Current Concepts Review

Distal Biceps Tendon Injuries

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- Distal biceps tendon ruptures present with an initial tearing sensation accompanied by acute pain; weakness may follow. The hook test is very reliable for diagnosing ruptures, and magnetic resonance imaging can provide information about the integrity and any intrasubstance degeneration of the tendon.
- There are subtle differences between the outcomes of single and modified two-incision operative repairs. With regard to complications, there is a higher prevalence of nerve injuries in association with single-incision techniques and a higher prevalence of heterotopic ossification in association with two-incision techniques.
- Fixation techniques include the use of bone tunnels, suture anchors, interference screws, and cortical fixation buttons. There is no clinical evidence supporting the use of one fixation method over another, although cortical button fixation has been shown to provide the highest load tolerance and stiffness.
- Postoperative rehabilitation has become more aggressive as fixation methods have improved.

The treatment of distal biceps tendon ruptures remains a controversial topic as recent studies continue to delineate more about the native anatomy of the tendon and the epidemiology, diagnosis, and treatment of the ruptures. On the basis of available biomechanical and clinical studies, operative fixation of these injuries is recommended in the majority of cases; however, the optimal surgical approach and fixation technique to restore the anatomic attachment of the distal biceps tendon remains a topic of debate. The ideal treatment of these injuries would involve minimal morbidity during the surgical approach and excellent strength of the fixation to the bicipital tuberosity while minimizing postoperative complications such as heterotopic ossification and nerve palsies. While treatment of these injuries continues to evolve, postoperative rehabilitation protocols have become increasingly aggressive in an effort to return patients to full preoperative function sooner. The purpose of this review is to present the current concepts on the diagnosis and treatment of injuries to the distal biceps tendon insertion on the basis of the best available studies in the literature.

Epidemiology

Rupture of the distal biceps tendon is a relatively rare injury that may have important functional consequences. The majority of these ruptures occur in the dominant extremity of male patients between the ages of thirty and sixty years. Safran and Graham performed a retrospective study of fourteen patients seen over a five-year period to help identify demographic variables, the incidence of these injuries, and the effect of smoking on these injuries in the general population[1]. The unique health-care system utilized by the patients in this study provides medical care to a known number of people in a geographic area defined by zip code and proximity to a medical center. All patients with clinically relevant injuries, such as tendon ruptures, were treated by an orthopaedic surgeon within the region in which that patient belonged so accurate demographic data could be obtained. The authors of this study projected an incidence of 1.2 distal biceps tendon ruptures per 100,000 patients per year with an average age of forty-seven years at the time of injury. The dominant extremity was involved 86% of the time, and smokers demonstrated a 7.5 times

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greater risk of injury compared with nonsmokers. Only one woman was identified in the cohort, and this was the first description in the literature of a female sustaining this injury.

Etiology

The pathogenesis of distal biceps tendon ruptures is not well understood. Current theories involve both hypovascular and mechanical mechanisms as reasons for rupture at the musculotendinous junction. Seiler et al. performed both an anatomic and a radiographic study to help elucidate these mechanisms[2]. The anatomic portion of the study included vascular injections of twenty-seven cadavers. A consistent vascular pattern was demonstrated, with a hypovascular zone measuring approximately 2.14 cm in diameter that corresponded to areas of focal degeneration seen on light microscopy (Fig. 1). Thus, one proposed theory was that the lack of blood supply to the distal biceps tendon predisposed it to rupture. The radiographic portion of the study included sequential computed tomography scans of ten patients with the forearm in positions of maximal supination, neutral, and maximal pronation. With the forearm in the fully pronated position, the distance between the lateral border of the ulna and the radial tuberosity, corresponding to the space available for the tendon, was 48% less than the distance in full supination (Fig. 2). Additionally, with the forearm in pronation, the biceps tendon occupied an average of 85% of the radioulnar space at the level of the tuberosity; thus, mechanical impingement of the tendon was proposed as a second theory to explain rupture of the distal biceps tendon. While the definitive cause of tears has yet to be delineated, these two theories continue to be cited most frequently in the literature as the cause of rupture.

Anatomy

The biceps tendon is composed of two heads and, 61% of the time, is innervated by a single branch of the musculocutaneous nerve at a point that is an average of 134 mm below the acromion[3]. A second branch of the musculocutaneous nerve may be present and innervates the biceps approximately 24 mm distal to this point. The long head of the biceps tendon originates from the supraglenoid tubercle, while the short head originates from the coracoid process and merges with the long head at the level of the deltoid tuberosity. Distally, the tendon unit inserts onto the bicipital tuberosity on the proximal portion of the radius. An associated structure, the lacertus fibrosus (bicipital aponeurosis), originates from the distal tendon as it passes anterior to the elbow joint and expands ulnarly, blending with the fascia of the forearm (Fig. 3).

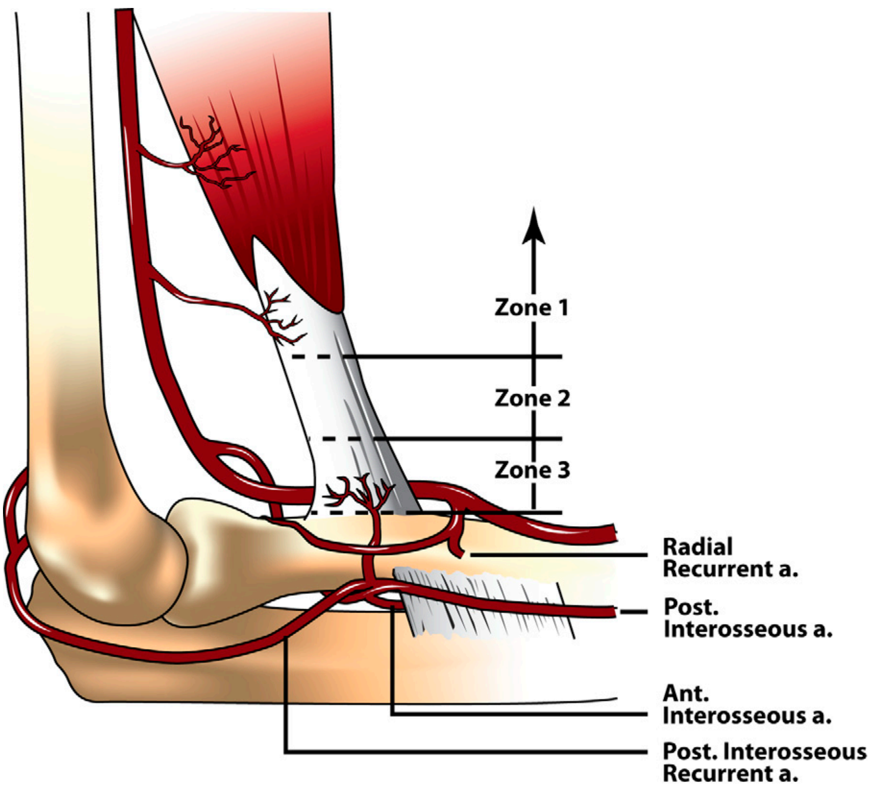

Fig. 1

Drawing demonstrating the three zones of vascularity at the distal biceps tendon insertion. Zone 2 is the hypovascular area of the tendon. (Modified from: 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. Reprinted with permission from Elsevier. J Shoulder Elbow Surg. 1995;4:149-56.)

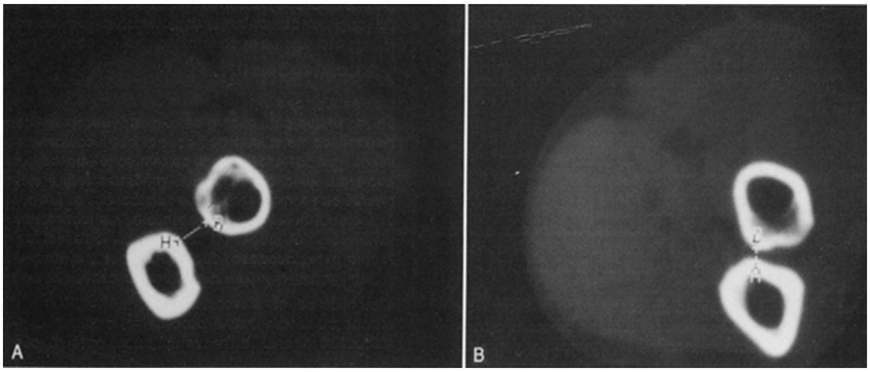

Fig. 2

Computed tomography scan demonstrating the decrease in radioulnar space at the level of the radial tuberosity as the forearm goes from full supination (A) to pronation (B). (Reprinted, with permission from Elsevier, from: 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;4:149-56.)

Recently, there has been an increased emphasis on the anatomy and function of the distal biceps tendon and the lacertus fibrosus, seemingly spurred on by a case report by Sassmannshausen et al.[4]. This report described rupture and subsequent repair of the medial head of a bifurcated distal biceps tendon, which had two completely unfused, distinct tendon units and musculotendinous junctions. In a study of seventy-four cadaver elbows, Kulshreshtha et al. not only described the dimensions of the tendon and its insertion but also noted that the tendon fibers themselves rotated in the coronal plane in a predictable pattern—namely, clockwise in left elbows and counterclockwise in right elbows[5]. Additionally, the

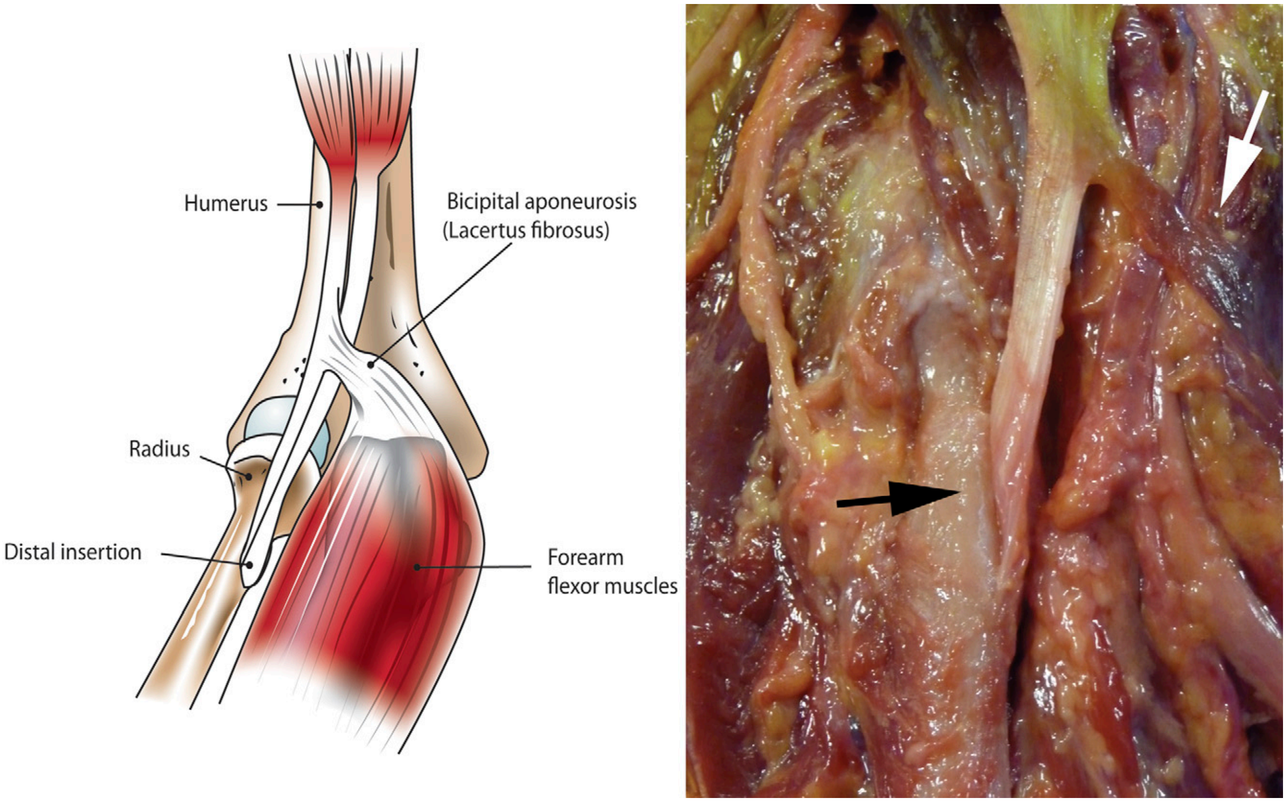

Fig. 3

Schematic of distal biceps anatomy (left) and a cadaver dissection (right) showing the same structures. The black arrow indicates the insertion of the distal biceps tendon while the white arrow indicates the bicipital aponeurosis (lacertus fibrosus).

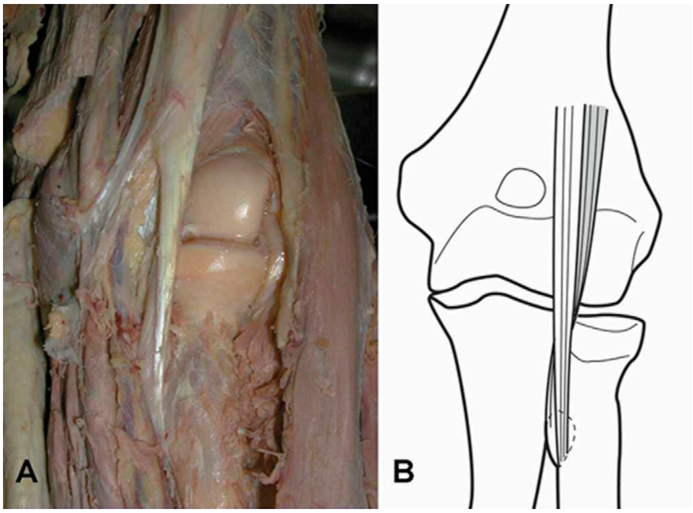

Fig. 4

Photograph (A) and diagram (B) demonstrating the rotation of biceps tendon fibers at the tendon's attachment in a left elbow. (Reprinted, with permission, from: Kulshreshtha R, Singh R, Sinha J, Hall S. Anatomy of the distal biceps brachii tendon and its clinical relevance. Clin Orthop Relat Res. 2007; 456:117-20.)

anteromedial fibers followed a linear path to their attachment, while the posterolateral fibers coiled beneath the medial fibers to their attachment on the tuberosity (Fig. 4). Kulshreshtha et al. described the insertion on the posterior rim of the tuberosity as long, vertical, and semilunar. Eames et al. further described the distal tendon unit as having two distinct parts (one each from the long and short heads of the muscle) in ten of seventeen cadaver specimens, with interdigitation of the two parts occurring in the remaining seven specimens[6]. The distal portion of the short-head contribution of the tendon inserted more distally on the tuberosity, where biomechanically it acts as a powerful flexor of the elbow. The distal portion of the long-head contribution inserted farther from the central axis of the forearm, thereby providing more powerful supination. The lacertus fibrosus was found to originate at the level of the musculotendinous junction and consisted of three distinct layers, enveloping the forearm flexor muscles and serving as a stabilizer to the distal tendon. As the forearm flexors contract, they tense the lacertus, subsequently causing a medial pull on the biceps tendon and perhaps contributing to its rupture. More recently, Athwal et al.[7], Mazzocca et al.[8], and Hutchinson et al.[9] also focused on describing the dimensions of the insertion and the angular orientation of the tuberosity. This is important in that the surgeon should attempt to recreate the native anatomy when performing a repair.

Clinical Evaluation

Patients with a distal biceps tendon rupture frequently report having experienced an unexpected extension force applied to a flexed elbow. This force is followed by an eccentric contraction of the biceps with a resulting tearing sensation in the antecubital fossa. As the acute pain subsides, chronic pain lingers, and the patient may report weakness with elbow flexion and marked weakness with forearm supination. A loss of the normal biceps contour and an obvious deformity may be present. Despite this presentation, a rupture may still be missed clinically, particularly when the lacertus fibrosus remains intact. A delay in diagnosis may preclude primary repair or lead to chronic weakness. Two recent studies have focused on facilitating early diagnosis of distal biceps ruptures[10,11].

Ruland et al. developed the biceps squeeze test to help elucidate the integrity of the biceps tendon[10]. With this test, which is similar to the Thompson test[11] used to aid in the diagnosis of an Achilles tendon rupture, the biceps brachii is squeezed to elicit forearm supination if the tendon is intact. Twenty-three of twenty-four patients with a positive test had a complete rupture as confirmed surgically or with magnetic resonance imaging, and a complete rupture was confirmed in twenty-one of twenty-two of those undergoing operative intervention. After operative repair, all twenty-one patients with a complete tear had the return of forearm supination with the biceps squeeze test while those who followed a nonoperative regimen did not have the return of supination with the biceps squeeze test at a three-month follow-up evaluation.

O'Driscoll et al. later described the so-called hook test for the diagnosis of complete biceps tendon avulsions[12]. This test is performed by inserting the finger under the lateral edge of the biceps tendon between the brachialis and biceps tendons and hooking the finger under the cord-like structure spanning the antecubital fossa with the patient's elbow flexed 90° (Fig. 5). The test was performed in forty-five patients about to undergo surgical exploration of the distal biceps, and the result was abnormal in all thirty-three patients who were found to have a complete tendon avulsion during the operation and was

Fig. 5
The integrity of the biceps tendon can be detected by the hook test.

normal in all forty-five of the uninjured, contralateral arms. The 100% sensitivity and specificity were higher than the 92% sensitivity (eleven of twelve patients) and 85% specificity (eleven of thirteen patients) demonstrated by magnetic resonance imaging in a portion of the same patient cohort. The authors reiterated that a crucial portion of the test is to hook the lateral edge of the biceps tendon, not the medial edge, as the examiner could mistake the lacertus fibrosus for an intact biceps tendon. Radiographs of the elbow occasionally show some enlargement and irregular changes about the radial tuberosity or an avulsion of the radial tuberosity itself. Magnetic resonance imaging can be useful to delineate the integrity and possible intrasubstance degeneration of the biceps tendon (Fig. 6). In 2004, Giuffrè and Moss described the flexed abducted supinated (FABS) position for magnetic resonance imaging of the distal biceps tendon[13]. This position includes 90° of elbow flexion, 180° of shoulder abduction, and forearm supination. Twenty-two elbows were imaged in this position and evaluated separately by two musculoskeletal radiologists. In all cases, the full length of the biceps from the musculotendinous junction to the radial tuberosity insertion was shown in one or two sections.

Treatment

Nonoperative Versus Operative Repair

As early as 1941, Dobbie described fifty-one new cases of distal biceps tendon rupture and twenty-four previous cases of rupture, all treated nonoperatively, and noted that it is "impractical and unwise to select a procedure more difficult, dangerous and time consuming when the same result can be obtained with less effort and without risk of serious complications."[14] In 1985, Baker and Bierwagen[15] (in a study of thirteen patients) and Morrey et al.[16] (in a series of ten patients) demonstrated better supination strength as well as flexion strength and endurance after operative intervention. These results corresponded to the biceps tendon's primary role as a supinator as well as its role as a secondary elbow flexor. More recently, a study by Chillemi et al. showed superior results for all items on the European Society for Surgery of the Shoulder and Elbow Score in a group of five patients treated operatively as compared with their nonoperatively treated counterparts (four patients)[17]. Hetsroni et al. examined a cohort of twenty-two patients with a distal biceps tendon rupture and found better subjective functional outcomes and objective (isokinetic testing) outcomes in patients who had been treated operatively[18].

In a recent retrospective study, Freeman et al. evaluated eighteen patients with an unrepaired distal biceps tendon rupture at a mean of fifty-nine months after injury and compared them with historical controls who had been treated operatively[19]. The mean supination and flexion strengths in the patients with an unrepaired rupture were 74% and 88%, respectively, compared with the strengths of the contralateral arm. The results, particularly supination strength, in the patients who had injured the nondominant arm were superior to those in the patients who had injured the dominant arm (mean supination strength, 83% compared with 60%). Only one patient had a persistent loss of motion, and all patients returned to work at their previous level of function at an average of twelve weeks. Compared with the operatively treated historical cohort, the patients with an unrepaired rupture had a significant difference in supination strength (74% compared with 101%) but not in flexion strength (88% compared with 97%). This effect was most pronounced when the dominant arm was injured and treated nonoperatively. The authors did note that the mean Disabilities of the Arm, Shoulder and Hand (DASH) score for the patients who had not undergone a repair was

Fig. 6
Magnetic resonance image (3-tesla) of a complete distal biceps rupture (arrow). (Courtesy of Dr. Charles Ho, Vail, Colorado.)

lower (indicating less disability) than the score for those who had been treated operatively for the distal tendon biceps rupture; however, the mean DASH scores for the operatively treated cohort varied substantially (range, 10 to 50 points). The authors concluded that satisfactory outcomes can be achieved with nonoperative management of distal biceps tendon ruptures with the benefit of avoiding operative complications.

Nonoperative treatment is now generally reserved for sedentary patients who do not require elbow flexion and supination strength and endurance or for patients who are not medically fit for operative treatment. Nonoperative treatment consists of temporary immobilization, pain control, and physiotherapy. There is a possibility that some chronic activity-related arm pain may persist after nonoperative treatment; however, satisfactory results can still be obtained.

Anatomic Versus Nonanatomic Repair

Once operative intervention became popular for distal biceps tendon injuries, there was discussion about anatomic repair to the radial tuberosity versus nonanatomic reattachment to the brachialis muscle. Meherin and Kilgore discussed the results of a study of nineteen patients in which they had compared nonoperative treatment (nine patients) with anatomic (six patients) and nonanatomic (four patients) operative treatment[20]. While these authors described a higher rate of disability in those treated nonoperatively, they noted a similarity between the results in the patients in whom the tendon had been attached to the radial tuberosity and the results in those with tendon attachment to the brachialis muscle.

Rantanen and Orava reported the results of nineteen patients who had undergone anatomic repair of a distal biceps tendon rupture; ten ruptures were chronic and nine were acute[21]. Eighteen of the nineteen patients had a good or excellent result. The same authors also performed a review of 147 cases reported in the literature; they noted a 90% rate of good or excellent results at an average of three years after anatomic reattachment and a 60% rate of good or excellent results at an average of three years following nonanatomic reattachment. The rate of good or excellent results dropped to 14% with nonoperative treatment.

More recently, Klonz et al. used isokinetic muscle testing to compare the functional results of anatomic and nonanatomic fixation in a study of fourteen patients[22]. Six patients in whom anatomic reattachment had been performed with suture anchors had a return of 96% of flexion strength and 91% of supination strength compared with the values on the contralateral side. Eight patients with nonanatomic reattachment to the brachialis muscle also had a return of 96% of flexion strength compared with that on the contralateral side, but four of the patients did not recover supination strength, which ranged from 42% to 56% of that on the contralateral side. The authors reported no major complications (such as radioulnar synostosis or nerve damage) but did note four cases of asymptomatic heterotopic ossification after anatomic repair.

Taylor et al. described a method of fixation that combines both anatomic and nonanatomic fixation[23]. In a series of fourteen patients, these authors utilized anatomic fixation with suture anchors augmented with a so-called de-tensioning suture to the brachialis muscle. This suture is thought to help restore anatomic alignment and the isometric pull of the distal biceps tendon. All fourteen patients had full recovery of strength and range of motion.

Two-Incision Versus One-Incision Repair

Since as early as 1961, there has been controversy about the use of a one-incision versus a two-incision technique[24]. Complications accompany both approaches and involve a spectrum of nerve injuries ranging from paresthesias to palsies to complex regional pain syndrome as well as morbidities such as heterotopic ossification, radioulnar synostosis, loss of forearm rotation, and wound infection.

Boyd and Anderson[24] developed their two-incision technique in response to the high rate of nerve injuries noted with the one-incision techniques that had been described by Dobbie[14] and by Meherin and Kilgore[20]. Boyd and Anderson noted that the two-incision technique allowed both a lower rate of nerve injury and a more anatomic reattachment of the distal biceps tendon. This technique does involve some stripping of the interosseous membrane and reattachment of the tendon with the use of bone tunnels for secure fixation. After reporting on a series of four cases treated for symptomatic radioulnar synostosis, and in an effort to decrease symptomatic heterotopic ossification, Failla et al. described a modification of the classic Boyd and Anderson approach[25]. Their technique involves a limited muscle-splitting approach between the common extensor muscle mass and the supinator without exposure of the proximal ulnar periosteum.

Several series have shown promising results with the two-incision technique. Baker and Bierwagen used Cybex testing to evaluate ten patients who had undergone treatment of a distal biceps rupture with use of a two-incision technique and three patients who had undergone conservative treatment of such a rupture[15]. Fifteen months to six years postinjury, all ten patients who had undergone the two-incision operative intervention had a return of full elbow flexion and forearm supination strength and endurance, and no unsatisfactory results were reported. D'Alessandro et al. reported on ten athletes who had undergone anatomic reattachment of the distal biceps tendon through a two-incision technique and were followed for an average of fifty months[26]. Subjective results on a 10-point scale were documented, and isokinetic muscle testing was also performed. All ten athletes returned to full, unrestricted activity and had a mean subjective rating of 9.75 points on the 10-point scale. Isokinetic testing demonstrated full forearm supination strength and full elbow flexion strength but 20% less endurance when the dominant extremity had been injured. When the nondominant extremity had been injured and subsequently repaired, flexion strength and endurance were normal but supination strength was decreased by 25%. Comparable results, particularly in the nondominant extremity, were reported by Leighton et al. in a series of eight patients[27]. Davison et al. used similar methods and found decreased supination strength in five of eight patients treated with the two-incision technique; six of the eight patients had a good or excellent satisfaction score[28]. These results were corroborated by Moosmayer et al.[29].

To our knowledge, Karunakar et al. reported on the largest series of distal biceps ruptures (twenty-one ruptures in twenty patients) treated with the two-incision technique, with an average duration of follow-up of forty-four months[30]. All patient outcomes were assessed with the DASH outcome questionnaire, isokinetic testing, and patient subjective scores[31]. The range of motion of the forearm was decreased in four of the twenty-one cases, and elbow flexion was decreased in one. Supination strength was decreased in ten of the cases, and flexion strength was decreased in three. Particularly noteworthy was the fact that seven of twenty patients sustained complications; heterotopic ossification occurred in three of these patients and resulted in a radioulnar synostosis in one of the three. All twenty patients had an excellent or good outcome subjectively despite the decreased strength and endurance, and the high complication rate.

While the success of the two-incision technique is well documented, there are also reports of complications. Katzman et al. described a delayed posterior interosseous nerve palsy that occurred four months after the repair and required a surgical release[32]. Lin and Leslie noted a case of postoperative median nerve entrapment[33]. Kelly et al. reported a complication rate of 31% following seventy-four consecutive repairs performed with the modified two-incision technique over a seventeen-year period[34]. Six patients had persistent anterior elbow pain, five had sensory nerve paresthesias (three involving the lateral antebrachial cutaneous nerve and two involving the posterior interosseous nerve), four had heterotopic ossification, three had restricted forearm rotation, and three had a superficial wound infection. Other complications included a transient posterior interosseous nerve palsy, one rerupture of the tendon, and one case of complex regional pain syndrome. The complication rate was higher when the injury was chronic (41%) than when it was acute (24%). Chavan et al. performed a systematic review of the literature on two-incision distal biceps tendon repairs and noted an overall complication rate of 16% (twenty-three of 142), with the majority of the complications being a loss of forearm rotation or rotational strength[35]. Of note, the authors arbitrarily determined that heterotopic ossification was not considered a complication unless it was associated with pain or loss of >30° of motion in any plane.

Lintner and Fischer reported on the results of five patients with a distal biceps rupture treated surgically with a single anterior incision and fixation with suture anchors[36]. At a mean of 2.5 years postoperatively, all patients had a symmetric range of motion when compared with that of the contralateral extremity, and none had evidence of nerve damage or heterotopic ossification. Additionally, all had returned to their preinjury activity level at five months after treatment. All five of the patients had excellent objective and subjective outcome scores. Sotereanos et al. reported on sixteen patients with a biceps tendon rupture treated through a single anterior incision with suture anchor fixation; eight of the ruptures were acute (occurred less than six weeks before treatment), and eight were chronic (occurred more than six weeks before treatment)[37]. The authors noted that all eight patients treated acutely regained full elbow and forearm strength and power. The eight patients with a chronic condition had on average a slight decrease in flexion power (14%) and supination strength (16%). There were no cases of radioulnar synostosis, posterior interosseous nerve palsy, or failed repair. Balabaud et al. performed a prospective study involving eight patients with a total of nine distal biceps ruptures who had undergone operative intervention through a single anterior incision; the tendon was secured to bone with suture anchors in seven and with transosseous tunnels in two[38]. All nine patients regained a full range of motion of the elbow and forearm and were satisfied with their clinical result. Isokinetic testing demonstrated only a 6% decrease in elbow flexion strength and no decrease in supination strength. The authors noted no cases of radioulnar synostosis and no nerve palsies.

McKee et al. reported the results of fifty-three patients who had been treated with suture anchor tendon fixation through a single anterior incision by one surgeon over the course of an eight-year period; the average duration of follow-up was twenty-nine months[39]. None of the patients lost more than 5° in the flexion-extension or pronation-supination arc. The average DASH score was 8.2 points, which was not substantially different from the average score of 6.2 points in a previously reported series of healthy controls[31]. The DASH scores of the operatively treated cohort were better when patients with a Workers' Compensation claim were excluded. The authors noted four complications: two transient paresthesias of the lateral antebrachial cutaneous nerve, one transient posterior interosseous nerve palsy, and one wound infection. John et al. also reported on fifty-three patients treated with a single anterior incision and suture anchor fixation; the duration of follow-up was thirty-eight months[40]. Forty-six patients obtained an excellent result, and seven had a good result. No patient had a fair or poor result. Three complications, including a mild loss of rotation due to heterotopic ossification in two patients and a transient radial nerve palsy that resolved at eight weeks in one, were noted. More recently, Khan et al. performed a retrospective study of seventeen patients with a total of eighteen distal biceps ruptures who had undergone fixation with suture anchors through a single anterior incision[41]. At an average of forty-five months postoperatively, there was an average loss of 5.3° of extension and 6.2° of flexion along with a loss of 11.0° of pronation and 6.4° of supination. Flexion-in-supination strength, as determined with dynamometer testing, was 82.1% of that on the uninjured side, and the mean DASH score was 14.45 points. At six months postoperatively, sixteen of the seventeen patients had returned to their preinjury level of activity. The authors reported two complications: one transient radial nerve palsy and one case of heterotopic ossification.

To our knowledge, Bain et al. were the first to report the clinical results of a single-incision technique with cortical button fixation for the repair of distal biceps tendon ruptures[42].

The authors described a series of twelve patients followed for an average of seventeen months. The mean flexion-extension arc was from 5° to 146°, with supination averaging 81° and pronation averaging 80°. All patients had a return of full strength, and there were no instances of radioulnar synostosis or neurological injuries. All patients were satisfied with their outcome and were able to return to their normal daily activities. A second part of this study included five cadaver dissections that were performed to measure the distance from the distal biceps tendon insertion site to various structures about the elbow. A Steinmann pin was also advanced at various angles to simulate the drilling of a tunnel in the bicipital tuberosity. On the average, the distal biceps tendon insertion was 6 mm from the ulnar artery, 12 mm from the median nerve, and 18 mm from the posterior interosseous nerve. When the authors advanced the Steinmann pin at a 0° angle (directly posteriorly), the average distance to the posterior interosseous nerve was 14 mm. When the Steinmann pin was advanced at a 45° posterolaterally directed angle, the average distance to the posterior interosseous nerve was only 8 mm. Thus, the authors cautioned against drilling laterally or distally when creating the tunnel in the bicipital tuberosity for cortical button fixation.

Greenberg et al. also reported encouraging results, in fourteen patients followed with both a physical examination and dynamometer testing at an average of twenty months after tendon repair with cortical button fixation[43]. The mean amount of supination was 74°, which was equal to that on the contralateral side, and pronation averaged 73°, which was 98% of that on the contralateral side. The total flexion-extension arc was found to be 97% of that on the contralateral side, with a return of 97% of flexion strength and 82% of supination strength. There were no cases of radioulnar synostosis or of symptomatic heterotopic ossification. The authors did note three cases of transient lateral antebrachial cutaneous nerve symptoms, which resolved, but no instances of posterior interosseous nerve injury. A separate wing of this study included cadaver dissections, which showed an average distance of 9.3 mm from the cortical button to the posterior interosseous nerve and a consistent layer of supinator muscle interposed between the button and the nerve in all cadavers.

Most recently, Peeters et al. reported on twenty-three patients who had undergone repair with use of the cortical button fixation technique and were followed for a mean of sixteen months[44]. Flexion strength was 80% and supination strength was 91% of that of the contralateral extremity, and there was an average extension deficit of 2°. The average Mayo Elbow Performance Score was 94 points, with all patients having an excellent or good result, and the mean subjective satisfaction score was 9 of 10 (0 = no satisfaction, and 10 = complete satisfaction)[45]. There were no neurological complications, and two patients developed asymptomatic heterotopic ossification, which did not affect forearm rotation. Of note, three patients had incorrect positioning of the cortical button seen on radiographs. One of these buttons was lying in the subcutaneous fat on the posterior aspect of the forearm, necessitating subsequent removal, which was uneventful.

Heinzelmann et al. reported on a case series of thirty-one patients (thirty-two elbows) who had undergone a single-incision repair with use of a hybrid fixation method that included both cortical button fixation and interference screw fixation; the mean duration of follow-up was twenty-four months[46]. The authors suggested that the dual fixation allowed an earlier, more aggressive rehabilitation protocol. Additionally, they noted that placing the interference screw on the radial border of the tendon in effect provided fixation of the tendon more ulnarly and therefore more anatomically. Additionally, the ulnarward position of the tendon theoretically provided a biomechanical advantage when supination was performed. The authors reported excellent average postoperative scores and an average time to resumption of normal activities of 6.5 weeks. They did note one case of symptomatic heterotopic ossification causing a decreased arc of forearm rotation. Additionally, there were two superficial radial nerve palsies, which completely resolved by the time of final follow-up.

There are very few studies directly comparing single-incision with two-incision techniques. El-Hawary et al. conducted a prospective study comparing nine patients who had undergone single-incision suture anchor fixation with ten patients who had undergone a modified Boyd and Anderson two-incision technique[47]. At one year, the one-incision group had regained 11.7 more degrees of elbow flexion than the two-incision group (142.8° versus 131.1°); however, there was no difference in supination strength or motion or in flexion strength. The authors did note that flexion strength returned more rapidly in the two-incision group. Four of the nine patients in the one-incision group had a complication, with three cases of lateral antebrachial cutaneous nerve paresthesias and one case of symptomatic heterotopic ossification causing a flexion contracture. In the two-incision group, one of the ten patients had a complication—a transient superficial radial nerve palsy.

In a meta-analysis of one-incision distal biceps tendon repairs, Chavan et al. reported an overall complication rate of 18% (twenty-nine of 165 elbows), with the most common complication being nerve injury (occurring in 13%)[35]. The authors conducted an analysis of clinical outcomes of two-incision and one-incision techniques using inclusion criteria consisting of an acute repair (defined as within six weeks after injury) and at least one year of follow-up with the examination including objective strength and motion testing. Outcomes were defined as satisfactory if there was less than a 30° loss of motion in any plane and recovery of greater than 80% of the strength of the contralateral extremity. Unsatisfactory outcomes were defined as a loss of motion of greater than 30° in any plane, less than 80% recovery of strength, or persistence of a major complication. The authors reported a 69% satisfactory outcome rate (sixty of eighty-seven elbows) with the two-incision technique and a 94% satisfactory outcome rate (135 of 143 elbows) with the one-incision technique. This corresponded to an odds ratio of an unsatisfactory outcome after a two-incision approach of 7.6. The majority of the unsatisfactory outcomes were due to loss of forearm rotation or strength.

Methods of Operative Fixation

While controversy continues to surround the optimal surgical approach for fixing distal biceps tendon ruptures, there is also debate regarding the ideal fixation method. Bone tunnels were used in the classic Boyd and Anderson technique. As the single-incision approach has gained popularity with the use of suture anchors, interference screws, and cortical fixation buttons, a number of biomechanical studies have been performed in attempts to clarify the "optimal" type of fixation.

Berlet et al. compared the fixation strengths of suture anchors and transosseous tunnels in cadaver forearms[48]. No specimen failed during cyclic testing to 50 N for 3600 cycles; however, the mean load to failure for transosseous sutures (307 ± 142 N) was significantly higher than that for two types of suture anchors (220 ± 54 N and 187 ± 64 N). There was no significant difference in the failure load or mechanism of failure between the two types of suture anchors. Pereira et al. also compared bone-tunnel repair with suture-anchor repair and found that the bone-tunnel repair was significantly stiffer and had greater tensile strength than the suture-anchor repair[49]. Lemos et al. utilized two suture anchors in their in vitro repair and compared that type of fixation with transosseous tunnels in nine matched cadaver specimens[50]. They showed the yield strength of suture anchor fixation (263 N) to be superior to that of transosseous fixation (203 N), suggesting that suture anchor fixation could provide repair strength that was equal, if not superior, to that achieved with bone tunnels. Idler et al. evaluated the biomechanical strengths of intact tendons, tendons fixed with transosseous tunnels, and those treated with interference screws in nine cadaver specimens[51]. They found no significant difference in strength or stiffness between the intact tendons and the interference screw fixation. The mean failure strength and stiffness of the transosseous fixation were significantly lower than those of the intact tendons and interference screw fixation.

In a biomechanical study, Greenberg et al. evaluated the pullout strengths of suture anchors, sutures in transosseous tunnels, and cortical fixation buttons[43]. The pullout strength of the cortical fixation buttons was three times greater than that of the sutures in the bone tunnels (584 N versus 177 N, $p = 0.0001$) and two times greater than that of the suture anchors ($p = 0.0007$), thus providing compelling evidence for the use of cortical fixation buttons. Superior fixation of the cortical fixation button construct, as compared with that of suture anchors, sutures in bone tunnels, and interference screws, was confirmed in studies by Kettler et al.[52] and Mazzocca et al.[53]. The meta-analysis performed by Chavan et al. also demonstrated that, of currently available techniques, fixation with cortical buttons provides the highest load and stiffness[35].

Postoperative Rehabilitation

There has been a wide variation in postoperative protocols as improved fixation methods have allowed an earlier range motion and increasingly aggressive rehabilitation. Our current protocol calls for the arm to be immobilized in flexion with the forearm in neutral rotation for a period ranging from one week to six weeks. Passive and active-assisted range-of-motion exercises are gradually initiated and progressed with the goal of achieving full extension by six weeks postoperatively. Motion and strengthening are increased in intensity after the six-week postoperative mark.

Cheung et al. reported on their postoperative protocol following two-incision transosseous suture fixation in thirteen patients[54]. All patients were treated with a hinged elbow brace and allowed a self-directed passive range of motion from 60° of extension to full flexion along with full forearm rotation on the first postoperative day. The patients were allowed 20° of increased extension every two weeks until week six, when a full range of motion was regained. Strengthening began at eight weeks. After an average duration of follow-up of thirty-eight weeks, the patients had, on the average, no loss of extension, a 5.8° loss of flexion, a 3.5° loss of supination, and an 8.1° loss of pronation compared with the values on the contralateral side; flexion strength was 91.4% of that on the contralateral side, and supination strength was 89.4% of that on the contralateral side.

As discussed previously, Heinzelmann et al. used dual fixation with a cortical fixation button and an interference screw for distal biceps repair, in part to allow a more aggressive postoperative protocol[46]. Their protocol involved removing the postoperative splint at three to five days and applying a compressive sleeve to allow home therapy, including gentle active pronation, supination, flexion, and extension, at one week. Strengthening began with 1-lb (0.45-kg) weights at one week postoperatively with a return to activities of daily living by two to three weeks with active motion as tolerated. No excessive elbow resistance was allowed until two to three months postoperatively. Most patients returned to normal activity by four weeks postoperatively.

Overview

Patients with a distal biceps tendon injury typically experience a tearing sensation and an acute onset of pain after an unexpected or massive extension force has been applied to the flexed elbow. Typically, there is pain and deformity with weakness of supination. Patients with a complete rupture will have a positive hook test. Magnetic resonance imaging can also be helpful to delineate the integrity, and evaluate the quality, of the remaining tendon in patients with a partial tear or severe tendinopathy.

There are differences in the outcome and complication profiles between the modified two-incision and single-incision techniques, so the choice of surgical technique should be guided by the surgeon's comfort and training. With respect to complications, there is a higher prevalence of nerve injuries after single-incision techniques and a higher prevalence of heterotopic ossification after two-incision techniques.

Currently, there is no definitive evidence to support one method of fixation over another, although in the laboratory the hybrid method involving use of a cortical button and an interference screw has seemed to optimize restoration of anatomy and provide the most secure fixation. Clinically, no difference has been demonstrated with respect to rerupture rates or implant failures, but biomechanically stronger fixation constructs such as cortical button fixation or a combination of cortical button fixation and interference screw fixation may allow a more aggressive rehabilitation protocol. Initial clinical results are promising, but there is a need for larger comparative studies in the future. ■

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