Acute distal biceps tendon ruptures: anatomy, pathology and management - state of the art

Neil Kruger, Joideep Phadnis, Deepak Bhatia, Melanie Amarasooriya, Gregory Ian Bain

ABSTRACT
All patients with acute complete distal biceps tendon ruptures who are not low demand or medically unfit to proceed with surgery are offered operative repair. This restores arm shape, supination strength and function, and decreases their cramping symptoms. Surgical repair technique varies significantly depending on location and training centre. Nuances in technique and appropriate implant selection need to be noted in order to achieve a strong repair allowing early active range of motion. Intimate knowledge of distal biceps tendon anatomy is key to avoid complications associated with the different approaches. The cumulative body of evidence on complications, coupled with knowledge of the different biomechanical construct strengths of the alternative methods of fixation, points to the use of the cortical button technique without the addition of an interference screw. Subtle variations in drill hole positioning on the bicapital tuberosity secures either an anatomic or non-anatomic repair. Anatomic repair results in greater supination peak torque and fatigue strength, and in greater flexion fatigue strength. It is advisable to perform an anatomic repair in elite athletes or those patients who significantly rely on supination strength and endurance for their livelihood. A universal postoperative protocol is suggested for all repairs.

INTRODUCTION
Acute complete rupture of the distal biceps tendon (DBT) is a relatively common pathology in middle-aged males, occurring classically with an eccentric load to the flexed elbow. It predominantly occurs in the dominant arm, and incidence is on the rise from 1.2 per 100 000 in 2002, to 5.4 per 100 000 in 2010. Kelly et al postulate reasons for this increase being a combination of a male population that is both living and remaining active for longer, coupled with an increased clinical and diagnostic imaging ability. Notable risk factors include smoking, obesity and anabolic steroid usage. There is an increased incidence in athletes and those involved in high load resistance training, and pre-existing tendinosis makes the DBT more vulnerable to rupture.

Surgical repair of acute complete ruptures is the treatment of choice to restore anatomical tendon continuity, arm contour and supination strength. Recent reviews all conclude that the method of fixation and surgical approach should be surgeon and centre dependent, as good outcomes are achievable with both anterior and posterior approaches, using any of the described methods of fixation. This however requires skilful application of appropriate operative techniques, taking care to avoid the known complications in each.

Key elements to surgical success involve intimate knowledge of distal biceps anatomy, an understanding of the methods of fixation available and pitfalls to avoid in each method. This article describes the surgically relevant distal biceps anatomy, pathology and patient assessment, and describes robust techniques for tendon reattachment. It proposes a universal guideline for the postoperative protocol for all acute repairs and concludes with recommendations in adopting specific fixation techniques and approaches, based on patient needs and the severity of potential complications.

SURGICAL ANATOMY OF THE DISTAL BICEPS TENDON
Tendon anatomy
The DBT begins in the distal arm at the musclobellotinous junction of the biceps brachii and traverses the cubital fossa to insert into the bicapital tuberosity (BT) of the proximal radius. The tendon begins about 3 cm proximal to the anterior elbow crease and inserts 3–5 cm distal to this crease. It is a mean of 9 cm (7–12 cm) long and is in close proximity to multiple neurovascular structures along its length. The lacertus fibrosis is an aponeurosis on the medial aspect of the DBT, and divides the tendon into three structural zones: preaponeurotic, aponeurotic and postaponeurotic.

The aponeurosis envelops the medial neurovascular structures in the cubital fossa. It additionally prevents retraction of the ruptured DBT, and is often torn or elongated in retracted DBT tears. The biceps brachii muscle has two distinct muscle bellies that continue as the long and short biceps tendons. The bellies may be contiguous proximal to the origin of the DBT, but then continue as long and short components within the single tendon (figure 1).

The DBT fibres supinate 90° and the tendon then fans out into a wider footprint attachment over the BT. The long head inserts proximally on the footprint, and the short head distally (figure 2). Biomechanically, the short head is a more efficient flexor at 90° of elbow flexion, and a more efficient supinator in the neutral and pronated forearm. The long head is a more significant supinator in the already supinated forearm. The DBT insertional anatomy shows three distinct footprint types that may be quantified using a distal biceps footprint index, and in more than half of cases, the DBT...
attachment is bifid, with two distinct tendons inserting onto the footprint.9 12

Osseous anatomy
The BT is a roughened semilunar protuberance, 3–4 cm distal to the radial head. The mean dimensions are length 23 mm, breadth 13 mm and thickness 16 mm.9 On the dry bone both a smooth area for the bursa and a dorsal ridge can be seen. The tendon attaches dorsal to the ridge.14

Narrowing of the radioulnar space (RUS) during forearm pronation may cause mechanical impingement of the DBT. Postoperative tendon thickening and implant fixation techniques may cause the DBT to impinge, wear and potentially re-rupture. Bhatia et al identified that the RUS reduces significantly in pronation, especially on the distal aspect of the tuberosity.9 Furthermore, the RUS is inadequate in pronation for incremental increases in DBT thickness. Clinically, postoperative DBT impingement in the RUS may be prevented by avoiding techniques that increase tendon thickness, especially at the distal aspect of the tuberosity.9

Neurovascular anatomy
Elbow and cubital fossa neurovascular anatomy is variable, and many structures are at risk in the anterior approach.10 In the lower arm, the lateral aspect of the DBT is the relatively safe side. The cephalic vein and the lateral cutaneous nerve of the forearm are in close proximity to the upper lateral aspect of the DBT. The radial nerve is more lateral. Medial to the DBT are three major neurovascular structures: median nerve, brachial artery and vein (figure 3). In the upper forearm, the DBT passes deep to and near the radial vessels. The posterior interosseous nerve (PIN) and a division of the superficial radial nerve are close to the radial aspect of the DBT. The ulnar and radial vasculature travels on the medial aspect. In most specimens, a single radial recurrent artery courses anterior to the tendon (mean 4 mm proximal and 15 mm volar to the tuberosity). In almost half of the specimens, a smaller recurrent artery originating from the brachial artery courses dorsal to the DBT.15 The radial artery itself might run dorsal to the DBT.16

PATHOLOGY OF THE DISTAL BICEPS TENDON
Acute tears of the distal biceps occur in tendons both with and without preceding pathological changes. Bilateral disease has been reported as 8% at a mean of 4.1 years apart, much higher than the reported general incidence.17 This suggests an underlying genetic predisposition in some.

Risk factors for the development of tendinopathy may be divided up into intrinsic and extrinsic factors. Intrinsic factors include age, tendon perfusion, gender, obesity and muscle imbalances, while extrinsic factors include repetitive force and strain placed on the tendon, occupation, sport and training load.18

There appears to be a complex interplay between these intrinsic and extrinsic factors, as well as a genetic susceptibility in individuals with identified genes encoding for blood group O,19 the COL5A1 gene for type 5 collagen20 and Tenascin-C.21

The pathological spectrum affecting the DBT includes bicipitoradial bursitis, biceps enthesopathy, biceps tendinopathy, partial tears (intrinsic or extrinsic) and complete tears. Bicipitoradial bursitis is almost synonymous with all conditions affecting the distal biceps. The degree of inflammation and subsequent

Figure 1  Cadaveric demonstration illustrating a completely separate long and short head of the distal biceps tendon (DBT) from origin to insertion (arrows).

Figure 2  Cadaveric specimen of the proximal radius and distal biceps tendon (DBT) demonstrating the rotation and insertion of the separate heads of the tendon into the bicipital tuberosity.

Figure 3  Cadaveric dissection illustrating the neurovascular structures relative to the distal biceps tendon (DBT). The brachial artery (BA) and median nerve (MN) course medial to the DBT, while the lateral cutaneous nerve (LCN) exits laterally at its musculotendinous junction. Note the DBT passing dorsal at the bifurcation of the BA and its intimate relation to the radial (RA) and ulnar arteries (UA). BR, brachioradialis.
bursal fluid collection reflects the severity of the pathology acutely. This may be significant enough to cause neurovascular compression, but may recede in more chronic conditions.\textsuperscript{22}

Biceps tendinopathy is a diseased tendon, however enthesopathy is a diseased tendon insertion. Tendon collagen degeneration occurs when a suboptimal strain environment stimulates viable tenocytes to differentiate into non-tenocyte cells, with associated mucoid, lipid and calcium accumulation.\textsuperscript{23} This causes tendinosis within either the tendon or enthesis. The two pathologies often coexist and place the tendon at greater risk of rupture.\textsuperscript{22}

**CLINICAL PRESENTATION**

Complete tears have a distinctive history and usually happen after an eccentric contraction of the biceps.\textsuperscript{24} Patients occasionally report a popping sensation in the elbow and are required to stop the action they were doing. Sometimes there is a history of repetitive flexion and supination movements or a single inciting event. Another mechanism is the hyperextension of the already extended arm as with missing a punch in boxing. Tendinopathy and partial tears cause considerable pain which can be persistent for months and be recurrent. Cramping or weakness are usually the dominant symptoms, whereas a complete tear is acutely painful and settles with time.

Complete DBT rupture is more common in men. Women usually present with features of progressive tendon degeneration and partial, not complete, tears.\textsuperscript{22} They normally present more insidiously and at an older age than men. They also more often have underlying conditions like hypothyroidism, diabetes or renal disease.\textsuperscript{22}

**Diagnosis of complete distal biceps rupture**

Acute pain, swelling and ecchymosis usually settle within the first 14 days after injury. Biceps contour may be altered. The most useful test for diagnosis is the hook test. With the elbow bent to 90° and the forearm fully supinated, the examiner tries to hook the biceps tendon by ‘palpating the cubital fossa from lateral to medial while supination is maintained against resistance’ (figure 4).\textsuperscript{26} Absence of a ‘hookable’ DBT indicates a positive result. O’Driscoll et al reported this test to be 100% sensitive and specific if performed correctly.\textsuperscript{26} The patient will have clear weakness in resisted supination but an intact brachialis usually preserves flexion strength. Palpating proximally for the ruptured tendon end beneath the skin and observing for the normal biceps and the forearm fully supinated, the examiner hooks their thumb (or finger depending on preference) from lateral to medial to ‘hook’ the biceps tendon. If done medial to lateral the lacertus fibrosis may confound the examiner creating the false positive impression of an intact biceps tendon.

![Figure 4](image)

The different types of biceps tears are summarised in Table 1. Abnormal A1 grading is based on the absence of the DBT, Abnormal A2 on the presence of a pseudo tendon and Abnormal A3 on tendon retention. Abnormal A4 is reserved for the rare complete tear with tendon retraction. Abnormal A5 is reserved for the rare complete tear with tendon retraction. Abnormal A6 is reserved for the rare complete tear with tendon retraction.

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tendon advancement to the posterior edge of the BT, and provides significantly greater supination strength. Traditionally, this requires a two-incision approach with a reported higher incidence of heterotopic ossification (HO). Non-anatomical reattachment is usually achieved through a single anterior incision which decreases the chances of HO, but increases the chance of neurapraxia of the lateral antebrachial cutaneous nerve. With newer techniques anatomic tendon reattachment is possible through an anterior-only incision.

SURGICAL TECHNIQUES FOR ACUTE COMPLETE TEARS
Both open and endoscopic techniques for the surgical repair of acute complete DBT injuries have been described. There are three main controversies in the surgical repair: single versus double incision exposure, anatomical versus non-anatomical repair and the method of fixation. Open techniques remain the mainstay for acute complete distal biceps ruptures. In the acute setting, open surgery is performed through a discrete incision. It provides adequate visualisation of all relevant structures to enable repair. Perfect anatomical fixation through a single incision anterior approach is difficult to achieve. Drilling from the relatively posterior located anatomical footprint requires significant forearm hypersupination and soft tissue retraction or drill sleeve compression on the ulnar side. Often the fixation method is also determined by the choice of approach, as bone tunnels are more difficult to perform using the single anterior incision. There are currently no randomised controlled trials comparing outcomes for single vs double incision for each fixation technique.

Regardless of method of fixation, universal setup and surgical approach is involved. The patient is positioned supine and the operative extremity placed on a hand table. The procedure is performed under general or regional anaesthesia, with or without a tourniquet on the upper arm. Via an anterior incision the biceps tendon is identified. There is usually the bicipital bursal sheath that leads down to the tuberosity. The BT is approached by blunt dissection and the superficial vessels

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**Figure 5** The Flexion, ABduction and Supination position of the left arm in the scanner.

**Table 2** Classification of distal biceps pathology

<table>
<thead>
<tr>
<th>Grade</th>
<th>Injury</th>
<th>Clinical findings</th>
<th>Hook test grade</th>
<th>MRI findings</th>
<th>Recommended management</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Tendinopathy, bursitis</td>
<td>Atraumatic, tender, swollen</td>
<td>N</td>
<td>Bursitis, fluid, tendinopathy</td>
<td>Non-surgical management, bursectomy, biopsy</td>
</tr>
<tr>
<td>1A</td>
<td>Low-grade partial defect (&gt;50%)</td>
<td>Pain and weakness against resistance</td>
<td>N, A1</td>
<td>Bursitis, effusion, footprint irregularity</td>
<td>Debridement</td>
</tr>
<tr>
<td>1B</td>
<td>Isolated head rupture</td>
<td>Weakness against resistance</td>
<td>A1</td>
<td>Isolated head avulsion</td>
<td>Repair of isolated head rupture</td>
</tr>
<tr>
<td>1C</td>
<td>High-grade partial defect (&gt;50%)</td>
<td>Pain and weakness against resistance</td>
<td>A1</td>
<td>Incomplete footprint detachment</td>
<td>Detachment and reattachment of tendon</td>
</tr>
<tr>
<td>2</td>
<td>Complete tendon rupture, lacertus fibrosus intact</td>
<td>Tendon medialised by intact lacertus fibrosus Marked weakness of supination</td>
<td>A2</td>
<td>Complete footprint detachment Tendon within sheath</td>
<td>Repair</td>
</tr>
<tr>
<td>3</td>
<td>Complete tendon and lacertus rupture with retraction</td>
<td>Retracted muscle Marked weakness of supination</td>
<td>A3</td>
<td>Complete footprint detachment Retracted tendon and muscle</td>
<td>Repair</td>
</tr>
<tr>
<td>4A</td>
<td>Chronic rupture</td>
<td>Tendon medialised by intact lacertus fibrosus Marked weakness of supination</td>
<td>A1, A2</td>
<td>Complete footprint detachment and contracted tendon within sheath (A2) A pseudotendon may bridge the native tendon to the footprint (A1)</td>
<td>Repair</td>
</tr>
<tr>
<td>4B</td>
<td>Chronic retracted rupture</td>
<td>Retracted muscle Marked weakness</td>
<td>A3</td>
<td>Complete footprint detachment Retracted tendon within fibrous cocoon</td>
<td>Repair in flexion or with tendon graft</td>
</tr>
</tbody>
</table>

are carefully dissected and cauterised as necessary. Deep right-angled retractors are used for careful retraction (especially radially) to avoid compression neurapraxia of the lateral antecubital cutaneous nerve. The tendon is often retracted proximal to the elbow crease. In some cases, the tendon can be retrieved by milking it distally through squeezing the biceps muscle belly, or by flexing the elbow and digitally retrieving it through its sheath. The frayed distal tendon stump can be debrided. The tendon is whip stitched according to the surgeon’s preference and repaired using a high tensile braided non-absorbable suture.

For surgical tendon reattachment, single and dual incision techniques are described below, each with different tips and tricks, and pitfalls to avoid. With all of the techniques any bony debris is removed and irrigated to minimise the risk of HO.38 Multiple methods of surgical fixation have been used to reattach tendon to bone (table 3).

**SINGLE INCISION APPROACH**

**Cortical button technique—Bain et al[37]**

Via an anterior incision, the tendon is retrieved outside the skin and sutured to a cortical button. The sutured button-tendon construct is prefabricated so that a 2 mm interval is left between the end of the tendon stump and the cortical button. This is necessary for the button to be deployed through the opposite cortex of the radius. A leading and a trailing suture are inserted in the outer holes of the button. The elbow is then extended and the forearm hypersupinated to expose the BT.

The technique involves opening the near cortex of the BT with a burr to permit biceps tendon passage.37 An alternative technique is to use a guide wire drilled centrally in the tuberosity, with two cannulated drill bits used sequentially to enlarge the hole for passage of the button-tendon construct.

Care is taken not to aim too radial or distal as this increases the risk of a PIN injury (figure 6).39 The near cortex is drilled with an 8 or 9 mm cannulated drill over the guide pin. The far cortex is then drilled with a 4.5 mm drill. The guide pin is used to shuttle the leading and trailing sutures through the bone tunnel (figure 7). The button is flipped once it clears the second cortex and the repair is tested by traction on the tendon. Its position is verified with fluoroscopy.

In an attempt to avoid PIN injury, Siebenlist et al modified this technique by perforating only the anterior cortex twice, using a 3.2 mm drill bit drilled over a K-wire angulated at 60° to the cortex, thereby allowing passage of two Endobuttons to obtain intramedullary, unicortical fixation. This double button construct proved biomechanically sound40 and achieved very good results in a series of 24 patients reviewed at a mean of 28 months postoperatively. They however noted a high incidence of radiographic HO, with one patient requiring revision surgery for stiffness.41

**ENDOSCOPIC APPROACH**

**All-endoscopic dual anchor repair—Bhatia[36]**

Two portals (proximal parabiceps portal and the distal anterior portal) are used for non-retracted complete tears, and a third portal (the mid-biceps portal) is necessary for tears that have

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**Table 3** Types of repair: based on type of incision and fixation

<table>
<thead>
<tr>
<th>Repair</th>
<th>Single incision</th>
<th>Endoscopic</th>
<th>Dual incision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-anatomic repair</td>
<td>Suture anchor 199332</td>
<td>Endoscopic Endobutton 200533</td>
<td>“Trap door” tuberosity fixation 196144</td>
</tr>
<tr>
<td>Anatomic repair</td>
<td>Single incision footprint technique 201535</td>
<td>Single incision footprint technique 201536</td>
<td>Mayo modification dual incision technique 199144</td>
</tr>
</tbody>
</table>

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Figure 6 When the forearm is fully supinated, there is a 30° safe zone at the posterior aspect of the radius, at the level of the radial tuberosity (copyright GJ Bain and M Crespi).
retracted proximal to the elbow crease. A 2.9 mm arthroscope and gravity fluid inflow are used to distend the bicipitoradial bursa, and the distal biceps insertion is visualised. Complete tears demonstrate a bare tuberosity, and remnants of the tendon stump may be visualised. A grasper is used to deliver the proximal end of the non-retracted DBT via the distal anterior portal under endoscopic visualisation. DBT tears that have retracted proximal to the elbow crease are explored and retrieved via the mid-biceps portal. The tendon is then shuttled across the elbow crease and is retrieved via the distal anterior portal. The BT is prepared and two double-loaded all-suture anchors are passed 1 cm apart. One suture from each pair is used to whip stitch the tendon, and the other end is pulled to dock the tendon on the tuberosity. Non-sliding knots are used to fix the DBT securely to the tuberosity.

**Figure 7**  (A) Straight-eyed needle with leading and trailing sutures is passed anterior to posterior. (B) The Endobutton advances the tendon into the intramedullary canal of the radius under fluoroscopic control. (C) Endobutton locks the tendon into position, and the leading and trailing sutures are removed.

**Figure 8** Endoscopy picture of the debrided radial tuberosity.

**Figure 9**  (A) The drill bit is directed volar to dorsal and radial to ulnar, directed at the posterior aspect of the bicipital tuberosity. (B) Two shuttle sutures are passed to retrieve the free ends of the Krakow suture in the biceps tendon through the two drilled holes. (C) The two sutures are tensioned sequentially to dock the tendon to the bicipital tuberosity. (D) The suture ends are tied over an Endobutton, distal first.

**DUAL INCISION APPROACH**

**Dual incision technique—Boyd and Anderson[42]**

Boyd and Anderson described the two-incision technique with the tendon delivered to a second incision, via a curved clamp on the posterolateral forearm. Via this second incision the radial tuberosity was exposed with the radius in pronation. The tendon is advanced into a trough and tied over a bony bridge. There have been issues with HO and radioulnar synostosis in this approach. To minimise this risk, Bourne and Morrey modified the technique by passing a curved clamp adjacent to the radius, taking care to avoid injury to the proximal ulna. Also irrigate to remove any bony debris.

Schmidt recommended a 3–4 cm posterior incision over the extensor carpi ulnaris (ECU) parallel to the ulna. The incision begins 2 cm distal to the lateral epicondyle and 2.5 cm dorsal to the ulnar ridge. Pronating the forearm to guard against PIN injury, ECU muscle is dissected along its fibres to reveal an obliquely directed supinator muscle. The supinator muscle is only ‘incised directly over the radial tuberosity’. The tuberosity is palpated in the pronated forearm or with the use of intraoperative fluoroscopy.

Clear the footprint of soft tissue. Schmidt obtained fixation with unicortical buttons. A 3.2 mm drill is used to make near cortex holes in the centre of the footprint of each head (figure 10). To help the ease of flipping the unicortical buttons inside the medullary canal, the drill holes are angled 60° distal to the radial shaft. Then in full forearm supination, use a Kelly clamp to pass the tendon from anterior to posterior along its route. To ensure the tendon retains its normal orientation, it is externally rotated 90° and passed retaining this rotation, so

**Tips and tricks**

- Fogging of the endoscope may occur—wipe the lens with alcohol-soaked gauze.
- Slightly pronate the forearm to lateralise the anterior drill holes ensuring the cortical button does not impinge on the repaired biceps tendon.
- Traction the distal sutures of the cortical button while tying the proximal sutures to ensure the tendon is advanced onto the bone.
the short head (solid coloured) inserts distal and long head (striped colour) proximal on the footprint (figure 11).

The docking limb of each suture is placed through the centre holes of the cortical button and into their respective drill holes (short: distal, long: proximal). The buttons seat against the near cortex by pushing them into the hole with the flat end of the drill pin and drawing on the docking suture arm (figure 12). Traction on the docking limbs of each suture compresses the respective biceps heads against the footprint. Before securing the sutures, fluoroscopy may be used to check both buttons are seated parallel to and abutting the near cortex. Each button then acts as an intramedullary pulley and the repair is completed by throwing multiple knots to secure it.

OUTCOMES

Outcomes are partially dictated by the complications experienced (discussed below), which in turn are related to the surgical approach, and both the anatomical position and method of fixation used. Non-anatomical repairs will achieve the functional treatment goals in many patients, however anatomical repairs have shown significantly better peak torque and work with repetitive supination, as well as flexion (figure 13).30

Tanner et al described and evaluated the Single Incision Power Optimising Cost-effective technique. This anatomic repair achieved excellent supination strength (91%).34 In a different cohort, MRI scans demonstrated no statistical difference (p=0.548) between the biceps repair position using a Posterior Anatomic Footprint Repair and an uninjured control group.31 Here, their postoperative mean supination strength compared with normal at an average of 1.4±0.4 years was 94.0% in 60° of pronation, 92.2% in neutral and 81.3% in 60° supination.31 Maintaining this superior supination strength through the whole arc of forearm rotation is important in returning athletes to their former elite performance levels.

Regarding choice of fixation, interference fit screws have been proposed by some authors, but have been associated with a higher complication rate.46 Suture anchor fixation is also commonly used, but some concerns have been published about failure by gapping.47

POSTOPERATIVE PROTOCOL

Despite there being no adequate randomised controlled trials comparing postoperative protocols for DBT reattachment, two large retrospective cohort analyses totalling 1754 patients found the re-rupture rate to be only 1.5%–1.8%.32 33 Re-ruptures occurred at a mean of 3–7 weeks, with none occurring after 86
days. This provides good evidence that unrestricted return to full activity may commence 12 weeks postsurgery. In the first 12 weeks, pain and maximum tolerable biomechanical construct strain should be the determining factors guiding early rehabilitation to regain range and strength. Early unassisted postoperative rehabilitation has shown a significant reduction in time to full range of motion without an increase in any complications or re-ruptures.

A sling only for comfort is advocated in the acute setting, and early active and passive range initiated, with graduated resisted movement as pain allows. Although the pullout strength of most methods of fixation is at least 20 kg, it is prudent to restrict the maximum weight to half this in the first 12 weeks.

COMPLICATIONS
The largest systematic review on complications of primary repair of the DBT reports on 3091 procedures and gives a total complication rate of 24.4%. Complications may be stratified by frequency and severity. Four important major complications include PIN palsy (1.6%), re-rupture (1.4%), symptomatic HO (0.3%) and radioulnar synostosis (0.1%), as these are either functionally disabling or require reoperation. With the reoperation rate from primary repair being 1%, symptomatic HO and radioulnar synostosis account for almost half of these cases. Re-rupture accounts for the majority of the remainder, but appears not to be related to the specific method of surgical fixation. In another systematic review, Watson et al found the overall complication rates for bone tunnels and cortical buttons to be significantly lower in comparison with other fixation techniques, and some concerns have already been raised around the addition of an interference screw as mentioned earlier. Reassuringly, almost all of the motor nerve palsies resolve with expectant management.

The most common overall minor complication is sensory nerve injury (10.9%), either of the lateral antebrachial cutaneous nerve or the superficial branch of the radial nerve. Limited single incision (not crossing the cubital crease), extensile single incision (crossing the cubital crease) and double incision were compared with regard to their complication profile and the incidence of injury to the lateral antebrachial cutaneous nerve was significantly higher with limited single incision. Injury to the superficial branch of the radial nerve was significantly higher with the extensile single incision. Radioulnar synostosis occurred exclusively with the double incision technique.

CONCLUSION
Overall good outcomes can be achieved using many different techniques for distal biceps tendon reattachment. It is however important to try and improve these outcomes by abolishing possible causative factors for failure and eliminating complications. Especially those complications considerably impacting patients or requiring reoperation. Significant complications include motor nerve injury (90% of which recover spontaneously), re-rupture (which is related to the biomechanical strength of the construct fixation) and symptomatic HO and synostosis.

In addressing these, the addition of an interference screw for tendon fixation does not decrease the re-rupture rate and adds no additional biomechanical strength. It does increase the stress riser at the radial neck and may cause osteolysis and fracture. Screw anchor fixation has been associated with tendon gapping requiring revision and is biomechanically inferior to several other methods of fixation. Using incision techniques that decrease the risk of HO seems a reasonable option. Performing an anatomic or non-anatomic repair should be based on patient functional

Key articles

Figure 13 Schematic representation of a non-anatomic (A) and anatomic (B) repair showing how the improved peak torque and work with repetitive supination is achieved by increasing the moment arm of the biceps tendon in anatomic repairs.

State of the art review


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311
State of the art review

Future perspectives

► Multiple fixation techniques have been used to reattach the acutely ruptured distal biceps tendon.
► Despite good results with most, some concerns have been raised regarding the use of suture anchor fixation, as this is both biomechanically inferior when compared with other methods, and some of these repairs have failed by gapping.
► When performing an Endobutton or transosseous suture repair, addition of an interference fit screw to the fixation construct does not decrease the re-rupture rate and adds no additional biomechanical strength, but it may increase the risk of radial neck osteotomy and fracture.
► The fixation techniques are carried out through either a single or dual incision approach, but the dual incision approach carries the risk of significant heterotopic ossification and radioulnar synostosis.
► It seems reasonable to employ a single incision approach, to eliminate this risk for the patient, recognising that the single incision approach has a higher risk of (transient) lateral antebrachial cutaneous nerve injury.

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REFERENCES