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Antoine Vanderlinden, MD, Romain Carlat, MD, Bruno Vincent, MD, Christine Detrembleur, PhD, Serge Ayong, MD

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Biomechanical and clinical outcomes after distal biceps tendon reattachment using an endo button technique and a interference screw.

Antoine Vanderlinden MD - Clinique Saint Anne Saint Remy, Bruxelles, Belgium

Romain Carlat MD – Clinique Saint Pierre, Ottignies, Belgium

Bruno Vincent MD – Clinique Saint Pierre, Ottignies, Belgium

Christine Detrembleur PhD – Clinique universitaire Saint Luc, Bruxelles, Belgium

Serge Ayong MD – Clinique Saint Pierre, Ottignies, Belgium

Corresponding Author: Romain Carlat, MD romain.carlat01@gmail.com

Clinique Saint Pierre 47 avenue Victor Gilsoul, 1200 Woluwe Saint Lambert, Bruxelles, Belgium

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Abstract

Context

Rupture of the long head of the distal bifid biceps tendon is a rare injury, for which surgical anatomical repair should be considered in active patients.

The aim of this study was to review our patients who benefited from the Endobutton technique via a single anterior approach, comparing the clinical outcomes with the contralateral uninjured side and assessing their quality of life. Our hypothesis was that an "anatomical" insertion, through an anterior approach, by reinserting the two distinct tendons on the radial tuberosity, would restore the supination ability of the forearm more effectively than flexion strength.

Methods

This study included 25 patients who underwent surgery between June 2015 and January 2021. All patients underwent distal biceps reattachment using an endo-osseous fixation technique with the same device.

Each patient completed a quality-of-life questionnaire and participated in biomechanical performance tests.

Results

We observed a significant 14% reduction in strength during flexion on the operated side compared to the healthy side. However, no significant differences in strength were found for supination, extension, and pronation between the operated and non-operated limbs in these same patients.

In terms of endurance, flexion on the operated side tended to exhibit greater endurance than on the healthy side, while endurance in supination appeared similar between the operated and healthy sides. This finding held irrespective of whether the operated limb was dominant or non-dominant.

We also discovered a strong correlation between the time elapsed since surgery and differences in strength during both flexion and supination.

Conclusion

The ultimate goal is to achieve an anatomical surgical repair to restore all functions and maximize patient outcomes. As demonstrated, we have obtained good clinical results with Endobutton repair and a single anterior approach. The results in terms of strength and endurance are similar to those reported in the literature, and all our patients are satisfied. No postoperative complications were found.

Keywords: distal biceps tendon, endobutton technique, single anterior incision, distal biceps rupture, elbow, clinical evaluation.

Levels of evidence : Technical Note

While ruptures of the biceps brachii tendon are common, involvement of the proximal long head tendon is typical, whereas distal ruptures are uncommon. According to the literature, distal ruptures account for 3 to 5%[1,19,21] of all biceps lesions, which constitute 10% of all tendon injuries. The annual incidence is 1.2 per 100,000 patients. [1,19,21,27]

Conservative treatment may result in a poorer functional prognosis due to inadequate recovery of elbow flexion and supination. Based on current knowledge, surgical anatomical repair is recommended for active patients diagnosed with a distal biceps tendon rupture.[2,21]

Objective

The objective of this study was to evaluate patients who underwent the endobutton technique via a single anterior approach, comparing clinical outcomes (strength - peak torque and endurance) with their uninjured contralateral side, as well as their quality of life. We hypothesized that achieving an 'anatomical' insertion through the anterior approach, reattaching the two distinct tendons to the radial tuberosity, would restore forearm supination ability more effectively than flexion strength.

II. Materials and methods

This retrospective study was approved by the ethics committee of the clinic. All participants provided informed consent by completing the questionnaire and participating in the biomechanical testing.

A. Patients

This study involved 25 patients who underwent surgery between June 2015 and January 2021. All patients underwent distal biceps reattachment using an endo-osseous fixation technique with the same devices: an Arthrex EndoButton (Arthrex, Naples, FL, USA) and an interference screw. These procedures were performed by two senior surgeons at the same clinic, with patients assigned to the first available surgeon. Clinical diagnoses were confirmed by sonography, and in some cases, magnetic resonance imaging (MRI) was necessary. Patients with non-acute tears, partial tears, or tears requiring graft reconstruction were excluded.

B. Surgical technique

All surgical procedures adhered to the manufacturer's instructions for the Arthrex implant. Both senior surgeons employed identical approaches and techniques.

The patient was positioned supine with the arm supported on an arm board. The arm was exsanguinated, and a high-arm tourniquet was applied. The elbow was extended, and the forearm fully supinated. A transverse incision was made on the proximal forearm, 3 cm distal to the antecubital skin crease (Figure 1). Care was taken during skin retraction to avoid injury to the lateral cutaneous nerve of the forearm. The brachioradialis muscle was identified and reflected laterally to protect the motor branch of the radial nerve. The median nerve was identified and protected medially. The arterial pedicle was meticulously dissected at the elbow flexion crease and safeguarded.

The distal tendon was identified and retrieved by digital palpation, then tested with traction to assess feasibility for reattachment to the bicipital tuberosity without tension.[1] In some cases, minor tenolysis was necessary to mobilize the tendon and remove degenerative tissue.

If the tendon is retracted, a counter-incision is sometimes made more proximally to find the tendon.

The ruptured distal tendon is secured in a Krackow configuration from proximal to distal using a FiberLoop (Arthrex, Naples, FL, USA) to reinforce the tendon construct over a 2.5 cm length. Subsequently, it is passed through a 7 mm sizing block to ensure it can pass through an 8 mm bone tunnel in the radius. If the tendon is too large, we slice it to obtain a suitable size.

With the elbow fully extended and forearm fully supinated, the radial tuberosity was exposed and débrided. Under C-arm fluoroscopy guidance, a 3.2 mm guide pin was drilled bi-cortically through the central aspect of the radial tuberosity, angled 30° ulnarly (based on the ideal tendon insertion angle from Hutchinson et al[18]) to protect the posterior interosseous nerve. Subsequently, an 8 mm cannulated drill was passed through the anterior cortex and intramedullary canal without breaching the posterior cortex. Care was taken to avoid radial blowout due to excessive drill diameter[2]. (Figure 2)

With the elbow at 30° flexion and full supination, the EndoButton was passed through the radial tuberosity, flipped, and locked after engaging the second cortical layer by tensioning the traction suture. The biceps tendon was then gently drawn into the transosseous tunnel by progressively tensioning each limb of the suture. Tension was applied until the tendon made contact with the posterior cortex. Once the tendon was fully seated, knots were tied under tension using both suture threads, with one thread back-passed through the biceps tendon. This tension slide technique reduces pistoning and macro-motion at the repair site[22]. The procedure was completed by inserting a 7 mm × 10 mm unicortical interference screw on the radial side of the hole, orienting the tendon ulnarly to maximize the cam effect and potentially enhance supination strength. Placing the tendon intraosseously increases the contact area between the tendon and bone, promoting improved healing. (Figures 3 and 4)

C. Post operative rehabilitation

All patients were immobilized in a brachial-antebrachial cast with the elbow flexed at 90° for two weeks. This approach aimed to prevent excessive premature loading, which could potentially fracture the bone bridges formed in the radius. Following this initial period of rest, rehabilitation began with unrestricted range of motion exercises, facilitated by the strong fixation achieved on the opposite radial cortex. Muscle strengthening exercises without resistance commenced after 6 weeks, followed by resistance training at 8 weeks. Full return to strenuous activities was anticipated by the 3-month mark.

D. Outcomes measure

All patients underwent in-person evaluations by an independent physiotherapist who conducted isokinetic tests in June 2021. Additionally, each patient completed the Quick Disabilities of the Arm, Shoulder, and Hand Outcome Measure (Quick DASH) questionnaire. We also recorded the time required for patients to return to their previous occupation.

Biomechanical testing was performed using a Biodex Isokinetic Testing machine (Biodex Medical Systems, Shirley, NY, USA). Measurements included peak torque and endurance for forearm supination-pronation and elbow flexion-extension.

This was carried out on both arms of the patient.

The isokinetic testing was conducted by the same physiotherapist in a consistent sequence for each subject: right flexion-extension peak torque, left flexion-extension peak torque, right flexion-extension endurance, left flexion-extension endurance, right supination-pronation peak torque, left supination-pronation peak torque, right supination-pronation endurance, and left supination-pronation endurance. This sequence was chosen to minimize the need for exchanging attachments on the Biodex machine, recalibrating the apparatus, and repositioning subjects during testing sessions. Range of motion stops were applied to ensure consistent bilateral use of identical ranges of motion for the descriptive profile development.

Peak torque for flexion-extension was assessed at 60° per second. Subjects completed 5 consecutive maximum effort trials for each condition. Peak torque was calculated as the average peak value across the 5 trials and measured in Newton meters (Nm).

Endurance for flexion-extension was evaluated at 180° per second. Subjects performed 15 repetitions, with endurance calculated using the formula: 1 - (mean peak torque from the 2nd to the 5th repetitions minus mean peak torque from the last 5 repetitions) divided by (mean peak torque from the 2nd to the 5th repetitions), and reported as a percentage (%).

Peak torque for supination-pronation was tested at 30° per second. Subjects completed 5 consecutive maximum effort trials for each condition. Peak torque was calculated as the average peak value across the 5 trials and measured in Newton meters (Nm).

Endurance for supination-pronation was assessed at 180° per second. Subjects performed 15 repetitions, with endurance calculated using the formula: 1 - (mean peak torque from the 2nd to the 5th repetitions minus mean peak torque from the last 5 repetitions) divided by (mean peak torque from the 2nd to the 5th repetitions), and reported as a percentage (%).

E. Statistical analysis

A Power analysis performed by Wittsein et al[34] when comparing isokinetic biceps performance in dominant and non-dominant arms found that five subjects were required to detect a significant difference in peak supination or flexion torque with 80% power and an alpha value of 0,05 (based on standard deviations described by Leighton et al)[20].

Statistical analyses were conducted using SPSS (IBM Corp., Armonk, NY, USA) SigmaPlot 13 software (Grafiti LLC, Palo Alto, CA, USA). Variables were reported as mean (standard deviation) or as median and interquartile range [first and third quartiles].

Firstly, the effect of surgery on force and endurance between the operated and healthy sides was assessed using paired t-tests. All continuous variables met the assumptions of homoscedasticity (= equal variance of stochastic errors across observations).

Secondly, the influence of dominance (dominant or non-dominant operated side) on the results was examined. Student's t-test was employed for continuous data meeting homoscedasticity assumptions, while the Mann-Whitney test was used for other data.

Thirdly, Pearson correlation coefficients were calculated to assess relationships between differences in flexor and supinator forces (operated side force minus healthy side force), QuickDASH score, time before surgery, and days between surgery and biomechanical testing.

Statistical significance was set at the 0.05 level.

III. Outcomes measurement

A. Patient demographics

The study included 25 subjects (24 men, 1 woman), The study included 25 subjects (24 men, 1 woman), seven did not show up to take the mechanical test and one patient presented with a chronic injury. These eight patients were excluded from the study. Their age ranged between 41-51 years, with an average age of 49 years. The dominant side was injured 11/17 (65%). The mean time elapsed between the injury event, and the surgery was 11 days (range 6-37). The time elapsed between the surgery event and the biomechanical test is 28.5 months.

B. Patient-reported outcomes measures (PROMS) and biomechanical performance outcomes

All patient benefited from a reattachment of the distal biceps tendon using an endobutton fixation and an interference screw, majority of the tests reflected good postoperative QuickDASH scores and good strength recovery.

We have been able to demonstrate a significant loss of 14% strength in flexion on the operated side compared to the healthy side, whereas in these same patients we couldn't find any difference in strength for the supination, extension and pronation between the operated and non-operated limb.

In terms of endurance, it tends to be greater in flexion on the operated side than on the healthy side, while it seems identical in supination on the operated side than on the healthy side. This result seems to be irrelevant whether it is the dominant or non-dominant member that was operated on.

Time to surgery is an important parameter, we have found a heavy correlation between the time to surgery and the difference in strength in flexion and in supination. If we wait more than two weeks there is a real impact on strength recuperation.

Within our study period, we didn't count any infection, posterior interosseous nerve injuries or a re-ruptured of the distal biceps tendon reattachment. (Tables 1,2,3,4)

IV. Discussion

Conservative or nonanatomic repairs have been shown to prevent restoration of the bicep's native function and compromise patient outcomes[15]. The aim of this study is to compare biomechanical capacities, which are supination as well as flexion, after reinsertion of the distal biceps tendon.

The strengths of the study include the relatively large number of patients for biomechanical testing of this particular injury, the accuracy and consistency of the testing devices and the assessment of not only peak torque but also endurance. The surgical techniques are identical for all patients. All patients have performed the tests at the same physiotherapists, by the same machine and analyzed by the same evaluators.

It is known that patients with an untreated distal biceps tendon rupture complain of pain and fatigue with repetitive elbow flexion and forearm supination[22]. While biomechanical tests on those patients reported 40% loss of supination strength, 30% loss of flexion strength, and 79% loss of supination endurance and 30% loss of flexion endurance. Other studies found no difference in endurance on the involved and uninvolved sides, and they explain the complain of fatigue symptoms, not because the remaining muscles have less endurance but because they start their activity from a lower maximal torque. [22,29]

As we have shown, surgical repair of the ruptured tendon seems to improve strength in flexion and supination, although not always to normal, we still have 14% loss of strength in flexion.

Endobutton fixation is biomechanically stronger than anchor techniques. Olsen and al.[24] showed that patients treated with an anchor had higher DASH scores at 6 months but experienced greater weakness compared to patients treated with an endobutton. However, the quantitative strengths between the two are similar. Regarding mobility, they demonstrated better pronation with the endobutton and better flexion and supination with the anchor.

Potapov and al. [25] reported the occurrence of radial osteolysis after distal biceps tendon repair with a bioresorbable screw. Eighteen of the 19 patients treated with a bioresorbable screw developed osteolysis, but there was no clear clinical correlation.

Cain et al [4] found that neurapraxias were more frequent with endobutton fixation and that re-rupture rates were higher with the anchoring system. They did not find a significant difference in the overall complication rate between the fixation methods. However, this study also included chronic ruptures. Interestingly, there was no difference in complication rates when the repair took place more than 4 weeks after surgery. The time before the intervention would be an important factor concerning the recovery of strength in flexion and supination.

Watson and al. [33] reviewed 498 elbows that underwent acute repair and found that the endobutton method had significantly lower complication rates compared to suture anchors. However, the sample size for endobutton fixation did not have the statistical power to state that this method is superior to others.

According to the literature, it is difficult to demonstrate the superiority of one technique over another. Our study highlights the good recovery of strength and endurance with the endobutton technique.

Creating an anatomical tunnel in the radius for distal biceps tendon reinsertion is crucial for optimal functional recovery. The radial tuberosity has a precise anatomy, featuring a specialized protrusion just anterior to the biceps insertion that acts as a supination cam.

For this supinator muscle to perform its rotation (supination), torque must be induced. The supinator muscle fibers must wrap around the radius when the forearm is in pronation and should not cross the axis of forearm rotation. [22] This is possible because the position of the radial tuberosity is shifted ulnar relative to the axis of the radius in supination, dorsally in the neutral position, and radially in pronation. This precise anatomy creates a cam effect to produce supination of the radius in pronation, in the neutral position, and in supination.[7]

The incision technique can affect the ability to achieve anatomical tunnel placement. Jobin et al [16] reported a more anatomical tunnel position using a two-incision technique compared to a single-incision technique.

Hasan et al [13] also examined cadaveric models of tunnel placement and found that a greater percentage of the footprint was covered when using a two-incision technique compared to a single-incision technique (73.4% vs. 9.7%).

Henry et al [14] studied the biomechanical effects of different tendon attachment sites and found a tendency for loss of supination when the tendon was placed in a more anterior position on the bicipital tuberosity.

Prud'homme-Foster[26] et al and Schmidt et al[30] reached similar conclusions. Using MRI to study single-incision repairs with an endobutton, they found that all tendons had healed, but the repair was often non-anatomical, being on average more radial compared to uninjured controls. There was a significant loss (67%) of supination strength compared to the uninjured side. They concluded that with non-anatomical anterior repairs, the tendon unfolds when the forearm supinates, thus losing its ability to generate maximum force.[28]

Hansen et al[12] also examined the biceps tendon positioning after single-incision repair using anchors through CT scans. They found that, on average, the anchor placement was more radial relative to the apex of the tuberosity. Patients in this study exhibited a significant decrease in supination strength. Therefore, when the tendon is repaired in a non-anatomical position anteriorly and more radially, the biceps cannot generate supination force when the forearm is in supination.

Complications following distal biceps repair are not uncommon, with reported rates reaching up to 36%. [4] Complications include injuries to the lateral antebrachial cutaneous nerve, posterior interosseous nerve, infection, heterotopic ossification, radioulnar synostosis, hematoma, and tendon re-rupture.

In a systematic review by Chavan et al [5], the overall complication rate for single-incision repairs was 18%, whereas for double-incision repairs it was 16%. The most recent systematic review by Watson et al reported a complication rate of 23.9% for the single-incision technique versus 25.7% for the two-incision technique.

Nerve injuries are the most common complication of distal biceps repairs. The rate of lateral antebrachial cutaneous nerve neuropraxia ranges from 3% to 26%. Posterior interosseous nerve palsy has been reported in up to 9% of patients undergoing distal biceps repair, but it is generally transient and resolves spontaneously.[3, 18]

Nigro et al[23] conducted a study on 280 patients, among whom 9 presented with posterior interosseous nerve palsy. All showed symptom resolution within an average of 3 months.

Heterotopic ossification and radioulnar synostosis result in a loss of mobility. The prevalence of heterotopic ossification ranges from 2% to 10%. The risk of heterotopic ossification formation is higher with repairs performed using the traditional Boyd-Anderson technique. The incidence has decreased since the advent of the muscle-splitting double-incision approach.[3]

In an MRI study by Schmidt et al[28], 42% of repairs showed heterotopic exostoses without clinical consequences. Similarly, Greenberg et al[10]. reported an asymptomatic heterotopic ossification rate of 36%.

Prophylaxis against heterotopic ossification has been reported[11], but no studies prove its effectiveness in preventing their formation. Radioulnar synostosis initially presents as pain and swelling, eventually leading to a loss of mobility, particularly supination. In cases of radioulnar synostosis, surgical resection and radiotherapy can help improve movement and prevent recurrence but should be performed once the soft tissues have healed.

Re-rupture rates are described in the literature at 4.4%[18,11]. In the recent systematic review by Watson et al[33], the overall re-rupture rate was 1.6%. Ruptures occur more frequently with anchor repairs than with endobutton use. In the series by Cain et al[4], all 4 re-ruptures occurred in the suture anchor group.

<u>Limitation of our study</u>

Various biases can be found in our study. The first of them is the heterogeneity of our population, the comparison between the dominant and non-dominant side can be biased according to the occupation (professional and recreational) of the patients that we didn't collect.

As shown in a study of professional tennis players, who have a statistically stronger dominant side for wrist extension, flexion, and pronation, but significantly weaker forearm supination strength ($p < 0.01$) on the dominant side compared to the non-dominant side (21). On the contrary, in a heterogeneous population the dominance will not impact the strength of the limb[34].

Another bias is the surgical technique, we suppose that all reinsertions were on the more posterior aspect of the radial tuberosity. But it is likely that wasn't always the case. It has been shown by previous study that 35% of the radial tuberosities were in extreme pronation (on the posterior side of the radius), and even using an anterior approach with forearm hypersupination, a straight guide pin could not be placed into the native footprint[22].

We have not been able to find a correlation between the strength recovery and the QuickDASH score. This could be because patients have adapted their way of living and the QuickDASH score is not sensible and specific enough. We think that a more monomodal and bimanual score could give different results. We strongly suggest for future investigation a monomodal and bimanual score like abilHand[8,9].

V. Conclusion

Understanding the anatomy and effect of the three distal insertions of the biceps brachii tendons (lacertus fibrosus, the short and long head) is essential to treat his rupture. They all have an important and different role on the elbow and forearm.

The ultimate goal is to achieve an anatomical surgical repair to restore all functions and maximize patient outcomes. As demonstrated, we have obtained good clinical results with Endobutton repair and a single anterior approach. The results in terms of strength and endurance are similar to those reported in the literature, and all our patients are satisfied. No postoperative complications were found. The ideal repair technique would offer anatomical restoration while minimizing surgical morbidity.

Understanding the effect of a ruptured biceps tendon function of the upper extremity is important to interpret patient symptoms and counsel patients regarding anticipated functional loss in case of conservative treatment. Patients will need all the information to choose not to have their tendon repaired and evaluate strength improvements after surgery[34].

Time to surgery is an important parameter for the capacity of strength recovery and complications. We hardly suggest the operation to be in the first two weeks after the trauma.

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Legends for figures and tables

Figure 1: The radial tuberosity can be exposed through an anterior approach with hypersupination

BR, brachioradialis m.; *EDC*, extensor digitorum communis m.; *ECU*, extensor carpi ulnaris m.; *A*, anconeus m.; *S*, supinator m.; *FCU*, flexor carpi ulnaris m.; *PT*, pronator teres m. [21]

Figure 2: Identification X-ray using a pin peroperative

Figure 3 : illustrations of the surgical steps in the Tension-slide technique of anatomical distal biceps tenodesis using an EndoButton. (a) Preparation/ suturing of distal biceps tendon in a

krackow fashion way. (b) Passing suture threads through the 4-holed EndoButton. (c) Passing the guide wire through radial tuberosity. (d) Reaming the anterior cortex and the intramedullary canal over the guide wire using a cannulated drill. (e) Drilling the posterior cortex over the guide wire using an EndoButton drill. (f) Inserting a threaded EndoButton through the bone tunnel. (g) Tightening the suture threads and flushing the EndoButton on the posterior cortex. (h) Tying the knot under tension after passing the suture ends through the distal end of the biceps tendon, adjacent to the bone tunnel. (i) Insertion of a unicortical tenodesis screw on the radial aspect of the hole, pushing the tendon ulnarly to mimic the natural anatomy. By : Modified Tension - Slide Technique for Anatomical Distal Biceps Tenodesis using a Bicortical EndoButton and a Tenodesis Screw Jagadish Prabhu and al

Figure 4: Control X-ray after insertion of the endobutton

Tables 1: T-paired test : effect of surgery on force and endurance

Tables 2: T-student: effect of the dominant or non-dominant operated side on the results

Tables 3: T-student: effect of the dominant or non-dominant operated side on the results

Tables 4: Pearson coefficient correlation

Tables 1

FORCE (Nm)	Healthy side	Operated side	p-value
	mean (SD)	mean (SD)	
Flexor	47.6 (14.5)	41.8 (15.2)	0,012
Supinator	10.2 (3.5)	10.5 (3)	0,81
Extensor	47 (12.3)	44.1 (15.1)	0,28
Pronator	14.4 (4.5)	13.3 (4.2)	0,2
ENDURANCE (%)			
Flexor	89.3 (13.4)	94.6 (13.9)	0,036
Supinator	90.9 (13.2)	88.9 (14.4)	0,63
Extensor	99.1 (13.1)	102.9 (17)	0,33
Pronator	94 (15.7)	106.5 (17.5)	0,026

Tables 2

FORCE (Nm)	Dominant side operated	No Dominant side operated	p-value
Operated Side	mean (SD)	mean (SD)	
Flexor	38.3 (15.3)	46.8 (14.7)	0,27
Supinator	9.9 (3.1)	11.3 (2.9)	0,4
Extensor	37.9 (13.8)	52.9 (13.7)	0,04
Pronator	13.6 [9.7-18.3]	12 [11.8-12.6]	0,67
FORCE (Nm)	**Dominant side operated**	**No Dominant side operated**	**p-value**
Healthy Side	mean (SD)	mean (SD)	
Flexor	43.9 (9.7)	52.8 (19.2)	0,22
Supinator	9.3 (2.3)	11.4 (4.7)	0,26
Extensor	45.0 (7.9)	49.9 (17.2)	0,44
Pronator	12.9 (4.5)	16.3 (4.1)	0,15

Tables 3

ENDURANCE (%)	Dominant side operated	No Dominant side operated	p-value
Operated Side	mean (SD)	mean (SD)	
Flexor	94.0 (17)	95.2 (8.9)	0,87
Supinator	93.9 [86.3-98.8]	87.7 [67.7-101.7]	0,33
Extensor	99.1 [89.8-113.79]	98.3 [89.7-113]	1
Pronator	109.3 [94.4-121.2]	102.1 [81.4-125]	0,53
ENDURANCE (%)	**Dominant side operated**	**No Dominant side operated**	**p-value**
Healthy Side	mean (SD)	mean (SD)	
Flexor	88.4 (14.8)	90.6 (12.2)	0,75
Supinator	93.1 (12.3)	87.7 (14.7)	0,42

Extensor	96.2 [91.3-104.6]	94.1 [90.1-104.5]	0,73
Pronator	95.2 (15.5)	92.2 (17)	0,72

Tables 4

	Difference of Flexor force (Nm)	Difference of Supinator force (Nm)	Dash score	Delay before surgery (days)	Month between surgery and biomechanical tests (month)
Difference of Flexor force (Nm)		0,55	-0,39	-0,6	-0,49
Difference of Supinator force (Nm			0,3	-0,59	0,09
Dash score				0,16	0,7
Delay before surgery (days)					0,34

Figure 1

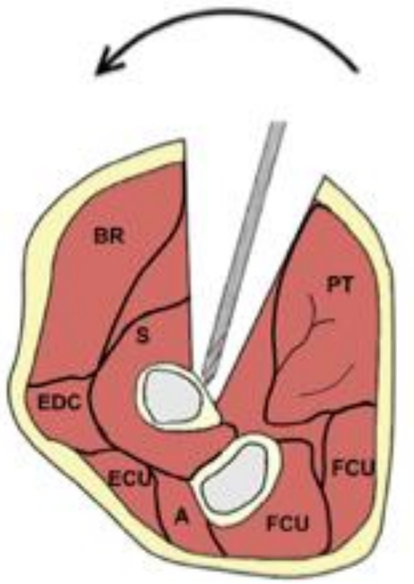

Figure 2

Figure 3

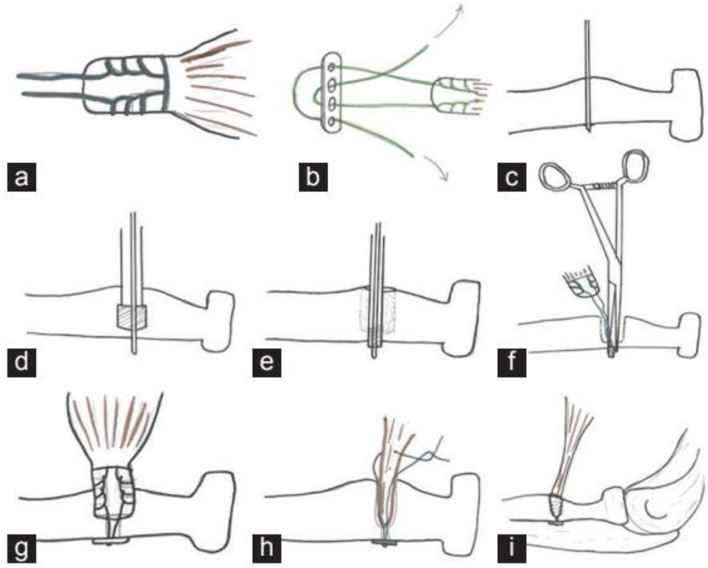

Figure 4