Ruptures of the Distal Biceps Tendon

James P. Ward, M.D., Mark C. Shreve, M.D., Thomas Youm, M.D., and Eric J. Strauss, M.D.

Abstract
Distal biceps ruptures occur most commonly in middle-aged males and result from eccentric contraction of the biceps tendon. The injury typically presents with pain and a tearing sensation in the antecubital fossa with resultant weakness in flexion and supination strength. Physical exam maneuvers and diagnostic imaging aid in determining the diagnosis. Nonoperative management is reserved for elderly, low demand patients, while operative intervention is generally pursued for younger patients and can consist of nonanatomic repair to the brachialis or anatomic repair to the radial tuberosity. Anatomic repair through a one-incision or two-incision approach is commonplace, while the nonanatomic repairs are rarely performed. No clear advantage exists in operative management with a one-incision versus two-incision techniques. Chronic ruptures present a more difficult situation, and allograft augmentation is often necessary. Common complications after repair include transient nerve palsy, which often resolves, and heterotopic ossification. Despite these possible complications, most studies suggest that better patient outcomes are obtained with operative, anatomic reattachment of the distal biceps tendon.

The first report of a rupture of the distal biceps tendon was reported by Starks in 1843.1 Successful surgical repairs were reported in the late 1890s independently by Johnson and Acquaviva.2,3 Dobbie published the first major series of distal biceps ruptures in 1941 in which he surveyed surgeons across the country and determined treatment preferences and outcomes.4 The extensile volar Henry approach was utilized at the time, and surgical management was abandoned due to unacceptably high rates of complications, commonly involving injuries to the radial and median nerves.

Epidemiology
Of all biceps injuries, only 3% occur as a rupture or avulsion at the distal insertion.1 The most common site of injury of the distal biceps tendon is avulsion from the radial tuberosity, although myotendinous injuries have been reported.6 The most common mechanism of injury involves eccentric muscle contraction against a heavy load in a semi-flexed position.7,8 Safran and Graham in 2002 reported the incidence of distal biceps ruptures to be 1.2 per 100,000 persons per year.9 They also evaluated demographics and risk factors related to rupture and found that 43% of patients with ruptures reported regular tobacco usage, compared to 9% in the general population, resulting in a 7.5 times increased risk of rupture in smokers. Other significant risk factors include anabolic steroid use and weightlifting.10-12 The majority of patients were males in their fourth to fifth decade of life, and 61% to 86% of ruptures occurred in the dominant upper extremity. Females typically present late and with partial tears.

Seiler and coworkers evaluated the possible mechanisms for rupture. They determined that a watershed area exists approximately 2 cm proximal to the insertion on the radial tuberosity, and that this could predispose to rupture.5 However, as most ruptures occur at the tuberosity, their mechanical theory may have more merit. In moving from full forearm supination to pronation, the space available for the distal biceps tendon at the proximal radioulnar joint decreases by 50%. The tendon at this level occupies approximately 85% of the available space, possibly leading to rupture from repetitive microtrauma.5

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Anatomy
The biceps brachii muscle is composed of two heads: the long head originates from the apex of the glenoid, and the short head originates from the tip of the coracoid process. Both heads insert distally onto the radial tuberosity. It functions as the primary supinator of the forearm and the secondary flexor of the forearm along with the brachialis. It is supplied by the musculocutaneous nerve.

The tendon inserts onto the radial tuberosity over an area of 3 cm². It wraps around the radial neck during supination with its collagen fibers inserting at an angle of 60°. Type I collagen is seen throughout the course of the tendon and Type II collagen along with Type IX collagen are seen in the fibrocartilaginous area of the insertion. The primary vascular supply of the distal tendon is derived from the paratenon and is supplied by small branches of the cubital artery. Two microscopic positions of the distal tendon exist with a traction portion on the ulnar aspect and a gliding portion on the radial aspect. The distal tendon spirals in a predictable pattern distally to the bicipital aponeurosis, spiraling clockwise in left elbows and counterclockwise in right elbows. The anteromedial fibers follow a relatively straight course and attach inferiorly whereas the posterolateral fibers coil under the medial fibers to attach superiorly.

The footprint of the distal biceps insertion is located on the posteroulnar aspect of the radial tuberosity and occupies approximately one-third of the total area of the tuberosity. The insertion is semilunar in shape in 80% of cases with the remaining 20% being ovoid. Mazzocca and associates demonstrated in a cadaveric study that 88% of radial tuberosities had a ridge, usually of medium size. The tendon does not insert upon the ridge, but rather passes over it, inserting on the ulnar aspect of the tuberosity. The function of that ridge has not yet been elucidated, but it may serve as a pulley to increase the mechanical advantage of the distal aspect of the tendon. In terms of the size of the tuberosity, it has an average length of 22 mm ± 3 mm and average width of 15 mm ± 2 mm. Many have shown in cadaveric studies that the two heads of the biceps can commonly be found inserting in two distinct tendinous parts. Most recently, Cho and colleagues found that 48% of specimens had two distinct and separate parts that were easily defined on insertion, with the long head inserting more proximal and posterior, and the short head inserting more distal and anterior about the tuberosity. In looking closer at the biomechanical function of the separate heads of the biceps, Jarett and coworkers found that the short head of the biceps was a more efficient supinator in the neutral and pronated positions of the forearm, whereas the long head was a more efficient supinator with the forearm in 60° of supination. They also found the short head to be a more efficient elbow flexor at 90° of flexion, being able to carry a 15% greater load.

Diagnosis and Imaging
O’Driscoll and associates evaluated the utility of a physical exam maneuver called the “hook test” in diagnosing distal biceps ruptures. The exam maneuver is performed by having the patient actively flex the elbow to 90° and fully supinate the forearm, and with a normal test, the examiner should be able to insert the index finger about 1 cm deep to a cord like structure in the antecubital fossa, approached from the lateral side to avoid false positives from the intact lacertus aponeurosis. A positive test is signified by inability to hook or palpate cord like structure. Partial tears result in a painful test but with a palpable cord. O’Driscoll demonstrated a 100% sensitivity, specificity, and positive and negative predictive values, which exceeds the values found with MRI.

Another physical exam maneuver described in the literature is the biceps squeeze test, analogous to the Thompson test for Achilles tendon ruptures. The patient’s affected elbow is rested on his or her lap in slight pronation with the elbow flexed 60° to 80°. The biceps muscle belly is then firmly squeezed with both hands, and the lack of forearm supination signifies a positive test. Ruland and colleagues found a sensitivity of 96% in diagnosing distal biceps ruptures with this test. All patients who underwent surgical repair of the tendon had a negative squeeze test postoperatively.

Yet another diagnostic tool described is the biceps crease interval, proposed by El Maraghy and coworkers. The biceps crease interval is defined as the distance between the antecubital crease of the elbow and the cusp of the distal descent of the biceps muscle, defined as the point at which the curve of the distal biceps begins to turn most sharply toward the antecubital fossa. The population norm was determined to be 4.8 cm ± 0.6 cm. No influence by arm dominance was identified, and high interobserver reliability was seen. A positive test is considered to be greater than 6 cm, two standard deviations above the norm. Sensitivity was determined to be 92% and specificity 100%, with a positive predictive value of 100% and negative predictive value of 71%.

In terms of imaging, radiographs are usually obtained to rule out any associated elbow injuries, and may occasionally show irregularity about the radial tuberosity or avulsion fractures. Ultrasound has been proposed as a useful tool in diagnosing distal biceps ruptures as it is faster and cheaper than other forms of advanced imaging but is user dependent. When MRI is indicated, standard arm positions may not adequately demonstrate the course of the tendon as its oblique course is difficult to fully evaluate in a longitudinal position. Giuffre and Moss described the optimal patient position to evaluate the full course of the tendon with the patient prone, shoulder abducted overhead, with elbow flexed to 90°, and forearm fully supinated.

Non-operative Versus Operative Management
Treatment options for distal biceps tendon rupture include nonoperative or operative management. Non-operative management is reserved for older, low-demand patients or those with significant medical comorbidities resulting in an
unacceptably high risk for surgery. The trend for surgical reattachment over nonoperative management began in the 1980s. Baker and Bierwagen in 1985 performed Cybex strength testing on patients that underwent surgical reattachment of the ruptured biceps tendon and compared them to patients treated nonoperatively. They found that nonoperative treatment results in a 47% decrease in supination endurance and a 21% decrease in supination strength of the involved dominant side compared to the opposite non-dominant extremity. In the operatively treated group, supination strength was 13% stronger, and supination endurance was 32% higher. Morrey and associates also showed similar results with nonoperative management resulting in 40% loss of supination strength and 30% loss of flexion strength.

Previously, tenodesis of the torn biceps tendon to the brachialis muscle belly in a non-anatomic manner was advocated. Bell and coworkers in a retrospective review, evaluated nonoperative, brachialis tenodesis, and anatomic reattachment with various fixation methods and found that tenodesis to the brachialis resulted in a 40% decrease in supination strength and 17% decrease in flexion strength, which was equivalent to nonoperative management. Klonz and colleagues also looked at a comparison between anatomic and non-anatomic repair and reported that patients treated with non-anatomic fixation to the brachialis attained an average 96% flexion strength compared to the contralateral arm, but mean supination strength in half of the patients was less than 50% of the contralateral arm.

More recently, Chillemi and coworkers reported on anatomic reattachment versus nonoperative management and looked at patient reported clinical outcome scores and found that European Society for Shoulder and Elbow Surgery (SECEC) elbow scores favored surgical reconstruction in all domains, although there was no comment on statistical significance. Hetsroni and associates looked at subjective functional outcome scales and isokinetic strength and endurance testing. They reported that there was higher satisfaction and higher isokinetic strength and endurance in elbow flexion and forearm supination in the operative group, all of which reached statistical significance.

Overall, most studies suggest that better patient outcomes are obtained with operative, anatomic reattachment of the distal biceps tendon, with nonoperative management reserved for those older, lower-demand patients. Nonoperative management may result in chronic activity related arm pain, and the goal is to treat these injuries acutely to obtain the best possible clinical outcome.

**Biomechanics: One-incision Versus Two-incision Techniques and Fixation Types**

Surgical options can be divided into either one- or two-incision techniques, with the two-incision technique most commonly utilizing bone tunnel fixation and the one-incision technique utilizing several fixation techniques, including suture anchors, interference screws, or cortical button based constructs. Many biomechanical cadaveric studies have been performed to evaluate the different repair techniques and to evaluate to restoration of the footprint anatomy, in order to determine which approach and fixation technique is most optimal. The native tension on the biceps tendon when the elbow is held at 90° of flexion against gravity has been found to be 50 N. The mean failure strength required to rupture intact biceps tendon is around 204 N.

In regards to footprint restoration, Hasan and coworkers performed a cadaveric study evaluating the footprint coverage from both the one- and two-incision approaches. A guide wire was placed in the most likely area of tunnel placement, and a 7.5 mm tunnel was centered about this point. The two-incision approach covered 73% of the native footprint compared to 10% with the one-incision approach. The one-incision reconstruction resulted in a lateralized tunnel and often was completely outside the original footprint.

Henry and colleagues compared the one- and two-incision techniques and showed no difference in supination or flexion torques between the two techniques. They found the highest supination torque when the reconstruction tunnel was centered on the posterior central portion of the tuberosity from either approach. There was a trend toward loss of supination strength with one-incision repair, but this was not statistically significant.

With respect to suture anchor fixation, Lemos and associates compared the use of bone tunnels to suture anchor fixation in a cadaveric biomechanical study. They found the yield strength of suture anchor fixation to be 263 N compared to bone tunnel fixation at 203 N. The suture anchors used in this study were of larger size, and the investigators used two instead of one anchor than in previous studies that found inferior biomechanical strength compared to bone tunnels. Most failures in the suture anchor group were due to suture breakage. A direct correlation was found between increased bone density and greater yield strength of the repair.

Krushinski and coworkers evaluated the repair strength of bio-tenodesis interference screws versus suture anchor repair. There was no significant difference between pull-out strength of interference screw fixation and native tendon. There was a significantly higher pull-out strength of the bio-tenodesis screw fixation (192 N) compared to 2 x 3.5 mm metallic suture anchor repair (147 N), with no difference in the stiffness of the constructs. Bio-tenodesis screws have been found in previous studies to induce direct tendon-to-bone healing upon histological examination, and this healing occurs with a Sharpey’s fiber-like pattern. There has been no difference in biomechanical or histological characteristics of tendon healing to a cortical bone or a cancellous bone trough.

Cortical buttons have been found to have the highest load to failure of all techniques. Mazzocca and coworkers performed a cadaveric biomechanical study comparing the relative strengths of the four most commonly used fixation types; bone tunnels, suture anchors, interference screws,
and cortical buttons. The cortical button was found to have the significantly higher load to failure than the other three techniques, with no significant difference in displacement rates after cyclical loading.

Given the superior biomechanical properties of cortical button fixation and increased use of this technique, the safety of the posterior interosseous nerve was brought into question while drilling through the posterior cortex. The posterior interosseous nerve is placed at greater risk with perpendicular drilling through the posterior cortex as compared to drilling with a 30° ulnar deviated axis. The distance to the posterior interosseous nerve was significantly greater, by approximately 5 mm, with the ulnar directed drilling with no significant difference in tunnel length.42

Sethi and associates described a further modification to the cortical button fixation technique, called the tension slide, which allows for improved contact between tendon and bone tunnel, and obviates the need for premeasuring the appropriate distance to cortex in the cortical button construct. The construct can be combined with an interference screw inserted radially with the limbs tied over the screw for additional fixation. Adding the interference screw resulted in the highest load to failure and gapping of this construct after cyclical loading was superior to all other fixation methods. Radial placement of the screw, with resultant ulnarization of the tendon, theoretically improves the supination moment arm of the reconstructed tendon.

In an effort to decrease the risk of injury to the posterior interosseous nerve with the cortical button construct, an intramedullary cortical button technique has been developed. Siebenlist and colleagues performed a cadaveric study comparing 1- or 2-button intramedullary fixation with single extramedullary cortical button-based repair. The highest load to failure was found with the double intramedullary button repair, with no significant difference between single intra- or extramedullary buttons. This technique reduces the risk of posterior interosseous nerve injury as the posterior cortex of the proximal radius is not violated. The relative thin anterior cortex when compared with the posterior cortex served as the rationale for using two intramedullary buttons. On a technical note, the intramedullary button must be drilled at a 60° angle to allow sufficient intramedullary space for engaging or flipping the button.45

In summary, cortical button based constructs appear to have the most favorable biomechanical characteristics based on cadaveric studies. The two-incision approaches appear to recreate the normal anatomy more accurately. However, no clear evidence exists suggesting that the two-incision approaches have a clinically significant advantage.

Two-Incision Approach

The original description of the two-incision approach was proposed by Boyd and Anderson in 1961 in response to the high complication rates associated with the extensile one-incision volar Henry approach.47 In the original description, suture was passed through a bone trough created in the radial tuberosity, and the tendon was passed through the tunnel which involved subperiosteal stripping of the ulna. The technique was later modified by Morrey and coworkers in 1985 as there was a risk of radioulnar synostosis involved with the ulnar stripping. Morrey employed a muscle splitting approach to decrease the risk of heterotopic ossification.

Karunakar and associates performed a retrospective, 4-year follow-up review of 21 patients treated with this modified Boyd-Anderson repair. Decreased flexion motion was seen in 5% of patients, and 19% of patients demonstrated decreased forearm rotation. Almost half of the patients had a deficit in supination strength, and a third demonstrated a deficit in supination endurance. The total complication rate was 35% with a 14% incidence of heterotopic ossification and a complete radioulnar synostosis in one patient. Despite these results, they reported good to excellent DASH scores in 20 of 21 patients.

Weinstein and colleagues and Lynch and associates both performed similar retrospective reviews of distal biceps ruptures treated with the use of suture anchors through the two-incision approach. In separate series, both reported restoration of equivalent supination and flexion parameters compared to the opposite uninjured upper extremity on isokinetic testing. No synostoses were seen in either series, and the most common complication was transient lateral antebrachial cutaneous nerve palsy. There were no significant differences in range of motion of the upper extremities compared to the uninjured side.

In regards to immediate postoperative active range of motion, Cil and coworkers evaluated the two-incision approach with bone-tunnels in a case series of 21 patients. The patients were permitted a sling for 2 days and then began active forearm flexion and extension and passive rotation. Limited weightlifting with a 2 pound limit was begun at 6 weeks with a return to full activity at 3 months. There were no postoperative re-ruptures, and the complication rate was 19% with two cases of heterotopic ossification, both without any effect on forearm rotation. However, there was an 11% decrease in supination strength on the injured side, but a 12% improvement in flexion strength.

Another study from Cheung and associates also evaluated immediate postoperative motion using the two-incision technique with bone tunnels. Patients were placed in a hinged brace beginning postoperative day one with flexion limited to 60°. The motion block was decreased sequentially at 2 and 4 weeks postoperatively, and strength training commenced at 8 weeks. Flexion and supination strength returned to approximately 90% of the uninjured side. One re-rupture did occur in a non-compliant patient. These two studies suggest that early active range of motion is feasible with an acceptable re-rupture rate.

Davison and coworkers retrospectively reviewed eight patients in a long-term follow-up study with an average fol-
low up of 6 years. Six of the eight patients were subjectively satisfied with the outcomes but all reported being able to perform less work involving repetitive supination. Strength testing demonstrated decreased supination strength in six of the eight patients, which was not statistically significant.

**One-Incision Approach**

The original one-incision extensile volar Henry approach was associated with an unacceptably high rate of nerve palsy as reported by Dobbie in 1941.4 Renewed interest in the one-incision approach coincided with the advent of suture anchors, which allowed for a less extensive anterior dissection. The theoretical benefit of the one-incision approach is a reduced risk of radioulnar synostosis as the ulnar periosteum is not violated.

John and associates54 performed a retrospective review of 53 patients treated with the one-incision approach using two suture anchors for fixation of the torn tendon. They reported all excellent or good Andrews-Carson validated outcomes scores with only a 5.6% complication rate. There were two cases in the series of patients with resultant heterotopic ossification with limited, but still functional forearm rotation. Table 1 lists several of the larger, higher quality studies that exist demonstrating the outcomes of suture anchor repair via the one-incision techniques. All studies were retrospective in nature with relatively small sample sizes. Complication rates range from 5.6% to 40% with a significant number of cases with heterotopic ossification, albeit most of these were non-motion limiting. Scores on validated outcome measures demonstrate overall very positive results using this technique.

Fenton and coworkers59 evaluated the use of an interference screw alone via the one-incision technique in the largest series using this fixation method. Mayo Elbow Performance Scores demonstrated all patients had good to excellent results with no difference in range of motion between injured and non-injured upper extremities. The mean time to return to sport was just over 4 months.

Peeters and colleagues60 retrospectively reviewed 26 patients that underwent cortical button fixation using the one-incision approach. The average postoperative Mayo Elbow Performance Score was 94 indicating overwhelmingly positive results. Flexion strength returned to 80% of the contralateral side with supination strength returning to 91%. A low complication rate was seen in this cohort, with both cases of heterotopic ossification having no effect on forearm rotation. Table 2 lists the three higher quality studies using the cortical button one-incision approach, including the study by Peeters and colleagues. All studies were retrospective with complication rates ranging from 8.25% to 5%. The study with a 50% complication rate included four cases of asymptomatic heterotopic ossification. Return to near normal strength was seen in all three series.

Others have combined the use of cortical buttons and interference screws with a tension slide technique as mentioned previously. Heinzelmann and coworkers63 performed a retrospective review of the tension slide cortical button technique with a radially based interference screw to theoretically improve supination biomechanics. Twenty-nine of 32 patients rated their outcome as excellent. The patients were allowed range of motion at 1 week and activity of daily living retraining at 2 weeks postoperatively. The more

### Table 1 One-Incision Repair Using Suture Anchors

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Outcomes</th>
<th>Complication Rate</th>
<th>Patients with HO</th>
</tr>
</thead>
<tbody>
<tr>
<td>John 200754</td>
<td>Retrospective 53 patients</td>
<td>46 excellent, 7 good</td>
<td>5.6%, 2 patients</td>
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<tr>
<td>McKee 200555</td>
<td>Retrospective 53 patients</td>
<td>DASH: 8.2, 81% satisfied</td>
<td>7.5%, 0 patients</td>
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<td>Gallinet 201156</td>
<td>Retrospective 28 patients</td>
<td>91% strength</td>
<td>40%, 10 patients</td>
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<tr>
<td>Khan 200857</td>
<td>Retrospective 17 patients</td>
<td>DASH: 14.5, 82% strength</td>
<td>11.8%, 1 patient</td>
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<tr>
<td>Balabaud 200458</td>
<td>Retrospective 9 patients</td>
<td>Restored supination</td>
<td>n/a, 3 patients</td>
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</table>

### Table 2 One-Incision Repair Using Cortical Button

<table>
<thead>
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<th>Study Design</th>
<th>Outcomes</th>
<th>Complication Rate</th>
<th>Patients with HO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peeters 200960</td>
<td>Retrospective 26 patients</td>
<td>MEPS: 94, VAS: 1.5</td>
<td>11.5%, 2 patients</td>
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<tr>
<td>Greenberg 200361</td>
<td>Retrospective 14 patients</td>
<td>97% flexion, 82% supination</td>
<td>50%, 4 patients</td>
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<td>Bain 200062</td>
<td>Retrospective 12 patients</td>
<td>“Grade 5 power”</td>
<td>8.25%, 0 patients</td>
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aggressive rehabilitation protocol was credited to the higher load to failure of the construct. They reported a complication rate of 9.7% with one case of motion-limiting heterotopic ossification and two transient lateral antebrachial cutaneous nerve palsies.

Some have even proposed endoscopic management of distal biceps tendon ruptures. Gregory and associates64 reviewed 23 patients who underwent endoscopic repair, with the overwhelming majority reporting high levels of satisfaction and most returning to their original level of work or preferred sport, as well as return to near normal range of motion in both flexion and forearm rotation. One patient did suffer a postoperative median nerve palsy, which was thought to be due to fluid extravasation and scarring, which did not completely recover, even after exploration and neurolysis.

**Comparison of Approaches**

Few comparative studies between techniques have been performed, and of those presented, most are retrospective and not well controlled. Citak and colleagues65 retrospectively reviewed 54 patients treated with either a one-incision suture anchor fixation or the modified Boyd-Anderson two-incision approach using transosseous sutures. There was no significant difference in DASH scores between the two groups. The suture anchor repair group had a higher overall complication rate. The re-rupture rate was 5.6% with all cases in the suture anchor repair group.

El-Hawary and coworkers66 evaluated 19 patients who underwent the modified Boyd-Anderson two-incision technique or a one-incision repair with suture anchors. They found improved flexion range of motion in the one-incision group with similar forearm rotation between the two groups. There were no significant differences in strength or outcome scores at 1 year postoperatively. The one-incision group did have significantly more complications, 44% versus 10%, with lateral antebrachial cutaneous nerve palsies being the most common.

Johnson and associates67 reviewed 26 patients who also underwent one-incision suture anchor repair or two-incision modified Boyd-Anderson repair. No significant differences were seen between the two groups with respect to flexion and supination strength or endurance. In this cohort, there was no significant difference in the complication rate between the two groups; however, there were slightly higher satisfaction rates in the two-incision group. Again, lateral antebrachial cutaneous nerve palsies were more common in the one-incision group.

There are no well-designed, prospective, randomized studies comparing one- or two-incision approaches or the different fixation techniques. No technique has clearly demonstrated clinical superiority to another and each approach is associated with a specific subset of complications. The best method of fixation and approach to perform the selected fixation remains to be seen.

**Chronic Ruptures**

Since the recognition of acute distal biceps ruptures can be missed at initial presentation and definitive diagnosis may be delayed, the tendon can retract in a matter of weeks making direct repair more difficult. Several treatment options have been described for the treatment of chronic distal biceps ruptures. Direct repair is possible if the tendon is able to be reapproximated to the tuberosity with less than 30° to 40° of elbow flexion.68 If greater flexion angles are required, then graft augmentation should be considered. Autograft options include fascia lata, split and double looped flexor carpi radialis, or semitendinosus. Allograft options include Achilles tendon with or without bone block, semitendinosus, or tibialis anterior.

Wiley and colleagues69 compared the results of seven patients who underwent reconstruction of a chronic rupture with a semitendinosus allograft using the two-incision technique with bone-tunnels and seven patients who were treated nonoperatively. The surgical group had return to normal flexion and supination strength, whereas the nonoperative group had a residual 20% strength deficit. There was no significant difference in endurance. Several retrospective studies have been performed evaluating the results of chronic distal biceps rupture reconstructions and are listed in Table 3. All have relatively low numbers of patients with varied graft choices. Overall, excellent results were noted after

<table>
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<th>Study Design</th>
<th>Incisions/Fixation</th>
<th>Graft</th>
<th>Outcomes</th>
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<tr>
<td>Vastamaki 2008 70</td>
<td>Retrospective 14 patients</td>
<td>One, Tunnel or Anchor</td>
<td>Variable</td>
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<tr>
<td>Sanchez 2002 71</td>
<td>Retrospective 4 patients</td>
<td>Two, Bone Tunnel</td>
<td>Achilles</td>
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<td>Levy 2000 72</td>
<td>Retrospective 5 patients</td>
<td>One, Suture Anchors</td>
<td>Double looped FCR</td>
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<tr>
<td>Hallam 2004 71</td>
<td>Retrospective 9 patients</td>
<td>One, Endobutton</td>
<td>Semitendinosus</td>
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<tr>
<td>Darlis 2006 74</td>
<td>Retrospective 7 patients</td>
<td>One, Suture Anchors</td>
<td>Achilles</td>
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the reconstructions with restoration of strength and endurance in most cases. Definitive statements regarding number of incisions, graft choice, and fixation method cannot be made from currently available studies. Figure 1 illustrates a case of a middle-aged male who presented with a chronic distal biceps rupture that could not be repaired with direct approximation. Achilles tendon allograft was utilized, and the graft was fixed with a cortical button using the tension slide technique. Of note, the repair was augmented with an interference screw placed radially as described previously.

**Partial Ruptures**

Partial ruptures often present in a delayed fashion with persistent anterior elbow pain. Physical examination maneuvers demonstrate pain with palpation of the tendon. MRI demonstrates edema along the distal tendon with disruption of some fibers, especially on T2-weighted images. Partial ruptures involving greater than 50% of the insertion should be taken down during surgery and treated as a complete rupture with the repair method and approach of the surgeon’s choice.75

Frazier and associates76 reviewed the results of 17 patients with varied surgical approaches and fixation. Flexion strength of the involved limb was improved compared with the uninjured side with supination strength being only slightly decreased. Range of motion was symmetric in 14 of the 15 patients tested. Complication rates were similar to other series of acute repairs.

**Complications**

The most common complication after both one- and two-incision approaches is nerve palsy, more specifically lateral antebrachial cutaneous nerve palsy. Complication rates range from 15% to 40% in most larger series.48,77-79 The incidence of heterotopic ossification and radioulnar synostosis appears to be higher with the two-incision approach, although cases of motion limiting heterotopic ossification have been reported after the one-incision approach.

Kelly and coworkers77 reviewed the complications in a cohort of 78 patients that underwent the two-incision technique for repair and reported a complication rate of 31%. The most common problems were transient nerve palsy (8.1%, most commonly lateral antebrachial cutaneous nerve) or persistent elbow pain (8.1%). Four cases of non-motion limiting heterotopic ossification were noted, but no cases of radioulnar synostosis were seen. There was a trend toward a higher rate of complications with increased time from injury to surgery.

Failla and colleagues80 reported on four cases of complete radioulnar synostosis with the original two-incision approach and their results after surgical resection. All synostoses were excised, but a 50% recurrence rate was seen. They advocated a muscle splitting approach modification to the Boyd-Anderson approach. Austin and associates78 later performed a retrospective review of the two-incision approach using the muscle splitting modified Boyd-Anderson approach and reviewed risk factors for development of synostoses. They noted that half of the patients presenting with synostoses had a posterior incision which crossed the ulnar crest, indicating potential violation of the ulnar periosteum. They determined that the proximity of the posterior incision to the ulnar crest was associated with an increased risk of synostosis.

Anakwenze and coworkers81 reviewed 34 patients who underwent a modified two-incision approach, with all patients receiving indomethacin for 6 weeks postoperatively. They reported no cases of heterotopic ossification or synostoses at 6 weeks as documented on radiographs. However, no long-term studies exist proving the efficacy of indomethacin.
or radiation therapy for preventing heterotopic ossification after distal biceps repair.

Potapov and colleagues82 reviewed 19 consecutive patients treated with interference screw fixation after distal biceps rupture via the one-incision approach. A 12% increase in tunnel size was noted on radiographs at 2-year follow-up. Furthermore, approximately 75% of screws persisted radiographically at final follow-up. One patient required screw removal and several reoperations due to a massive osteolytic reaction. No association between osteolysis and clinical outcome was noted.

Summary
Operative treatment of distal biceps tendon ruptures is recommended for most patients as nonoperative treatment results in loss of supination strength and endurance. The cortical button construct placed using the tension-slide technique appears to have the best biomechanical characteristics in cadaver studies. Two-incision approaches result in better restoration of native anatomy; however, clinical studies have failed to demonstrate differences in flexion or supination strength and endurance between the two approaches or any of the various fixation techniques.

The rate of heterotopic ossification and radioulnar synostosis is higher after the two-incision approach, especially if the ulnar periosteum is violated, and the role of indomethacin or radiation therapy to prevent this has not yet been defined. The rate of lateral antebrachial cutaneous nerve palsy is noted to be higher after the one-incision approach. Well-designed prospective randomized clinical trials to determine the optimal approach and fixation type are lacking.

Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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