Repair of the Ruptured Distal Biceps Tendon

A Systematic Review

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Background: Reinsertion of the acutely ruptured distal biceps is the preferred method of treatment for most patients and is designed to restore flexion and supination strength. It is not clear which, if any, method of fixation is superior or whether a 2-incision or single-incision approach is associated with fewer complications or better outcomes.

Hypotheses: (1) There is no difference in biomechanical performance between currently used fixation methods, (2) there is no difference in incidence of complications between the 2-incision and single-incision approach, and (3) there is no difference in clinical outcomes between the 2-incision and single-incision approach.

Study Design: Systematic review; Level of evidence, 4.

Methods: The authors performed a systematic review of the literature studying treatment of the ruptured distal biceps tendon to determine optimal fixation method as well as surgical approach with lowest incidence of complications and highest proportion of satisfactory results.

Results: The review identified 8 articles that had relevant biomechanical data, 23 with relevant complication data, and 19 with relevant clinical results data. EndoButton fixation performed best in comparative biomechanical studies. There was no difference in overall incidence of complications between 2-incision approaches (16%) and single-incision approaches (18%), but there were significantly more instances of significant loss of forearm rotation with the 2-incision approach. There were significantly more unsatisfactory clinical results in the 2-incision repair group (31% vs 6%; odds ratio, 7.6; 95% confidence interval, 3.2-17.7), with the majority of unsatisfactory results in the 2-incision group due to loss of forearm rotation or rotational strength.

Conclusion: EndoButton fixation has the highest load and stiffness of currently available fixation methods. Two-incision repairs have a significantly greater proportion of unsatisfactory results than do single-incision repairs.

Keywords: distal biceps; systematic review; tendon; biceps; rupture

Anatomical reinsertion of the ruptured distal biceps tendon has become the preferred treatment for patients wishing to achieve full return of strength after distal biceps rupture. The original technique of repair as reported by Boyd and Anderson[8] required 2 large incisions and was complicated by instances of loss of motion and significant heterotopic ossification and/or radioulnar synostosis. Later modifications of the 2-incision approach were designed to reduce the incidence of these complications. The introduction of suture anchors,[26] various types of metallic buttons including the EndoButton[1] (Smith & Nephew, Inc, Largo, Fla) and its derivatives, and interference screws[15] all allowed repair of the distal biceps through a single anterior incision but also seemed to carry an increased risk of injury to the superficial radial nerve and/or lateral antebrachial cutaneous nerve. As a result of the introduction of newer fixation methods and the option for a single-incision anterior approach, the surgeon treating the ruptured distal biceps tendon now must choose from a variety of fixation methods and must decide whether to use a modified 2-incision approach or a single anterior approach. The decision regarding method of fixation should ideally be made first using data available from biomechanical testing, followed by confirmation in clinical studies. The optimal fixation method would be simple surgically and be strong enough to allow immediate motion of the repaired elbow both in flexion/extension and in pronation/supination. The preferred surgical

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approach would be simple and have a low incidence of complications. The combination of optimal fixation and surgical approach would result in a repair that allowed immediate motion, had minimal risk of surgical complications, and reliably resulted in satisfactory clinical outcomes.

The purpose of this study is to systematically review the literature on distal biceps tendon repair to (1) identify the optimal method(s) of tendon fixation as evidenced in the biomechanical literature, (2) determine which surgical approach is associated with the lowest incidence of complications, and (3) determine which method of repair is associated with the highest proportion of satisfactory clinical outcomes. Our hypotheses are as follows: (1) There will be no difference in ultimate tensile load or stiffness in single load testing to failure between various methods of fixation, and there will be no difference in displacement during cyclic testing or ultimate tensile load after cyclic testing between various methods of fixation; (2) there will be no difference in incidence of complications between the 2-incision and single-incision approach; and (3) there will be no difference in clinical outcomes between the 2-incision and single-incision approach.

METHODS

We searched Medline and PubMed databases and used the evidence-based medical reviews Cochrane Database of Systematic Reviews, American College of Physicians Journal Club, Database of Abstracts of Reviews of Effects, and Cochrane Central Register of Controlled Trials to find relevant articles on distal biceps tendon repair. We used the keywords *distal biceps* alone or with *rupture*, *repair*, *injury*, *biomechanics*, or *complications*, as well as *elbow* and *biomechanics*, *kinematics*, or *injuries*, to identify all articles on the subject. We also reviewed the references of included articles for articles not identified by our literature search. We reviewed the abstract of every article to determine the methods of the study and included all articles investigating biomechanical testing of fixation methods for distal biceps tendon repair as well as any articles reporting the results or complications of surgical treatment by anatomical reinsertion. We included in our review all articles reporting the results of acute (within 6 weeks of injury) anatomical reinsertion of the tendon but excluded patients having tenodesis of the biceps to the brachialis and late reconstruction with any type of graft material, as well as those series comparing results of different treatment methods that did not allow extraction of the patient data for analysis. We also excluded articles exclusively reporting nonoperative management. Specific inclusion criteria for clinical studies were those reporting complete ruptures treated surgically with at least 1-year follow-up and objective strength and motion testing. We divided outcomes into satisfactory and unsatisfactory as follows. A satisfactory outcome resulted in less than 30° motion loss in any direction (flexion, extension, pronation, or supination) and return of strength to within 80% of the contralateral extremity. An unsatisfactory outcome resulted in 30° or more of motion loss in any direction, less than 80% strength return, or persistence of a major complication (such as nerve injury) at the time of final follow-up. Studies also needed to specifically mention whether any complications occurred. Studies included in the calculation of complication incidence needed to meet the same criteria, with the exception that we included studies with less than 1 year of follow-up. Heterotopic ossification was not considered a complication unless it was noted to be associated with pain or cause a loss of greater than 30° of motion in any plane. All inclusion and exclusion criteria as well as our definitions of complications were defined before performing the literature review. Each clinical study was given a level of evidence by consensus agreement of the investigators.[31] Incidence of complications was compared using either χ^2 with Yates correction or the Fisher exact test as appropriate. One and 2-incision repairs were compared for proportion of successful results by Pearson's χ^2 analysis. Odds ratios and associated 95% confidence intervals were calculated for these comparisons. Differences for which the 95% confidence interval did not include 1 were considered statistically significant. A probability value of less than .05 was considered statistically significant in all tests performed. All statistical analyses were performed with SPSS software (version 15.0, SPSS Inc, Chicago, Ill).

RESULTS

Literature Search

Our search resulted in the identification of 950 articles, of which 104 were considered eligible after abstract review. Seventy-one articles were clinical, 11 were biomechanical, and 22 were found to be review articles, anatomical studies, radiographic studies, or technical reports without clinical or biomechanical data. Nineteen clinical articles included patients who met our inclusion criteria and had extractable data for outcomes (8 for 2-incision repair, 10 for single-incision repair, and 1 that included both methods), and 23 met inclusion criteria for the complications portion of the study (10 for 2-incision repairs, 12 for single-incision repairs, and 1 that included both methods). Two other articles, both reporting complications of the 2-incision repair, were designed specifically to review the complications of the 2-incision technique and thus are discussed separately from the other data because of their specific focus on complications. All clinical and review articles were assigned a level IV evidence by both reviewers. Eight articles had what we thought were relevant biomechanical data.

Biomechanical Testing

Loading of the intact distal biceps tendon to failure has resulted in an ultimate tensile load of 210 to 221 N[15,33] and a stiffness of 30 N/mm.[15] Biomechanical studies testing various methods of repair were divided into those performing single load-to-failure testing and those performing cyclic testing and are summarized in Table 1.

Several conclusions can be drawn from the results of biomechanical testing. First, in comparative studies using single load-to-failure testing, EndoButton fixation has higher failure loads than do repairs using the transosseous technique,[20] 1-suture anchor repairs are less stiff and have

TABLE 1
Summary of Biomechanical Studies of Distal Biceps Fixation

	Single Load to Failure Testing		After Cyclic Testing	
Fixation Method	Ultimate Tensile Load, N	Stiffness, N/mm	Ultimate Tensile Load, N	Displacement, mm
Transosseous tunnel	125-210[15,20,25]	15.9[15]	195-310[5,7,28]	3.55[28]
Interference screw	131-192[15,20]	30.4[15]	232[28]	2.15[28]
EndoButton	259[20]		249-440[28,35]	2.58-3.42[28,35]
Suture anchors	105-263[20,25]		209-381[5,28,35]	2.06-2.38[28,35]

lower tensile strength than do transosseous repairs,[33] 2-suture anchor repairs have higher yield strength than do transosseous repairs,[25] and interference screw fixation yields constructs that are closest to the ultimate tensile load and stiffness of intact tendon.[15] Interference screw repairs tend to fail by tendon pullout or fracture of the bicipital tuberosity, whereas other repairs tend to fail by shredding of the tendon by the repair suture. Second, in comparative studies using cyclic testing followed by load-to-failure testing, EndoButton repairs were stiffer than were suture anchor repairs[35] and had greater load to failure than did suture anchors, transosseous tunnels, and interference screws.[28] Transosseous tunnels were also stiffer and had greater loads to failure than did suture anchors after cycling.[5] Finally, when different suture materials were compared in transosseous repairs, a Bunnell stitch using No. 5 Ethibond was found to survive a greater number of cyclic loads than did a Bunnell stitch using No. 5 Fiberwire (Arthrex, Inc, Naples, Fla).[7] It would therefore seem on the basis of the above studies that the preferred methods of fixation would include the EndoButton, transosseous tunnel with the suture tied over a bony bridge, or interference screw fixation in the setting of adequate bone stock. Suture anchor fixation, with the exception of 1 study,[25] has been shown to have inferior biomechanical properties when compared directly with other repair methods by multiple authors[5,28,33,35]; however, it should be noted that 2 of these studies[5,33] used only a single suture anchor during testing.

Complications

Of 71 clinical articles reviewed, 11 two-incision articles* and 13 single-incision articles† met our inclusion criteria for calculation of complications. The 11 articles reporting results of 2-incision repairs had a total of 23 complications in 142 elbows, for a total complication rate of 16%, whereas the 13 articles reporting results of single-incision repairs had a total of 29 complications in 165 elbows, for a total complication rate of 18% (P = .88). The most common complication in the 2-incision group was loss of forearm rotation in 9%, whereas nerve injury was the most common complication of the single-incision group in 13%. There were significantly more cases of loss of forearm rotation greater than 30° in the 2-incision group than in the single-incision group (13/142 [9%] vs 2/157 [1%]; P = .01). Heterotopic ossification as a cause of limited range of motion was noted in 6% of the 2-incision repairs and 3% of the single-incision repairs, but this difference was not significant (P = .45). Note, however, that only 1 study specifically addressed heterotopic bone formation after surgery by performing postoperative radiographs in all patients.[4] In this series, 13 of 20 elbows had some degree of heterotopic ossification after surgery, with 1 of the patients developing a synostosis. The type, number, and incidence of complications for each repair technique are summarized in Table 2.

*References 2, 10-14, 18, 24, 27, 30, 32.
†References 1, 3, 13, 16, 17, 21, 22, 23, 26, 29, 32, 36, 37.

Clinical Outcome: Strength and Range of Motion

Clinical outcomes according to our criteria are presented in Tables 3 and 4. There were 87 elbows taken from 9 studies reporting treatment with a 2-incision approach and 143 elbows taken from 11 studies reporting treatment with a single anterior approach that met our inclusion criteria. There were 60 (69%) satisfactory outcomes and 27 (31%) unsatisfactory outcomes with the 2-incision approach and 135 (94%) satisfactory and 8 (6%) unsatisfactory outcomes with the single-incision approach. There was a significantly higher number of unsatisfactory results in the 2-incision group (P < .01), and the odds ratio of an unsatisfactory outcome after the 2-incision approach was 7.6 (95% confidence interval, 3.2-17.7), with the major reasons for an unsatisfactory outcome in the 2-incision group being loss of forearm rotation (11 elbows, 12%) and/or loss of rotational strength (18 elbows, 19%).

DISCUSSION

The purpose of our systematic review was first to determine the optimal method for distal biceps fixation based on the biomechanical literature, second to determine if there was a difference in the incidence of complications between the 2-incision and single-incision approach, and finally to determine if there was a difference in clinical outcomes between the 2 surgical approaches. We found that repairs using the EndoButton had the best performance in comparative biomechanical studies. There was no difference in the overall incidence of complications between the 2 repair methods as reported in clinical studies; however, there was a significantly greater incidence of loss of forearm rotation in the 2-incision group. The loss of forearm rotation with the 2-incision approach is probably owing to the dissection in the interval between the radius and ulna posteriorly.

TABLE 2
Type, Number, and Incidence of Complication According to Method of Repair

	2-Incision Technique: Total No. of Elbows Treated = 142		Single-Incision Technique: Total No. of Elbows Treated = 165		
Complication	n	%	n	%	*P*
Heterotopic ossification[a]	8	6	5	3	.45
Nerve palsy[b]	10	7	20	12	.12
Loss of forearm rotation	13	9	3	2	.01
Infection	0		3	2	.25
Flexion contracture	2	1	1	1	.61
Total number of elbows with a complication	23	16	29	18	.88

[a]Resulting in motion loss as defined in "Methods."
[b]Includes both transient and permanent nerve palsies.

TABLE 3
Clinical Outcomes After Distal Biceps Repair Using the 2-Incision Approach[a]

Author	No. of Patients	Method of Fixation	Satisfactory Results	Unsatisfactory Results	Reason for Unsatisfactory Result (No. of Patients)
Baker et al[2]	10	2-incision TO	10	0	
Cheung et al[9]	11	2-incision TO	11	0	
D'Alessandro et al[10]	8	2-incision TO	6	2	Decreased supination strength (2)
Davison et al[12]	8	2-incision TO	3	5	Decreased supination with decreased supination strength (2); decreased supination strength (2); decreased supination (1)
El-Hawary et al[13]	10	2-incision TO	10	0	
Karunakar et al[18]	18	2-incision TO	10	8	Decreased supination/flexion strength, decreased flexion (2); decreased supination strength (1); decreased pronation (1); decreased supination, transient lateral cutaneous nerve pain (1); HO, decreased supination strength (1); synostosis, decreased pronation/supination (1); HO, decreased pronation (1)
Leighton et al[24]	8	2-incision TO	4	4	Synostosis with decreased pronation/supination (1); decreased flexion strength (2); decreased flexion and supination strength (1)
Lynch et al[27]	5	2-incision SA (2 anchors)	2	3	Decreased supination strength (2); decreased pronation strength (1)
Moosmayer et al[30]	9	2-incision TO	4	5	Decreased pronation, decreased flexion and supination strength (1); decreased supination/pronation, decreased flexion and supination strength (1); decreased pronation (1); decreased flexion and supination strength (1); decreased supination strength (1)
Total			68	27	Decreased pronation/supination (11); decreased flexion/extension (1); weak pronation/supination (18); weak flexion (8)

[a]HO, heterotopic ossification; SA, suture anchors; TO, transosseous suture.

Single-incision repairs had significantly better outcomes according to our criteria, with the main reasons for inferior outcomes in the 2-incision approach being loss of forearm rotation or rotational strength. The significant difference in the proportion of patients recovering strength in supination between the 2 approaches, although not previously reported, is also not surprising and is probably owing to either dissection or division of the supinator muscle during

TABLE 4
Clinical Outcomes After Distal Biceps Repair Using the Single-Incision Approach[a]

Author	No. of Patients	Method of Fixation	Satisfactory Results	Unsatisfactory Results	Reason for Unsatisfactory Result
Bain et al[1]	10	1-incision EB	9	1	Decreased extension (1)
Balabaud et al[3]	9	1 incision; 2 TO; 7 SA (2 anchors)	9	0	
El-Hawary et al[13]	9	1 incision; 2 SA	8	1	Decreased supination due to HO (1)
John et al[16]	53	1 incision; 2 SA	52	1	Decreased supination/pronation (1)
Kamath et al[17]	5	1-incision SA	5	0	
Klonz et al[21]	6	1-incision SA	2	4	Decreased supination/flexion (1); decreased supination (2); sensory nerve damage (1)
Kobayashi et al[22]	9	1-incision 2SA (2 anchors)	8	1	Persistent anterior forearm pain (1)
Le Huec et al[23]	8	1-incision 2SA	8	0	
Lintner and Fischer[26]	4	1-incision SA (2 anchors)	4	0	
McKee et al[29]	22	1-incision SA (2 anchors)	22	0	
Sotereanos et al[34]	8	1-incision SA (2 anchors)	8	0	
Total			135	8	Decreased pronation/supination (3); decreased flexion/extension (1); weak pronation/supination (3); weak flexion (1)

[a]EB, EndoButton; HO, heterotopic ossification; SA, suture anchors; TO, transosseous suture.

the dorsal approach to the bicipital tuberosity. Surgeons wishing to avoid some loss of supination strength after a 2-incision approach may need to develop methods that limit injury to the supinator muscle.

There are several limitations of our study that are addressed in the following sections.

Biomechanical. In the biomechanical part of our review, repairs using the EndoButton consistently performed better than did other repair methods, but the minimum load and stiffness necessary for a satisfactory outcome are not known. It may well be that all repair methods are strong enough to survive current postoperative rehabilitation protocols, which generally recommend a period of protection after the surgery. A goal of both biomechanical and clinical studies in the future may therefore be to determine which repair methods are able to withstand more aggressive postoperative protocols,[7] which would include early active flexion and supination. In the clinical outcomes portion of our review, the vast majority of the patients had either suture anchor or transosseous repairs, and there was no reported case of rerupture, suggesting that these repair methods are strong enough to withstand current rehabilitation protocols. The senior author knows of at least 2 cases of early rerupture after repair (1 after transosseous repair[6] and 1 after suture anchor repair [unpublished report]); however, so this complication may be underreported.

Complications. Our review of complications after the 2 surgical approaches did not show a difference in the overall incidence of complications with either approach but did show a significantly higher incidence of loss of forearm rotation with the 2-incision approach. It is likely that the true incidence of complications for both approaches is underreported in the literature because 2 articles specifically addressing the incidence of complications after the 2-incision technique found higher rates than those calculated from reported series. Kelly et al[19] reported an overall complication rate of 31% and found a trend toward more complications with a delay in repair. Bisson et al[6] reported an overall complication rate of 27%, with patients having surgery within 2 weeks of injury having a lower rate of complications (20%) than did those having surgery more than 2 weeks from injury (40%). We did not include the articles by Kelly et al and Bisson et al in our comparison of complications between the 2 approaches because we thought that the incidence of complications found in articles specifically designed to identify complications would be higher than that in clinical series, and we were unable to find any articles specifically designed to identify the complications encountered after the single-incision approach.

Clinical outcomes. Our choice of loss of greater than 30° of motion in any plane as constituting significant motion loss may be considered arbitrary, particularly in flexion. However, we did not find that changing the magnitude of what we defined as significant flexion loss changed the conclusions of our study. We also arbitrarily defined a significant loss of strength to be less than 80% strength in flexion or supination, but we thought that because 1 of the primary indications for the surgery is to regain supination and flexion strength, relatively strict strength criteria for a satisfactory outcome were justified. Exclusion of cases with less than 1-year follow-up or lack of objective strength testing may have resulted in some studies being unfairly excluded, but this was done to provide objective evidence of the success of the procedure in the short term and to provide objective evidence of healing by strength testing. All the studies reviewed in both the complications and clinical outcomes portions of the study were level 4, and only 1 article directly compared the 2 approaches,[13] which also limits the conclusions that can be drawn from our data. Finally, we were unable to use any patient-derived criteria for comparison of outcomes.

The strengths of our study are that we performed an exhaustive review of the current literature on distal biceps repair with respect to biomechanics of repairs, complications after surgery, and clinical outcomes. We used strictly defined, prospective criteria for inclusion and exclusion of patients and definition of complications, and we were able to extract patient data for 230 patients for clinical outcomes and 307 patients for complications. The size and methodology of our study allowed us to find a significant difference in outcomes between the 2 approaches not reported in the literature to date, namely the finding of a significantly larger proportion of unsatisfactory results in the 2-incision approach group.

Future biomechanical studies should concentrate on methods that would allow earlier, more aggressive rehabilitation because the methods currently used have a low reported incidence of rerupture. A large, prospective review of the complications after the single-incision approach is necessary to define the true incidence of complications with that approach and allow comparison to the studies of Kelly et al[19] and Bisson et al.[6] Future clinical studies should include the development of techniques to preserve the supinator and limit loss of forearm rotation when using the 2-incision approach and to limit nerve injury when using the single-incision approach.

In conclusion, we performed a systematic review of the biomechanical and clinical literature regarding fixation methods, complications, and surgical approaches for reinsertion of the acutely ruptured distal biceps tendon. We found that EndoButton repairs exhibited the best performance in comparative biomechanical studies. There was no difference in the overall incidence of complications between the 2 surgical approaches when calculated from reported clinical series, but 2-incision repairs had significantly more cases of limited forearm rotation. At follow-up testing more than 1 year from surgery, 2-incision repairs had a significantly greater number of unsatisfactory results according to our criteria, with the major causes of an unsatisfactory result being weak or limited forearm rotation.

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REFERENCES

1. Bain GI, Prem H, Heptinstall RJ, Verhellen R, Paix D. Repair of distal biceps tendon rupture: a new technique using the Endobutton. *J Shoulder Elbow Surg*. 2000;9(2):120-126.
2. Baker BE, Bierwagen D. Rupture of the distal tendon of the biceps brachii: operative versus non-operative treatment. *J Bone Joint Surg Am*. 1985;67(3):414-417.
3. Balabaud L, Ruiz C, Nonnenmacher J, Seynaeve P, Kehr P, Rapp E. Repair of distal biceps tendon ruptures using a suture anchor and an anterior approach. *J Hand Surg Br*. 2004;29(2):178-182.
4. Bell RH, Wiley WB, Noble JS, Kuczynski DJ. Repair of distal biceps brachii tendon ruptures. *J Shoulder Elbow Surg*. 2000;9(3):223-226.
5. Berlet GC, Johnson JA, Milne AD, Patterson SD, King GJ. Distal biceps brachii tendon repair: an in vitro biomechanical study of tendon reattachment. *Am J Sports Med*. 1998;26(3):428-432.
6. Bisson L, Moyer M, Lanighan K, Marzo J. Complications associated with repair of a distal biceps rupture using the modified two-incision technique. *J Shoulder Elbow Surg*. 2008;17(1 suppl):67S-71S.
7. Bisson LJ, de Perio JG, Weber AE, Ehrensberger MT, Buyea C. Is it safe to perform aggressive rehabilitation after distal biceps tendon repair using the modified 2-incision approach? A biomechanical study. *Am J Sports Med*. 2007;35(12):2045-2050.
8. Boyd HB, Anderson LD. A method of reinsertion of the distal biceps brachii tendon. *J Bone Joint Surg Am*. 1961;43:1041-1043.
9. Cheung EV, Lazarus M, Taranta M. Immediate range of motion after distal biceps tendon repair. *J Shoulder Elbow Surg*. 2005;14(5): 516-518.
10. D'Alessandro DF, Shields CL Jr, Tibone JE, Chandler RW. Repair of distal biceps tendon ruptures in athletes. *Am J Sports Med*. 1993;21(1):114-119.
11. D'Arco P, Sitler M, Kelly J, et al. Clinical, functional, and radiographic assessments of the conventional and modified Boyd-Anderson surgical procedures for repair of distal biceps tendon ruptures. *Am J Sports Med*. 1998;26(2):254-261.
12. Davison BL, Engber WD, Tigert LJ. Long term evaluation of repaired distal biceps brachii tendon ruptures. *Clin Orthop Relat Res*. 1996;333:186-191.
13. El-Hawary R, Macdermid JC, Faber KJ, Patterson SD, King GJ. Distal biceps tendon repair: comparison of surgical techniques. *J Hand Surg Am*. 2003;28(3):496-502.
14. Hartman MW, Merten SM, Steinmann SP. Mini-open 2-incision technique for repair of distal biceps tendon ruptures. *J Shoulder Elbow Surg*. 2007;16(5):616-620.
15. Idler CS, Montgomery WH III, Lindsey DP, Badua PA, Wynne GF, Yerby SA. Distal biceps tendon repair: a biomechanical comparison of intact tendon and 2 repair techniques. *Am J Sports Med*. 2006;34(6):968-974.
16. John CK, Field LD, Weiss KS, Savoie FH III. Single-incision repair of acute distal biceps ruptures by use of suture anchors. *J Shoulder Elbow Surg*. 2007;16:78-83.
17. Kamath RP, Chandran P, Varghese B, Wise DI. Repair of distal biceps tendon rupture with suture anchors and a single anterior incision: a review of six cases. *Eur J Orthop Surg Traumatol*. 2005;15:45–47.
18. Karunakar MA, Cha P, Stern PJ. Distal biceps ruptures: a followup of Boyd and Anderson repair. *Clin Orthop Relat Res*. 1999;363:100-107.
19. Kelly EW, Morrey BF, O'Driscoll SW. Complications of repair of the distal biceps tendon with the modified two-incision technique. *J Bone Joint Surg Am*. 2000;82(11):1575-1581.
20. Kettler M, Lunger J, Kuhn V, Mutschler W, Tingart MJ. Failure strengths in distal biceps tendon repair. *Am J Sports Med*. 2007;35(9):1544-1548.
21. Klonz A, Loitz D, Wohler P, Reilmann H. Rupture of the distal biceps brachii tendon: isokinetic power analysis and complications after anatomic reinsertion compared with fixation to the brachialis muscle. *J Shoulder Elbow Surg*. 2003;12(6):607-611.
22. Kobayashi K, Bruno RJ, Cassidy C. Single anterior incision suture anchor technique for distal biceps tendon ruptures. *Orthopedics*. 2003;26(8):767-770.
23. Le Huec JC, Moinard M, Liquois F, Zipoli B, Chauveaux D, Le Rebeller A. Distal rupture of the tendon of biceps brachii: evaluation by MRI and the results of repair. *J Bone Joint Surg Br*. 1996;78:767-770.
24. Leighton MM, Bush-Joseph CA, Bach BR Jr. Distal biceps brachii repair: results in dominant and nondominant extremities. *Clin Orthop Relat Res*. 1995;317:114-121.

25. Lemos SE, Ebramzedeh E, Kvitne RS. A new technique: in vitro suture anchor fixation has superior yield strength to bone tunnel fixation for distal biceps tendon repair. *Am J Sports Med*. 2004;32(2):406-410.
26. Lintner S, Fischer T. Repair of the distal biceps tendon using suture anchors and an anterior approach. *Clin Orthop Relat Res*. 1996;322:116-119.
27. Lynch SA, Beard DM, Renstrom PA. Repair of distal biceps tendon rupture with suture anchors. *Knee Surg Sports Traumatol Arthrosc*. 1999;7(2):125-131.
28. Mazzocca AD, Burton KJ, Romeo AA, Santangelo S, Adams DA, Arciero RA. Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. *Am J Sports Med*. 2007;35:252-258.
29. McKee MD, Hirji R, Schemitsch EH, Wild LM, Waddell JP. Patient-oriented functional outcome after repair of distal biceps tendon ruptures using a single-incision technique. *J Shoulder Elbow Surg*. 2005; 14(3):302-306.
30. Moosmayer S, Odinsson A, Holm I. Distal biceps tendon rupture operated on with the Boyd-Anderson technique: follow-up of 9 patients with isokinetic examination after 1 year. *Acta Orthop Scand*. 2000;71(4):399-402.
31. Obremskey WT, Pappas N, Attallah-Wasif E, Tornetta P III, Bhandari M. Level of evidence in orthopaedic journals. *J Bone Joint Surg Am*. 2005;87(12):2632-2638.
32. Ozyurekoglu T, Tsai TM. Ruptures of the distal biceps brachii tendon: results of three surgical techniques. *Hand Surg*. 2003;8(1):65-73.
33. Pereira DS, Kvitne RS, Liang M, Giacobetti FB, Ebramzadeh E. Surgical repair of distal biceps tendon ruptures: a biomechanical comparison of two techniques. *Am J Sports Med*. 2002;30(3):432-436.
34. Sotereanos DG, Pierce TD, Varitimidis SE. A simplified method for repair of distal biceps tendon ruptures. *J Shoulder Elbow Surg*. 2000;9(3):227-233.
35. Spang JT, Weinhold PS, Karas SG. A biomechanical comparison of EndoButton versus suture anchor repair of distal biceps tendon injuries. *J Shoulder Elbow Surg*. 2006;15(4):509-514.
36. Strauch RJ, Rosenwasser MP. Single incision repair of distal biceps tendon rupture. *Tech Hand Up Extrem Surg*. 1998;2(4):253-261.
37. Woods DA, Hoy G, Shimmin A. A safe technique for distal biceps repair using a suture anchor and a limited anterior approach. *Injury*. 1999;30(4):233-237.