SciMedCentral

Annals of Orthopedics & Rheumatology

Review Article

Biomechanical Evaluation of Lateral Ulnar Collateral Ligament Reconstruction Techniques

Molina RA, Bohlen H*, Kwiat D, Leasure J, Buckley JM and Lattanza L

Graduate Student, Berkley University of California, USA

***Corresponding author**

Bohlen H, Graduate Student, University of California, Berkeley, USA, Email: hunterbohlen91@gmail.com

Submitted: 16 February 2015

Accepted: 10 May 2015

Published: 12 May 2015

Keywords

- Elbow instability
- Interference screw
- Lateral ulnar collateral ligament
- Ligament reconstruction
- Biomechanics
- Cadaver study
- PLRI

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 anconeous 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

Email: hunterbohlen91@gmail.com

Figure 1 X-Ray of an elbow exhibiting Posterolateral rotatory instability (PLRI).

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 tendonwas 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 supracondylar 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 second 4.5 x 15mm PEEK interference screw was then

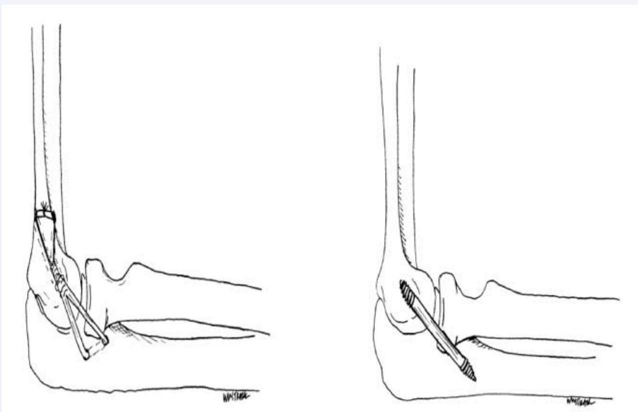

Figure 2 Diagrams showing the two surgical treatments for LUCL repair. (a) The docking technique. (b) The interference screw technique.

used to secure the graft on the humeral side at the most isometric point. The tendon graft was then also sutured to the anterior capsule in a similar fashion to the docking technique.

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 Praire, 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).

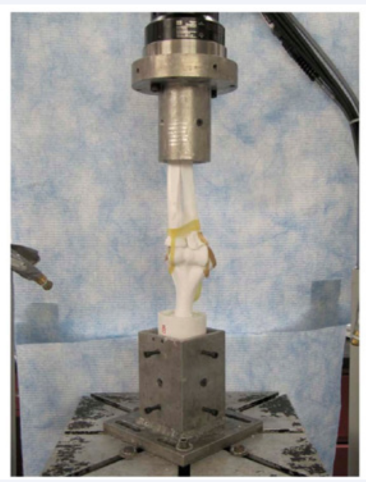

Figure 3 Depiction of "Sawbones" model.

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

Table 1: Results from biomechanical testing.

Sample Pair Number	Conditioning Relaxation(deg)		Conditioning Stiffness(N-m/deg)		Destrutive Ultimate Moment (N-m)	
N=6	Interference Screw	Docking Techinque	Interference Screw	Docking Techinque	Interference Screw	Docking Techinque
Mean	0.59+/-0.66	0.65+/-0.57	1.09+/-0.27	0.89+/-0.39	28.2+/-6.5	29.3+/-7.8
P	0.85		0.34		0.8	

screw technique. Failure resulting from graft slippage exposed a weakness in the graft - implant construct. This construct would have been stronger had bone quality not been an issue, and had a larger graft been used. In a true clinical situation we would employ larger grafts and implants, but for the sake of adequate comparison we decided to use equivalent grafts. In the clinical situation, implant and graft size would be tailored to the individual to allow for the largest graft size possible without risking bone fracture from too large of a tunnel diameter. It is also important to note that patients who normally sustain this injury are younger and bone quality is not an important factor [13]. Bone quality may have been an issue in one of the docking specimens as failure occurred from fracture of the tunnel; however, this also could have been poor tunnel placement.

The advantages of an all interference fixation for LUCL reconstruction are four-fold. First, in the docking technique construct, graft size is limited by the size of the ulnar tunnels. Creating larger tunnels to accommodate a large graft risks bone bridge fracture. A considerable advantage of an interference technique would be to employ a larger graft that may provide a stiffer construct. For ease of comparison, we tested equivalent diameters grafts, but in clinical trials we found that we can easily accommodate a larger graft with a 5.5 x 15mm implant both proximally and distally. Although the size of the interference tunnel and screw is still limited by the bony anatomy of the ulna, it is not limited to the same extent as in the traditional docking technique, which requires 2 bone tunnels in a small area. In addition, the interference screw can be more precisely placed at the actual anatomic site of insertion at the supinator tubercle. A second advantage of the interference fixation is that it can be used in revision surgery where bone tunnels have broken or are not in the correct location. Third, interference screw fixation reduces the number of drill holes necessary for graft fixation, thereby making the procedure less technically demanding. Lastly, less soft tissue dissection may reduce morbidity and allow for more rapid rehabilitation and recovery.

A disadvantage of the interference screw technique is theoretical higher cost of surgery due to the use of two implants. Although we did not study this, in our clinical experience use of this technique saves operative time and ultimately may offset implant cost.

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 docking procedure requires more extensive dissection on both the ulna and humorous, which could lead to more scarring. Also, the diameter of the graft size is limited by the amount of space available on the ulna for drilling two holes. Lastly, the docking technique is more technically demanding and in our hands requires more time to complete.

Potential shortcomings of this study include small sample size and the use of older specimens with osteoporotic bone, which does not reflect the usual age group for this clinical entity.

The optimal method of reconstruction of the LUCL has not been studied. The majority of the studies have focused on more common medial collateral ligament reconstruction techniques. Our study shows that from a biomechanics perspective the interference screw and docking methods for LUCL reconstruction are equivalent, however, given the perceived advantages and 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

1. O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am. 1991; 73: 440-446.
2. Ahmad CS, Lee TQ, ElAttrache NS. Biomechanical evaluation of a new ulnar collateral ligament reconstruction technique with interference screw fixation. Am J Sports Med. 2003; 31: 332-337.
3. Chou PH, Chou YL, Lin CJ, Su FC, Lou SZ, Lin CF. Effect of elbow flexion on upper extremity impact forces during a fall. Clin Biomech (Bristol, Avon). 2001; 16: 888-894.
4. Schneeberger AG, Sadowski MM, Jacob HA. Coronoid process and radial head as posterolateral rotatory stabilizers of the elbow. J Bone Joint Surg Am. 2004; 86-86A: 975-982.
5. Cohen MS, Hastings H 2nd. Rotatory instability of the elbow. The

anatomy and role of the lateral stabilizers. J Bone Joint Surg Am. 1997; 79: 225-233.

6. Dunning CE, Zarzour ZD, Patterson SD, Johnson JA, King GJ. Muscle forces and pronation stabilize the lateral ligament deficient elbow. Clin Orthop Relat Res. 2001; 118-124.

7. Fraser GS, Pichora JE, Ferreira LM, Brownhill JR, Johnson JA, King GJ. Lateral collateral ligament repair restores the initial varus stability of the elbow: an in vitro biomechanical study. J Orthop Trauma. 2008; 22: 615-623.

8. Rohrbough JT, Altchek DW, Hyman J, Williams RJ 3rd, Botts JD. Medial collateral ligament reconstruction of the elbow using the docking technique. Am J Sports Med. 2002; 30: 541-548.

9. Lattanza LL. Surgical treatment of posterolateral rotatory instability of the elbow in children. Tech Hand Up Extrem Surg. 2010; 14: 114-120.

10. ElAttrache NS. Ahmed CS. Arthrex Reconstruction of the Ulnar Collateral Ligament Elbow with Bio-Tenodesis System: Technique Guide. Arthrex Corporation

11. Ruland RT, Hogan CJ, Randall CJ, Richards A, Belkoff SM. Biomechanical comparison of ulnar collateral ligament reconstruction techniques. Am J Sports Med. 2008; 36: 1565-1570.

12. Nalla RK, Kruzic JJ, Kinney JH, Ritchie RO. Effect of aging on the toughness of human cortical bone: evaluation by R-curves. Bone. 2004; 35: 1240-1246.

13. Stoneback JW, Owens BD, Sykes J, Athwal GS, Pointer L, Wolf JM. Incidence of elbow dislocations in the United States population. J Bone Joint Surg Am. 2012; 94: 240-245.

14. Sanchez-Sotelo J, Morrey BF, O'Driscoll SW. Ligamentous repair and reconstruction for posterolateral rotatory instability of the elbow. J Bone Joint Surg Br. 2005; 87: 54-61.

15. Eygendaal D. Ligamentous reconstruction around the elbow using triceps tendon. Acta Orthop Scand. 2004; 75: 516-523.

16. Nestor BJ, O'Driscoll SW, Morrey BF. Ligamentous reconstruction for posterolateral rotatory instability of the elbow. J Bone Joint Surg Am. 1992; 74: 1235-1241.

17. O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am. 1991; 73: 440-446.

Cite this article

Molina RA, Bohlen H, Kwiat D, Leasure J, Buckley JM, et al. (2015) Biomechanical Evaluation of Lateral Ulnar Collateral Ligament Reconstruction Techniques. Ann Orthop Rheumatol 3(2): 1047.