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Dominant *vs* Nondominant Arm in Surgical Repair of Distal Biceps Tendon Rupture. A Case-Control Series of Isotonic Muscle Strength Evaluation

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SUMMARY

Background. This case-control study investigated arm recovery from surgery for a ruptured distal tendon in terms of maximal strength, power, and endurance compared to the healthy contralateral arm, taking into account limb dominance.

Methods. An S-shaped single incision and suture anchor repair was used in all 15 patients. All patients were right-arm dominant and of them none participated in a specific postoperative physical therapy program. Outcomes were evaluated based on range of motion and with the Disability of the Arm, Shoulder and Hand (DASH) test, Mayo Elbow Performance Index (MEPI), and Bromberg and Morrey questionnaire. Muscle function was assessed with MuscleLab.

Results. Average test scores were as follows: DASH, 3.53/100; MEPI, 93/100; and Bromberg and Morrey, 90.87/100. There were significant differences in supination (P = 0.007), maximum lifted weight (P = 0.005763), strength during endurance exercise (P = 0.004366), and maximum strength in flexion (P = 0.045584) between impaired and healthy arms.

Conclusions. Limb dominance is not a critical issue for the choice of treatment and functional evaluation following surgical repair of ruptured distal tendon.

KEY WORDS

Distal biceps; handedness; outcomes; surgery; surgical repair.

BACKGROUND

Most biceps tendon ruptures involve the proximal long head or, more infrequently, the short head; 3% of biceps injuries involve the distal insertion (1, 2). Males between the ages of 30 and 60 years account for 95% of cases, and the prevalence is between 0.9 and 1.8 per 100,000 patients per year (1, 2). Additionally, 60% to 86% of injuries involve the dominant arm, which is more debilitating for patients (2, 3). Biceps injuries are caused by hypovascularization in the tendon, which results in ipoxia and changes in tendon impingement on radial bone during pronosupination (2, 3). Other predisposing factors include high body mass index, tendinosis, osteophytes from mechanical overuse, prolonged steroid therapy, metabolic acidosis, smoking, and chronic inflammatory diseases (*e.g.*, rheumatoid arthritis) (2, 3). Athletes who play contact sports are also prone to distal biceps tendon injuries (3).

The increasing tendency of people of all ages to engage in sporting activities has led to increased rates of injury, prompting advances in surgical practices in the field of orthopedics to achieve better outcomes including more rapid restoration of function. In fact, conservative treatment of distal biceps ruptures can result in chronic pain, reduced grip strength, and weakness of flexion and supination (3-6).

Distal biceps tendon ruptures are relatively uncommon in clinical practice and there is no consensus regarding the optimal treatment and rehabilitation program, although surgery is the preferred intervention for this type of injury; the literature on this topic is mostly limited to case series (3, 5-8). Surgery to repair distal tendon ruptures is traditionally performed through a single anterior incision or double incision. In addition to different surgical approaches, various methods and tools are used for reattachment including suturing through bone tunnels, suspensory fixation devices, suture anchors, and interference screws. While surgical reinsertion of the distal biceps tendon has good outcomes in terms of restoring strength and range of motion, complications are not uncommon (3-5, 7, 9). Although there have been studies comparing different surgical techniques, there are no clear guidelines regarding the optimal approach for reducing complications and achieving good clinical outcomes (3, 4, 7-9). Only a few studies have reported functional outcomes comparing the dominant and nondominant arms or impaired and healthy arms (1, 6, 10-18).

In this case-control study, we evaluated the recovery of biceps brachii following surgery for distal tendon rupture in terms of maximal strength, power, and endurance compared to the healthy contralateral arm, while taking into account limb dominance.

MATERIALS AND METHODS

Study subjects

The study meets the ethical standards of the journal (19). Approval for this study was obtained from the local bioethics committee (study no. 062951891, protocol no. 21883).

We retrospectively evaluated 15 male patients who underwent surgery to repair unilateral rupture of the distal biceps brachii tendon between January 2015 and December 2017. A single surgeon performed all of the surgeries using the same technique, which involved tendon reinsertion into the radial tuberosity with 1 or 2 suture anchors through a single S-shaped incision using an anterior elbow approach. With the arm in maximum supination, the suture anchors were placed into the tuberosity and the torn tendon was reapproximated to the anchors. In most cases, 2 anchors loaded with sutures were used (20, 21).

The study participants were aged between 31 and 65 years (mean: 48 years). Seven patients had a left rupture and 8 had a right rupture. All patients were male and right-arm dominant. The time from the traumatic event to surgery ranged between 2 and 15 days (mean: 5 days), and the time from surgery to follow-up was between 28 and 54 months (mean: 42.6 months) (**table I**). After surgery, none of the patients engaged in a specific physical therapy program for the recovery of range of motion, strength, power, and muscular endurance.

The participants were informed in detail of the scope and procedures of the study before being asked to take part in clinical evaluation, and provided written, informed consent prior to participating in accordance with National Health Council Resolution No. 196/96 and the 1975 Helsinki Declaration, as revised in 2000.

Table I. Baseline demographic and clinical characteristics of patients.

Patient	Age	Injured side	Days since trauma	Follow-up, months	DASH	MEPI	B & M
1	31	Left	7	45	0	100	94
2	45	Left	10	41	0	100	100
3	56	Right	6	46	0.8	100	94
4	50	Left	5	42	12	85	86
5	65	Left	11	63	5.6	100	93
6	57	Left	13	29	0	100	100
7	50	Right	7	34	4.8	70	73
8	48	Right	5	43	4	100	93
9	47	Left	4	53	7.2	70	65
10	51	Right	8	26	0.8	100	100
11	38	Right	6	70	0	100	93
12	63	Right	9	22	13.6	85	86
13	47	Right	33	42	0	100	100
14	60	Right	35	94	0.8	100	100
15	57	Left	2	60	1.6	85	86

B & M: Bromberg and Morrey; DASH: Disability of the Arm, Shoulder and Hand; MEPI: Mayo Elbow Performance Index.

Outcome measures

Patients completed questionnaires that examined different aspects of upper limb functioning including the Disability of the Arm, Shoulder and Hand (DASH) test and Bromberg and Morrey (B & M) rating scale, which evaluated upper limb disability; and Mayo Elbow Performance Index (MEPI), which assessed limitations in daily life activities caused by impaired elbow function.

The patients were also evaluated with physical/functional tests. The MuscleLab system (Ergotest Technology, Langesund, Norway) was used to measure muscle isotonic strength, speed of motion, and muscular power with a linear encoder during elbow flexion-extension of the right and left limbs against resistance. The theoretical maximum weight lifted by each upper limb of each participant was calculated using the following equation (22):

Theoretical maximum weight = weight lifted / (1.0278 - 0.0278 × no. of repetitions).

This equation is reliable for a number of repetitions < 12. Measurements were first performed for the injured limb irrespective of whether it was the dominant one.

Submaximal and isotonic muscle endurance testing against resistance was carried out for each arm with the MuscleLab system. In the submaximal test, patients performed 3 flexion-extension repetitions at 90% of the theoretical maximum weight. In the endurance test, patients performed as many repetitions as possible in 1 min at 50% of the theoretical maximum weight. Participants were allowed a 10-min rest period between tests. For each arm, we also recorded the range of motion for flexion, extension, supination, and pronation of the elbow.

Statistical analysis

Data are reported as mean ± standard deviation and were analyzed with the parametric Student's t test for paired data between impaired and healthy arms of the same subject. Statistical analyses were performed with Excel software (Microsoft, Redmond, WA, USA). $P < 0.05$ was considered significant.

RESULTS

Clinical assessment

The patients were divided into 2 groups according to the side of the ruptured biceps tendon (left, n = 7; right, n = 8). Baseline demographic and clinical characteristics of the participants including age, time from trauma to surgery, time from surgery to follow-up, outcome scores, and functional test results/scores were normally distributed (**table II**).

In terms of clinical outcomes, 5/15 patients reported bearable pain near the brachiradial muscle. Average scores for the clinical assessment scales were as follows: DASH: 3.53/100; MEPI: 93/100; and B&M: 90.87/100. There were no statistically significant differences between the 2 groups (**table I**). None of the patients reported functional limitations in daily life activities, and were eventually able to return to work and engage in sports.

Functional assessment

We compared functional parameters between the operated (injured) and non-operated (healthy) arms. There were no differences in flexion and extension, but average supination was 80.8° in the impaired arm *vs* 87° in the healthy arm (P = 0.007), and average pronation was 79.73° *vs* 86.66° (P = 0.02) (**table III**). The theoretical maximum weight lifted, maximum strength and power during endurance exercises, and average strength and power during submaximal tests were measured. Prior to statistical analysis of MuscleLab functional performance data, we subtracted 10% from the values of the dominant right arm to normalize the data for the 2 arms. The average maximum weight lifted with the impaired arm was 13.37 kg as compared to 14.52 kg with the healthy arm (P = 0.005763); the average strength during endurance exercise was 64.77% in the impaired arm and 70.34% in the healthy arm (P = 0.004366); and the maximum strength in flexion was 150.04% and 161.82%, respectively (P = 0.045584). There were no significant differences in power expressed during the submaximal test and endurance exercise between arms (**table IV**).

Table II. Statistical parameters for patients' baseline demographic and clinical characteristics.

	Age	Months since rupture	Days since trauma	DASH	MEPI	B & M
Avg left	50.28571	47.57142857	7.428571429	3.7714287	91.4285714	89.14285714
Avg right	51.625	47.125	13.625	3.1	94.375	92.375
SD left	10.93487	11.88636674	4.035556255	4.65822365	11.8019369	12.088956
SD right	17.39301	25.32949532	11.1428228	47.8507523	9.9389805	23.25430068
P value	0.793726	0.963724582	0.223680698	0.78418795	0.62935914	0.576004703

Avg: average; B & M: Bromberg and Morrey; DASH: Disability of the Arm, Shoulder and Hand; MEPI: Mayo Elbow Performance Index; SD: standard deviation.

Table III. Range of motion in injured *vs* healthy limb.

	Supination		Flexion		Extension		Pronation	
	IL	HL	IL	HL	IL	HL	IL	HL
Average	80.8°	87°	133.6667°	136.3333°	- 2°	- 0.333333°	79.73333°	86.66667°
P value	0.007502973		0.164318		0.237666		0.023208	

HL: healthy limb; IL: injured limb.

Table IV. Strength evaluation in healthy and injured limbs.

	Maximum lifted weight, kg		STR during EE, kg		P during EE, %		Maximum FL STR, kg		P during submaximal test, %	
	IL	HL	IL	HL	IL	HL	IL	HL	IL	HL
Average	13.37333	14.52	64.77747	70.34713	- 0.00847	- 0.06276	150.0473	161.8267	117.9283	120.0785
P value	0.005763		0.004366		0.707989		0.045584		0.758272	

EE: endurance exercise; FL: flexion; HL: healthy limb; IL: injured limb; STR: strength.

DISCUSSION

This study evaluated clinical and functional outcomes following anatomic reinsertion of distal biceps tendon with an S-shaped single incision using anchors. Objective measures such as recovery of submaximal muscular strength, endurance, and range of motion along with subjective patient-reported outcome were evaluated. We also compared the results for dominant and nondominant limbs.

The surgical technique used in our study yielded good results in all patients in terms of recovery of functionality and autonomy in daily life, as assessed using clinical outcome measures. We compared our results to those of case control studies that used comparable surgical technique and materials and methods (**table V**) and found that our clinical results and subjective patient-reported outcomes substantially overlapped with the findings of most of these studies. However, isokinetic assessment outcomes in these (23-29) as well as our own study were inconsistent, which may be attributable to the various assessment tools and testing protocols used and different isokinetic parameters that were evaluated, precluding direct comparisons.

Only 5 of the previous studies considered the issue of limb dominance when analyzing the results (9, 15, 18, 23, 29) (**table V**), with conflicting conclusions. We therefore compared all case-control studies that analyzed this factor regardless of the surgical approach, type of tendon fixation, evaluation method, average follow-up time, and sample size (**table VI**) and found that they yielded variable findings regarding the issue of dominance.

Isokinetic analyses are known to be affected by limb dominance (30); however, the ratio of strength and endurance during flexion, extension, pronation, and supination between dominant and nondominant elbows is still debated (31). It has been suggested that the contralateral upper extremity can be used as a matched control in the evaluation of postoperative strength and endurance in biceps isokinetic testing, without adjusting the results for handedness (13). According to these indications, some studies assessing the contribution of limb dominance to surgical outcome (9, 14, 18, 23) did not normalize this ratio, since the strength difference favoring the dominant limb in isokinetic tests is in any case negligible. On the other hand, other studies (1, 6, 10, 11, 15, 16, 17) corrected for this factor using various methods (15).

All patients in our study were right-arm-dominant. Functional evaluation was performed with an isotonic strength test, and we subtracted 10% from right arm values to normalize data for the 2 arms according to Peterson *et al.* (32). This is based on the assumption that grip strength is an objective measure of upper extremity performance (33); it was shown that grip strength of the dominant hand was 10% greater than that of the nondominant hand, although this was only true in the case of right-arm dominance. Therefore, the 10% rule is recommended for right-handed subjects, and the arms should be considered as having equal strength for left-handed subjects (32). This is partly supported by the findings of Gallagher *et al.* (34), who showed that for the elbow, dominance does not affect extension, pronation, or supination but significantly influences flexion in terms of mean peak torque, work, and power. In our analysis, we considered only flexion in isokinetic tests: by normalizing the results for the 2 arms, we circumvented the issue

Table V. Cases treated with the suture anchor technique.

Study	Pt no.	Average time from injury tosurgery, days	Average follow-up, months	DASH, average	MEPI average	Evaluation tool for isokinetic analysis	Complications	Conclusions	Influence of dominance
Luciani, 2020 (23)	21	< 10 days	12, 36, 60	Not performed	93.12 ± 6.30	Biodex System 3	Transient paresthesia in LACN distribution (n = 2)	No differences between injured and uninjured sides in terms of flexion and supination in isokinetic analysis	No difference in flexion between dominant and nondominant operated sides during follow-up Peak torque and total work of supination showed recovery on dominant operated side relative to nondominant operated side at 1-, 3-, and 5-year follow-ups
Suda, 2017 (24)	49	17.8	32	Yes (results not reported)	Not performed	BTE PrimusRSTM	Permanent sensorial deficit in superficial ramus of radial nerve or LACN (n = 19)	Strength in elbow flexion and extension as well as forearm pronation and supination were diminished on operated side	Not evaluated
Witkowski, 2017 (9)	18	6.82 ± 9.90	47	Not performed	80.00 ± 15.00	Biodex System 3	None	Isometric torque values of muscle flexion and forearm supination were comparable in the 2 limbs	Operated dominant limb did not regain its preoperative dominance in flexion and supination strength Endurance was not evaluated
Pangallo, 2016 (25)	18	5	12	4.2	92.1 ± 12.6	Cybex isokinetic dynamometer	Transient neuropraxia in LACN distribution (n = 3) Permanent deficit in superficial ramus of radial nerve distribution (n = 1) Symptomatic heterotopic ossification (n = 1)	No difference between injured and uninjured sides in terms of isometric strength	Not evaluated
Siebenlist, 2014 (18)	49	21.7 ± 31.4	44	7.9 ± 13.9	97.2 ± 4.9	Isoforce Control®	Anchor failure (n = 4)	Differences between injured operated arm and uninjured arm in terms of deficit in isometric strength for elbow flexion and supination Endurance was not evaluated	Mean strength measurements did not differ between patients with dominant *vs* nondominant arm injury
Gasparella, 2015 (26)	18	5 ± 3	26	4.7 ± 6.3	96.8	Cybex isokinetic dynamometer	Long-term paraesthesia in LACN distribution (n = 2)	Increase in average flexion strength by 10.2% compared to non-operated arm in isokinetic evaluation	Not evaluated

Table V. Cases treated with the suture anchor technique.

Study	Pt no.	Average time from injury tosurgery, days	Average follow-up, months	DASH, average	MEPI average	Evaluation tool for isokinetic analysis	Complications	Conclusions	Influence of dominance
Hansen, 2014 (27)	21	Not reported	> 12	10 ± 7	Not performed	Biodex System 3	Not reported	Flexion strength of repaired side equal to that of normal side in strength test Supination strength and work performed were weaker on repaired side	Not evaluated
Mckee, 2005 (28)	53	16	21	8.2 ± 11.4	Not performed	BTE Work Simulator	Superficial wound infection (n = 1) Transient paresthesias in the LACN distribution (n = 2) Transient PIN palsy (n = 1)	No differences between injured and uninjured sides in terms of flexion strength and dynamic strength	Not evaluated
Balabaud, 2004 (15)	8	13	15	Not performed	Not performed	Cybex 6000 dynamometer	None	Isokinetic measurements showed a 5% strength deficit but 7% greater endurance, no strength deficit, and 13% more endurance for supination in flexion-concentric test	Dominant side had higher levels of peak torque, work, and power in the flexion-concentric test No differences between dominant and nondominant sides in supination-concentric and flexion-eccentric tests
Lynch, 1999 (29)	6	21.8	24	Not performed	Not performed	Cybex isokinetic dynamometer	None	Isokinetic tests revealed elbow flexion strength for peak torque, total work, and average power of 107%, 103%, and 110%, respectively, for uninjured arm Forearm supination strength measured by peak torque, total work, and average power were 97%, 85%, and 88%, respectively, for uninjured arm Forearm supination endurance was 10% lower in the injured arm	In injured biceps of the dominant arm, flexion values were 111%, 111%, and 119% of the peak torque, total work, and average power values of the uninjured arm, respectively Flexion endurance ratio for dominant extremities was equal to that of uninjured side Supination strength values were 103%, 101%, and 98% of the peak torque, total work, and average power values of the uninjured side, respectively

BTE: Baltimore Therapeutic Equipment; DASH: Disability of the Arm, Shoulder and Hand; LACN: lateral antebrachial cutaneous nerve; MEPI: Mayo Elbow Performance Index; PIN: posterior interosseous nerve; Pt no.: patient number.

Table VI. Studies addressing the influence of dominance.

Study	Pt no.	Average time from injury to surgery, days	Average follow-up, months	Surgical approach	Type of fixation	Evaluation tool for isokinetic analysis	Influence of dominance
Redmond, 2016 (14)	23	Not reported	80	Not reported	Cortical button	Biodex System 4	Arm dominance influenced the results: endurance in supination was greater when surgery was performed on dominant arm as compared to nondominant arm Dominant arm did not affect results of other strength and endurance measures
Dillon, 2011 (10)	27	Acute (< 28 days) (n = 1 7) Chronic (> 28 days) (n = 10)	30.9	Single anterior	Cortical button	BTE Work Simulator	Operated dominant limb recovered less maximal force in flexion and supination than operated nondominant limb No difference in endurance
Weinstein, 2008 (12)	32	29	42	2-Incision technique	Suture anchor	Biodex System 3	No differences in strength and endurance in flexion and supination after surgical repair between dominant and nondominant arms
Bell, 2000 (17)	23	9	43	2-Incision technique	Pull-out (n = 11) Suture anchor (n = 5) Screws (n = 5) Tenodesis (n = 2)	Lido Isokinetic Workset	No differences in flexion strength and endurance or supination strength and endurance between dominant repaired and nondominant repaired groups
Leighton, 1995 (1)	9	33	30	2-Incision technique	Pull-out	Cybex II System	Strength and endurance in both flexion and supination were completely restored in 3 repaired dominant extremities Deficits in flexion, endurance, and supination strength in 6 nondominant repaired extremities
D'Alessandro, 1993 (11)	10	17.1	50	2-Incision technique	Pull-out	Biodex System 3	Weakness during flexion endurance in dominant repaired extremities and loss of supination strength in nondominant repaired extremities
Agins, 1988 (16)	10	0-14	23	2-Incision technique	Pull-out	Cybex system	No differences in flexion strength and endurance between dominant repaired and nondominant repaired groups Differences in supination strength and endurance between dominant repaired and nondominant repaired groups
Baker, 1985 (6)	10	10.4	24-60	2-Incision technique	Pull-out	Cybex system	No differences in flexion strength and endurance between dominant repaired and nondominant repaired groups Differences in supination strength and endurance between dominant repaired and nondominant repaired groups

BTE: Baltimore Therapeutic Equipment: Pt no., patient number.

of dominance *vs* non-dominance for isotonic flexion muscle strength; additionally, we used the healthy contralateral arm as a matched control for the injured arm in each patient. We found that the healthy limb was superior in terms of maximum lifting weight, strength expressed during endurance exercise, and maximum strength during flexion; the impaired limb had less strength and lifted a lower weight. Muscle power during endurance and submaximal exercises was comparable; that is, while the impaired limb lacked explosive strength, muscle power during the endurance test was normal and adequate (**table III**).

Our study had 3 major limitations. Firstly, the small sample size and study design did not allow us to draw broad conclusions, especially regarding the application of the modified 10% rule. Secondly, we did not perform a detailed analysis of supination in terms of maximum strength and submaximal and endurance testing. Even after biceps tendon repair, a persistent loss of supination strength and range of motion are expected in both dominant and nondominant injured limbs (10, 12, 17, 18, 24, 27, 29). However, loss of supination strength and arc of motion in operated patients do not necessarily impact satisfaction scores, daily activities, or return to previous work (1, 10, 11, 12, 14, 17, 23, 24, 29). On the other hand, the considerable loss of supination strength (between 21% and 55%), endurance (up to 79%), and supination range of motion in injured biceps tendons that have not been surgically treated has been linked to lower satisfaction scores and can impede resumption of daily activities and work; this is true for both dominant and nondominant limbs (7, 35) and largely justifies surgical intervention in most cases. A third limitation of our study was the lack of a unified, comprehensive, and fully supervised postoperative physiotherapy program. Indeed, none of our patients followed a specific rehabilitation program after surgery, which may have biased our results. On the other hand, the good outcomes that were achieved highlight the value and effectiveness of the surgical technique.

A strength of our study was the normalization of isokinetic data for the 2 arms using the 10% rule, which allowed us to overcome the issue of dominance *vs* non-dominance for isotonic flexion muscle strength; and the use of the healthy contralateral arm as a matched control, which obviated the need to test a group of normal subjects (1, 10, 11, 15, 17).

CONCLUSIONS

Based on this new method of evaluating results, we conclude that limb dominance is not a critical factor in the choice of treatment for distal biceps injury at midterm follow-up. Patients should be informed of the possibilities of a persistent loss of flexion strength and limited supination range after suture anchor repair via a single-incision approach. We also recommend an appropriate postoperative rehabilitation program that includes muscle strength and endurance exercises as soon as the sutures allow to promote good recovery of supination.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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