options for both partial and acute complete ruptures.

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REFERENCES

1. **Eames MH, Bain GI, Fogg QA, van Riet RP.** Distal biceps tendon anatomy: a cadaveric study. *J Bone Joint Surg [Am]* 2007;89-A:1044–1049.
2. **Athwal GS, Steinmann SP, Rispoli DM.** The distal biceps tendon: footprint and relevant clinical anatomy. *J Hand Surg Am* 2007;32:1225–1229.
3. **Jarrett CD, Weir DM, Stuffmann ES, Jain S, Miller MC, Schmidt CC.** Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *J Shoulder Elbow Surg* 2012;21:942–948.
4. **Schmidt CC, Brown BT, Williams BG, et al.** The importance of preserving the radial tuberosity during distal biceps repair. *J Bone Joint Surg [Am]* 2015;97-A:2014–2023.
5. **Schmidt CC, Weir DM, Wong AS, Howard M, Miller MC.** The effect of biceps reattachment site. *J Shoulder Elbow Surg* 2010;19:1157–1165.
6. **Bhatia DN, Kandhari V, DasGupta B.** Cadaveric study of insertional anatomy of distal biceps tendon and its relationship to the dynamic proximal radioulnar space. *J Hand Surg Am* 2017;42:e15–e23.
7. **Miyamoto RG, Elser F, Millett PJ.** Distal biceps tendon injuries. *J Bone Joint Surg [Am]* 2010;92-A:2128–2138.
8. **Landa J, Bhandari S, Strauss EJ, Walker PS, Meislin RJ.** The effect of repair of the lacertus fibrosus on distal biceps tendon repairs: a biomechanical, functional, and anatomic study. *Am J Sports Med* 2009;37:120–123.
9. **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;4:149–156.
10. **Zeltser DW, Strauch RJ.** Vascular anatomy relevant to distal biceps tendon repair. *J Shoulder Elbow Surg* 2016;25:283–288.

11. Kelly MP, Perkinson SG, Ablove RH, Tueting JL. Distal biceps tendon ruptures: an epidemiological analysis using a large population database. *Am J Sports Med* 2015;43:2012–2017.
12. Safran MR, Graham SM. Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. *Clin Orthop Relat Res* 2002;404:275–283.
13. Green JB, Skaife TL, Leslie BM. Bilateral distal biceps tendon ruptures. *J Hand Surg Am* 2012;37:120–123.
14. Jockel CR, Mulieri PJ, Belsky MR, Leslie BM. Distal biceps tendon tears in women. *J Shoulder Elbow Surg* 2010;19:645–650.
15. Del Buono A, Battery L, Denaro V, Maccauro G, Maffulli N. Tendinopathy and inflammation: some truths. *Int J Immunopathol Pharmacol* 2011;24:45–50.
16. Laseter JT, Russell JA. Anabolic steroid-induced tendon pathology: a review of the literature. *Med Sci Sports Exerc* 1991;23:1–3.
17. Ray RD, Johnson RJ, Jameson RM. Rotation of the forearm: an experimental study of pronation and supination. *J Bone Joint Surg [Am]* 1951;33-A:993–996.
18. Kodde IF, van den Bekerom MP, Mulder PG, Eygendaal D. The size of the radial tuberosity is not related to the occurrence of distal biceps tendon ruptures: a case-control study. *Open Orthop J* 2016;10:1–6.
19. Rausch V, Kahmann SL, Baltschun C, Staat M, Muller LP, Wegmann K. Pressure distribution to the distal biceps tendon at the radial tuberosity: a biomechanical study. *J Hand Surg Am* 2020;45:776.e1–776.e9.
20. O'Driscoll SW, Goncalves LB, Dietz P. The hook test for distal biceps tendon avulsion. *Am J Sports Med* 2007;35:1865–1869.
21. Ruland RT, Dunbar RP, Bowen JD. The biceps squeeze test for diagnosis of distal biceps tendon ruptures. *Clin Orthop Relat Res* 2005;437:128–131.
22. ElMaraghy A, Devereaux M, Tsoi K. The biceps crease interval for diagnosing complete distal biceps tendon ruptures. *Clin Orthop Relat Res* 2008;466:2255–2262.
23. Schamblin ML, Safran MR. Injury of the distal biceps at the musculotendinous junction. *J Shoulder Elbow Surg* 2007;16:208–212.
24. Caekebeke P, Schenkels E, Bell SN, van Riet R. Distal biceps provocation test. *J Hand Surg Am* 2021;46:710.e1–710.e4.
25. Lynch J, Yu CC, Chen C, Muh S. Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion. *Orthop Traumatol Surg Res* 2019;105:861–866.
26. Festa A, Mulieri PJ, Newman JS, Spitz DJ, Leslie BM. Effectiveness of magnetic resonance imaging in detecting partial and complete distal biceps tendon rupture. *J Hand Surg Am* 2010;35:77–83.
27. de la Fuente J, Blasi M, Martínez S, et al. Ultrasound classification of traumatic distal biceps brachii tendon injuries. *Skeletal Radiol* 2018;47:519–532.
28. Fitzgerald SW, Curry DR, Erickson SJ, Quinn SF, Friedman H. Distal biceps tendon injury: MR imaging diagnosis. *Radiology* 1994;191:203–206.
29. Falchhook FS, Zlatkin MB, Erbacher GE, Moulton JS, Bisset GS, Murphy BJ. Rupture of the distal biceps tendon: evaluation with MR imaging. *Radiology* 1994;190:659–663.
30. Giuffrè BM, Moss MJ. Optimal positioning for MRI of the distal biceps brachii tendon: flexed abducted supinated view. *AJR Am J Roentgenol* 2004;182:944–946.
31. Schenkels E, Caekebeke P, Swinnen L, Peeters J, van Riet R. Is the flexion-abduction-supination magnetic resonance imaging view more accurate than standard magnetic resonance imaging in detecting distal biceps pathology? *J Shoulder Elbow Surg* 2020;29:2654–2660.
32. 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-A:2329–2334.
33. 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-A:414–417.
34. Meherin JM, Kilgore KS Jr. The treatment of the distal biceps brachii tendon. *Am J Surg* 1960;99:636–640.
35. 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-A:418–421.
36. Feller R, Illing D, Allen C, Presson A, Tyser A, Kazmers N. Evaluation of factors influencing surgical treatment costs for distal biceps rupture. *J Shoulder Elbow Surg* 2020;29:e229–e237.
37. Amarsooriya M, Bain GI, Roper T, Bryant K, Iqbal K, Phadnis J. Complications after distal biceps tendon repair: a systematic review. *Am J Sports Med* 2020;48:3103–3111.
38. Bellringer SF, Phadnis J, Human T, Redmond CL, Bain GI. Biomechanical comparison of transosseous cortical button and footprint repair techniques for acute distal biceps tendon ruptures. *Shoulder Elbow* 2020;12:54–62.
39. Schmidt CC, Madonna TJ, Vaudreuil N, Brown BT, Liu SY, Delserso S, et al. The effect of tendon rotation on distal biceps repair. *JSES Open Access* 2019;3:225–231.
40. 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;253:133–136.
41. Morrey BF. Tendon injuries around the elbow. In: Morrey BF, Sanchez-Sotelo J, eds. *The elbow and its disorders*. Philadelphia, PA: Elsevier, Saunders, 1993:492–504.
42. Bisson L, Moyer M, Lanighan K, Marzo J. Complications associated with repair of a distal biceps rupture using the modified two-incision technique. *J Shoulder Elbow Surg* 2008;17:675–715.
43. Schmidt CC, Brown BT, Qvick LM, Stacowicz RZ, Latona CR, Miller MC. Factors that determine supination strength following distal biceps repair. *J Bone Joint Surg [Am]* 2016;98-A:1153–1160.
44. Tat J, Hart A, Cota A, Alsheikh K, Behrends D, Martineau PA. Distal biceps repair with flexible instrumentation and risk of posterior interosseous nerve injury: a cadaveric analysis. *Orthop J Sports Med* 2018;6:2325967118810523.
45. Grewal R, Athwal GS, MacDermid JC, et al. Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: a randomized clinical trial. *J Bone Joint Surg [Am]* 2012;94-A:1166–1174.
46. 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-A:2086–2090.
47. 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;35:252–258.
48. Idler CS, Montgomery WH III, Lindsey DP, Badua PA, Wynne GF, Yerby SA. Distal biceps tendon repair: a biomechanical comparison of intact tendon and 2 repair techniques. *Am J Sports Med* 2006;34:968–974.
49. Caekebeke P, Corten K, Duerinckx J. Distal biceps tendon repair: comparison of clinical and radiological outcome between bio-absorbable and non-absorbable screws. *J Shoulder Elbow Surg* 2016;25:349–354.

- 50. Caekebeke P, Vermeersch N, Duerinckx J, van Riet R.** Radiological and clinical evaluation of the transosseous cortical button technique in distal biceps tendon repair. *J Hand Surg Am* 2016;41:e447–e452.
- 51. Siebenlist S, Buchholz A, Zapf J, et al.** Double intramedullary cortical button versus suture anchors for distal biceps tendon repair: a biomechanical comparison. *Knee Surg Sports Traumatol Arthrosc* 2015;23:926–933.
- 52. Siebenlist S, Elser F, Sandmann GH, et al.** The double intramedullary cortical button fixation for distal biceps tendon repair. *Knee Surg Sports Traumatol Arthrosc* 2011;19:1925–1929.
- 53. Siebenlist S, Schmitt A, Imhoff AB, Lenich A, Sandmann GH, Braun KF, et al.** Intramedullary cortical button repair for distal biceps tendon rupture: a single-center experience. *J Hand Surg Am* 2019;44:418.e1–418.e7.
- 54. Caekebeke P, Duerinckx J, Bellemans J, van Riet R.** A new intramedullary fixation method for distal biceps tendon ruptures: a biomechanical study. *J Shoulder Elbow Surg* 2020;29:2002–2006.
- 55. Siebenlist S, Lenich A, Buchholz A, et al.** Biomechanical in vitro validation of intramedullary cortical button fixation for distal biceps tendon repair: a new technique. *Am J Sports Med* 2011;39:1762–1768.
- 56. Kelly EW, Morrey BF, O'Driscoll SW.** Complications of repair of the distal biceps tendon with the modified two-incision technique. *J Bone Joint Surg [Am]* 2000;82-A:1575–1581.
- 57. Rausch V, Krieter JP, Leschinger T, et al.** The radioulnar distance at the level of the radial tuberosity. *Clin Anat* 2020;33:661–666.
- 58. Rokito AS, McLaughlin JA, Gallagher MA, Zuckerman JD.** Partial rupture of the distal biceps tendon. *J Shoulder Elbow Surg* 1996;5:73–75.
- 59. Bourne MH, Morrey BF.** Partial rupture of the distal biceps tendon. *Clin Orthop Relat Res* 1991;271:143–148.
- 60. Bain GI, Johnson LJ, Turner PC.** Treatment of partial distal biceps tendon tears. *Sports Med Arthrosc Rev* 2008;16:154–161.
- 61. Hobbs MC, Koch J, Bamberger HB.** Distal biceps tendinosis: evidence-based review. *J Hand Surg Am* 2009;34:1124–1126.
- 62. Bauer TM, Wong JC, Lazarus MD.** Is nonoperative management of partial distal biceps tears really successful? *J Shoulder Elbow Surg* 2018;27:720–725.
- 63. Tomizuka Y, Schmidt CC, Davidson AJ, et al.** Partial distal biceps avulsion results in a significant loss of supination force. *J Bone Joint Surg [Am]* 2021;103-A:812–819.
- 64. Nielsen K.** Partial rupture of the distal biceps brachii tendon: a case report. *Acta Orthop Scand* 1987;58:287–288.
- 65. Eames MH, Bain GI.** Distal biceps tendon endoscopy and anterior elbow arthroscopy portal. *Tech Shoulder Elbow Surg* 2006;7:139–142.
- 66. Vandenberghe M, van Riet R.** Distal biceps ruptures: open and endoscopic techniques. *Curr Rev Musculoskelet Med* 2016;9:215–223.
- 67. Grégory T, Roue P, Fontès D.** Repair of distal biceps tendon rupture using a suture anchor: description of a new endoscopic procedure. *Am J Sports Med* 2009;37:506–511.
- 68. Bhatia DN, Kandhari V.** Analysis of technical feasibility and neurovascular safety of endoscopic distal biceps repair: a cadaveric study. *J Shoulder Elbow Surg* 2018;27:2057–2067.
- 69. Bhatia DN, DasGupta B, Panjwani T.** Cadaveric study of anterior and posterior elbow endoscopy portals for endoscopic distal biceps repair: comparative anatomy-at-risk. *Surg Radiol Anat* 2016;38:781–791.
- 70. Caekebeke P, Galatz L, van Riet R.** Accuracy and safety of the endoscopic repair of the distal biceps: a cadaveric study. *Acta Orthop Belg* 2020;86:711–716.