Biomechanical Evaluation of Lateral Ulnar Collateral Ligament Reconstruction Techniques

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Abstract

Background: Posterolateral rotatory instability (PLRI) of the elbow requires surgical reconstruction. A docking technique with a tendon graft is traditionally used; however, the techniques for lateral ulnar collateral ligament (LUCL) reconstruction have evolved with attempts to increase the effectiveness of the surgery. The purpose of our study is to biomechanically compare a docking technique to an interference screw fixation technique for LUCL reconstruction.

Methods: Six matched pairs of cadaveric elbows underwent biomechanical testing. The first group used two 4.5 x 15 mm soft tissue interference screws (Arthrex PEEK) to secure the graft. The second group used a docking technique. Palmaris tendons were harvested from each arm. The elbows were cyclically loaded using 0.5 Nm supination torque with 70N of axial compression for 50 cycles at 0.1Hz, and then loaded to failure.

Results: The average stiffness and ultimate torque for the interference screw fixation group were not significantly different from reconstructed elbows using a docking technique. In cyclical loading testing, the conditional relaxation did not show any difference between the two groups as well.

Discussion and Conclusion: The interference screw reconstruction technique was biomechanically equivalent to the docking technique in this model. However, we chose a smaller screw so that tendon graft size was equal in the two groups. In a patient setting, the screw and graft size can be increased, likely leading to an even stronger construct. In addition, reduced soft tissue stripping and increased precision provided by the interference screw technique may make it the superior option for LUCL reconstruction. Level of Evidence: Basic Science, Biomechanics, Cadaver Model.

INTRODUCTION

Posterolateral rotatory instability (PLRI) is caused by injury to the lateral collateral ligament complex, usually from elbow dislocation; fracture dislocation, iatrogenic injury, or varus malalignment of the elbow. This is characterized by the external rotation of the radius and ulna in reference to the distal humerus. Further, it is manifested as posterior subluxation of the radial head in relationship to the capitellum with a non-concentrically reduced ulnohumeral joint. Originally described in 1991 [1], PLRI is considered the most common type of chronic elbow instability [2,3] (Figure 1).

Stability of the lateral side of the elbow is provided by osseous and ligamentous constraints. The coronoid process and radial head have been found to be necessary stabilizers in PLRI [4]. Additionally, dynamic constraints such as the lateral triceps, brachialis, extensor muscles and anconeus provide a degree of stability [5,6]. However, the main component involved in PLRI is the disruption or attenuation of the lateral elbow ligamentous complex, comprised of the annular ligament, the radial collateral ligament and the lateral ulnar collateral ligament (LUCL). Re-establishment of the RCL complex has been shown to restore initial elbow kinematics and stability [7]. Surgical treatment consisting of LUCL reconstruction is the mainstay of chronic posterolateral elbow instability.

Clinical presentation is many times vague, with symptoms of...
lateral elbow pain, catching, clicking and feelings of instability. Patients with elbow dislocations that develop continued instability require surgical reconstruction of the LUCL.

The optimal technique for reconstruction has not been determined. Fixation techniques are evolving with the aim of increasing strength and decreasing soft tissue dissection. Although there are many studies comparing fixation techniques of the medial collateral ligament of the elbow, to our knowledge there is no literature that compares different methods of fixation on the lateral side of the elbow.

The aim of our study is to compare the strength of two common LUCL reconstruction techniques, a docking type reconstruction and an interference screw construct. An adequate reconstruction technique seeks to restore the normal kinematics and provide stability to the lateral side of the elbow, while at the same time providing enough strength to allow for early rehab.

METHODS AND MATERIALS

Specimen preparation

Six paired fresh frozen cadaveric upper extremities were used for the purposes of comparing the two reconstructive techniques. Mean age of the cadaveric specimens was 57 years of age (54-61 years). All specimens were stored at -20 °C when not in use. Care was taken to minimize and ensure consistency in the number of freeze-thaw cycles used for specimen preparation, surgical approach, and biomechanical testing.

Each specimen was prepared for biomechanical analysis as follows. The upper arm was cut mid-humerus, and wood screws were placed through the humerus 1-2 inches distal from the cut. This region was then cast in a metal cup using a quick-set resin (Smooth Cast, Smooth-On, Easton, PA). Next, the distal radius and ulna were isolated, and k-wires were placed through the bones to preserve the natural orientation. The distal radius and ulna were also then cast en block in a metal cup using a quick-set resin.

Surgical approach

The paired (same donor) cadaveric specimens were randomly assigned to two different reconstruction techniques: (1) docking type reconstruction (Figure 2a); [8] or (2) interference screw construct (Figure 2b). If present, the Palmaris Longus tendon was harvested from the specimens and stored in saline soaked gauze for later reconstruction. Flexor carpi radialis tendon was used if no Palmaris tendon was found. Regardless of the graft donor site, each tendon was fashioned to equal size for each specimen, similar to what would be done in a clinical setting. A No. 2 looped Fiberwire suture (Arthrex, Naples, Florida) with a Krakow stitch was used to secure the tendon. Depending on the specimen size, all grafts were either 4.0 or 4.5mm in diameter.

For both testing groups, a standard lateral approach to the elbow was performed. The fascia was incised proximally along the suprasondylar ridge and extended distally. The interval between anconeus and extensor carpi ulnaris was developed, and the LUCL complex was identified. The elbow was then rendered unstable by transecting the LUCL complex, leading to PLRI instability.

For the docking technique, the supinator tubercle was located and used as a landmark for placement of the distal drill hole. It was normally found at the radial head/neck junction. A 4.0 mm drill hole was placed at the supinator tubercle. A second drill hole was made 1.5cm proximal and slightly posterior to the first hole. A heavy suture was placed through the ulnar tunnels; it was then used to find the isometric point on the humerus. We were careful to maintain the radio capitellar joint in a reduced position as the elbow was taken through a full arc of motion. The isometric point on the humerus was marked, and a 4.5 mm drill hole was made. Next, pair of docking holes was made with the 2.5 mm drill bit, 1.5cm proximally. The graft was then placed through the drill holes and tied over the bone bridge on the humerus, with the elbow in 45 degrees of flexion and the forearm pronated. The graft was further secured to itself with #2 fiberwire and sutured to the anterior capsule for additional fixation.

For the second testing group, the ligament was reconstructed with the use of interference fixation both proximally and distally [9]. One 4.5 x 15 mm PEEK Biotenodesis screw (Arthrex, Naples, Florida) was used to secure a 4.0mm graft at the supinator tubercle [10]. The isometric point was found on the humerus using the graft suture that was originally used to secure the tendon. A 4.5 x 15mm PEEK interference screw was then
Biomechanical testing

Biomechanical testing was conducted to simulate backwards falling with arms extended. This is a common injury mechanism for LUCL, involving a combination of axial compression, valgus and supination torque. Because the aim of this study is to compare repair techniques, we did not test the native intact specimen. The test set-up was as follows. Each specimen was positioned at full extension. The distal humerus was fixed horizontally to a lockable ball joint that allowed a small degree of poly-axial movement, but no rotational freedom. This custom fixture permitted the coronoid process and olecranon of the ulna to maneuver and disarticulate freely out of the joint without bone interference from the humerus during loading. The distal radius and distal ulna were fixed rigidly to a multiaxial load cell, (AMTI MC3A-6-500, Advanced Mechanical Technology, Inc., Watertown, MA) which was affixed to the actuator of an axial-torsional industrial hydraulic press (MTS 858 Mini-Bionix, MTS, Eden Prairie, MN). The actuator was used to apply simultaneous axial compression, valgus and supination. Displacement and rotation were continuously monitored via in-built linear and rotational displacement transducers, which are sensors that measure the amount of linear (distraction) and rotational (angular) motion from the distal to the proximal end of the specimen. To better simulate LUCL injury resulting from simultaneous axial compression supination torque and valgus force, the axis of the actuator was aligned with the axis of the ulna. Preliminary testing with anatomical ("Sawbones") models confirmed that this test set-up induced the correct injury mechanism to the LUCL (Figure 3).

Specimens were tested under non-destructive cyclic loading followed by quasi-static load-to-failure. Non-destructive testing consisted of 50 cycles at 0.1 Hz of 0.5 Nm supination torque, with simultaneous 70 N axial compressive load. This loading regime corresponds to 10% of the loading magnitude necessary to induce injury during backward falling [3]. Immediately following non-destructive testing, quasi-static load-to-failure testing was conducted at 4.5 deg/sec supination. This was done in accordance with established methods in the literature for UCL repair constructs [11]. An axial compressive load of 700 N (approximately 50% body weight) was applied continuously through the forearm during testing [3]. Supination angle was measured locally at the repair site using a commercial 3-D motion tracking system (Optotrak 3020, Northern Digital, Waterloo, Ontario, Canada).

**Result measures**

The following result measures were captured during biomechanical testing: (1) Stiffness; (2) Conditioning Relaxation; and (3) Ultimate Torque. Stiffness was calculated as the average slope of the torque-supination angle curves over all conditioning cycles. Conditioning Relaxation was defined as the change in supination angle between the first and last conditioning cycles. Ultimate Torque was taken as the maximum applied torque during the destructive loading cycle. Statistical comparison of result measures between testing groups was carried out by a paired sample t-test, calculated with Tukey's HSD post hoc method.

**RESULTS**

There were no differences between the interference screw and the docking technique in terms of Stiffness, Conditioning Relaxation, or Ultimate Torque (Table 1). Modes of failure in the interference screw group were graft slippage (5 out 6) and screw pullout (1 out of 6). Failures in the docking technique were classified as proximal suture failure (5 out of 6) and bone bridge fracture (1 out of 6).

**DISCUSSION**

The results of this study showed no distinction in the biomechanical integrity of a docking technique versus interference screw construct for LUCL reconstruction; however the methods of failure were quite different.

Presently there are no biomechanical studies evaluating an interference screw technique for LUCL reconstruction. On the medial side of the elbow, Ahmad et al studied an all interference screw technique, and showed comparable ultimate moments between the interference construct and the native ligament [2]. Unlike the results from our study, only 2 out of 10 of their failures were a result of graft slippage or screw pullout. Most of their encountered failures were from graft rupture. This likely reflects the bone quality in their specimens tested, where the average age was 43. In our study, in which the average age of the specimens was 57 years of age, and specimen bone quality was significantly lower, the method of failure for interference fixation was predominantly proximal graft slippage [12]. This occurred in 5 out of 6 specimens. In only a single specimen did the screw fail? Docking technique fixation exhibited proximal suture failure in 5 out 6 reconstructions. The remaining specimen failed as a result of proximal bone bridge fracture, which may have been a consequence of osteopenic bone or tunnel placement.

While the results for the interference screw and docking groups were equivalent, limitations of the study may have negatively affected our load to failure results for the interference
The primary advantage of the docking technique is that it is a tried and true method with proven results [14]. Another advantage is that there is no surgical implant cost. The disadvantages of the docking technique are as follows. The advantage is that there is no surgical implant cost. The disadvantages of both procedures, we prefer the interference screw fixation method. The interference screw technique permits greater ease of application, less surgical dissection, and most importantly provides the surgeon the flexibility to use a larger graft with a larger implant, which in a true clinical situation is often the case in young active patients with good bone quality. While both techniques are biomechanically equivalent, in our experience, these advantages make the interference screw fixation a preferable surgical option compared to the standard docking technique.

CONCLUSIONS

Overall results after LUCL reconstruction are encouraging, as the studies available have shown 80-90% satisfactory results [1,14-17]. However, the optimal method for LUCL reconstruction has not been proven. Interference fixation provides equivalent biomechanical integrity to the docking technique and at the same time allows an increase in graft size not usually possible with traditional bone tunnels. This fixation option shows promise however, more studies are needed to assess the clinical outcomes in these patients.

REFERENCES

5. Cohen MS, Hastings H 2nd. Rotatory instability of the elbow. The

<table>
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<tr>
<th>Sample Pair Number</th>
<th>Conditioning Relaxation(deg)</th>
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<tr>
<td>N=6</td>
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<tr>
<td>Mean</td>
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Table 1: Results from biomechanical testing.


