A Biomechanical Evaluation of a 2-Suture Anchor Repair Technique for Thumb Metacarpophalangeal Joint Ulnar Collateral Ligament Injuries

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Abstract

Background: A complete thumb ulnar collateral ligament (UCL) repaired with 1-suture anchor has been demonstrated to be significantly weaker compared with the intact UCL. The objective of this study is to test the biomechanical strength of a 2-anchor thumb UCL repair. **Methods:** Nine paired fresh-frozen hands were used for this biomechanical analysis. One thumb from each pair was randomized to the control group and one to the repair group. In the control group, the UCL was loaded to failure in tension. In the repair group, the UCL was dissected off of the proximal phalanx, subsequently repaired with a 2-anchor technique, and then tested to failure. **Results:** The mean yield load was 342 N (95% confidence interval [CI], 215–470 N) in the control group and 68 N (95% CI, 45–91 N) in the repair group. The mean maximum load at failure was 379 N (95% CI, 246–513 N) in the control group and 84 N (95% CI, 62–105 N) in the repair group. The mean stiffness was 72 N/m (95% CI, 48–96 N/m) in the control group and 17 N/m (95% CI, 13–21 N) in the repair group. The mean displacement at failure was 7.8 mm (95% CI, 7–9 mm) in the control group and 7.8 mm (95% CI, 7–9 mm) in the repair group. **Conclusions:** The 2-anchor repair technique we tested does not acutely reestablish the strength of the insertion of the native insertion of the UCL with this technique.

Keywords: thumb ulnar collateral ligament, thumb ulnar collateral ligament injury, thumb ulnar collateral ligament repair, skier's thumb, gamekeeper's thumb

Introduction

An incidence of 50 thumb ulnar collateral ligament (UCL) injuries per 100 000 thumbs has been reported.³ Partial or complete ruptures of the thumb UCL account for 86% of all injuries that occur at the base of the thumb.¹³ In 1955, C.S. Campbell first used the term gamekeeper's thumb when he reported that gamekeepers were predisposed to developing thumb UCL laxity. He suspected that this injury occurs secondary to attritional wear resulting from repetitive valgus loading of the thumb metacarpophalangeal joint (MCP) during the execution of wounded rabbits. Although thumb UCL injuries were initially described to occur as a result of this chronic process, more recently these injuries are more likely to result in athletes from a sudden hyperextension or hyperabduction force to the thumb.^{1,2,4,8–11,15,16} Another term used to describe this injury is skier's thumb, as skiers were found to be at an increased risk for sustaining this injury during falls because of the position of the restraint strap position while holding ski poles.¹³

Thumb MCP instability resulting from a UCL injury results in decreased pinch strength, pain, and degenerative arthritis.^{14,15} Partial thumb UCL injuries are often diagnosed if valgus stress applied to the MCP results in pain and has a firm end point.¹³ Partial injuries are often successfully managed with a period of approximately 4 weeks of immobilization in a thumb spica case or splint followed by a course of hand therapy.¹³ In contrast, surgical repair of complete UCL injuries has been favored because conservative management with immobilization often results in persistent thumb pain.³

A UCL repaired with 1-suture anchor has been demonstrated to be significantly weaker compared with the intact

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Figure 1. Test setup. (a) Proper and accessory bundles of ulnar collateral ligament, (b) potted specimen, and (c) potted specimen loaded in the materials test frame.

UCL.⁷ Therefore, UCL repairs have been protected and return to full activity has been limited until there is adequate ligament healing which occurs at approximately 10 to 12 weeks.¹³ A recent investigation of a 2-anchor thumb UCL repair reported that players returned to football between 4 and 7 weeks after surgery.¹⁵ Although return to play with an orthosis designed to protect the UCL was encouraged, some players returned with taping. The purpose of this investigation was to test the biomechanical strength of this 2-anchor thumb UCL repair to determine whether the strength of this repair is closer to the strength of the intact UCL ligament. We hypothesize that this 2-anchor repair is significantly weaker than the intact UCL ligament.

Materials and Methods

Nine paired cadaveric hands were used for this biomechanical analysis. The specimens were fresh frozen and stored

in a freezer at -40 degrees Fahrenheit. From each pair, one thumb was randomized to the control group and the contralateral side was assigned to the repair group. The specimens were thawed to room temperature, and the thumb was harvested at the level of the carpometacarpal. Care was taken to dissect all the soft tissues of the thumb, leaving only the UCL attached to the first phalanx and the metacarpal (Figure 1a).

Potting of the specimens was the same in both the control and repair groups. In the control group, the metacarpal and first phalanx were potted in 5 epoxy (Smooth-Cast 300; Smooth-On, Inc, Easton, Pennsylvania) to facilitate mounting on the material testing platform.¹² The metacarpal was mounted to the base of a servohydraulic materials test frame (MTS 810, Eden Prairie, Minnesota) using an unconstrained X-Y translational platform to ensure the loads remained aligned with the UCL (Figures 1b and 1c).⁶ The proximal phalanx was attached to the actuator of the test frame using

Table 1. Structural Properties of Intact Specimen Versus Repaired Specimens.

Variable	State	Observed	Mean	SE	SD	95% CI	P value
Yield load, N	Intact	9	342.4	55.3	166.0	214.8-469.9	.0003
	Repair	9	67.5	10.0	29.9	44.5-90.5	
	Difference	9	274.9	49.5	148.5	160.8-389.0	
Maximum load, N	Intact	9	379.2	57.9	173.8	245.6-512.8	.0003
	Repair	9	83.5	9.4	28.2	61.8-105.1	
	Difference	9	295.7	54.1	162.3	171.0-420.5	
Stiffness, N/mm	Intact	9	71.7	10.4	31.2	47.7-95.7	.0002
	Repair	9	17.3	1.7	5.2	13.3-21.3	
	Difference	9	54.4	9.0	27.1	33.6-75.3	
Displacement, mm	Intact	9	7.8	0.5	1.6	6.5-9.1	.4928
	Repair	9	7.8	0.6	1.7	6.5-9.1	
	Difference	9	0.0	0.6	1.9	-1.4 to 1.5	

Note. SE = standard error; SD = standard deviation; CI = confidence interval.

a universal joint to allow unconstrained rotation in flexion/extension and abduction/adduction motion such that the mechanical axis of the ligament was held collinear with the direction of pull of the actuator. This helped ensure that the load was distributed over the entire cross-section of the UCL. Starting with a small tensile force (2 N) applied at a rate of 1 mm/s, the intact ligament was tested in tension until failure (defined as a total displacement change of 15 mm). After failure, the specimen was examined under loupe magnification and the mode and location of ligament failure was recorded.

In the repair group, the insertion of the UCL on the proximal phalanx (proper and accessory) was detached using a scalpel. The ligament was then repaired using a previously described 2-anchor repair technique where a Minilok suture anchor with 2-0 braided polyester suture (Depuy Synthes, Raynham, Massachusetts) is placed into the UCL insertion site on the proximal phalanx aiming away from the joint surface.¹⁵ This is followed by insertion of a second, Microfix suture anchor with 4-0 braided polyester suture (DePuy Synthes, Raynham, Massachusetts) adjacent to the first anchor.^{7,15} Each specimen in the repair group was then potted, prepared, and tested in the same manner as the intact group until ligament failure.

Yield load, maximum load, displacement at maximum load, and linear stiffness were determined for all specimens. Yield load represents the force at which a material begins to undergo plastic deformation. Maximum load is the highest point on the load-time curve. Linear stiffness represents the slope of the load-displacement curve between the points corresponding to 20% and 80% of the yield load.¹² Means and 95% confidence interval (CI) were computed for each outcome variable. After failure, the specimen was examined under loupe magnification and the mode and location of ligament failure was recorded as midsubstance ligament tear or ligament avulsion in the control group and as suture anchor pullout or suture failure in the repair group.

Statistical Analysis

Differences between the intact and repaired specimens for yield load (N), maximum load (N), and stiffness (N/m) were compared using a paired *t* test. A *P* value of <.05 was defined as statistically significant, a priori. Statistical analysis was performed utilizing Stat SE 14 (College Station, Texas).

Results

The mean age of the cadavers was 52.6 ± 14.9 years. The mean yield and maximum load at failure were significantly less in the repaired UCL when compared with the intact UCL (*P* = .0003; Table 1). The mean stiffness was also significantly lower in the repair group compared with the control group (*P* = .0002; Table 1). Despite difference in the loads to failure, there was no difference in the displacement to failure (*P* = .4928; Table 1).

Examination of the UCL under loupe magnification after load to failure in the control group revealed that the UCL ligament failed midsubstance in 7 (78%) of the specimens, avulsed off of the proximal phalanx in 1 specimen, and avulsed off of the metacarpal in 1 specimen (Figure 2). In the repair group, suture anchor pullout was the mode of failure in 8 (89%) of the 9 specimens. Suture failure at the junction between the anchor and the ligament occurred in the one specimen. Post hoc power analysis revealed the power was 5% for displacement to failure.

Discussion

The purpose of this investigation was to determine whether the biomechanical strength of a previously reported 2-anchor thumb UCL repair is closer to the strength of the intact UCL ligament compared with previously reported 1-anchor repairs. We hypothesized that the 2-anchor repair

Figure 2. The mode of failure for the repaired specimens was suture anchor pullout.

is significantly weaker than the intact UCL ligament. This study showed that the yield load, maximum load, and stiffness of the repair group are all significantly lower compared with the intact UCL.

Biomechanical testing of the strength of a 1-anchor thumb UCL repair has revealed that the load at failure for the repaired specimen is 30% to 60% of the intact specimen.^{5,7} Firoozbakhsh et al demonstrated that pinching generates ligament strain that could compromise a 1-anchor repair.⁵ Therefore, they indicated that pinch activities should be avoided during the rehabilitation process. Our results demonstrate that the repair group maximum load to failure was only 20% of the maximum load to failure of the intact specimen. Similar to the UCL, the anterior cruciate ligament (ACL) is a 2-bundle ligament. Fleming et al described a method to distribute tensile load over the entire ACL cross-section in mechanical testing of the ACL.⁶ We adapted this method of testing for the UCL in this study. It is possible that previous investigations may have underestimated the strength of the intact thumb UCL ligament as the method used to deliver load to cause failure did not ensure that the load was uniformly distributed throughout both the proper and accessory UCLs.

This study tested the biomechanical properties of a 2-anchor repair for thumb UCL ruptures that was reported to have been utilized in collegiate football players.¹⁵ The investigators evaluated the patients by phone, email, or mail

at an average of 6-year follow-up. The average shortened Disabilities of the Arm, Shoulder and Hand (QuickDASH) score was 1 out of 100. They reported that these players returned to football between 4 and 7 weeks after surgery. Although return to play with an orthosis designed to protect the UCL was encouraged, some players returned with taping. Our results suggest that the strength of the repair with the 2-anchor technique restores of 20% of the strength of the intact UCL. In addition, the primary mode of failure in the repair group was suture anchor pullout. These data suggest that it is not possible to reestablish the tensile strength of the insertion of the native insertion of the UCL with the tested 2-anchor repair technique. Therefore, early return to play without immobilization should not be encouraged until the ligament is adequately healed after surgery.

Our study has several limitations. First, we surgically detached the UCL from its insertion onto the proximal phalanx. This represents the most common injury pattern seen clinically, but it does not account for the full extent of a UCL injury that occurs when it encounters a sudden force that exceeds its load to failure. However, this model did allow us to reproducibly repair the UCL and test the strength of the repair. Second, the natural mechanism of injury is either ligament attrition secondary to repetitive valgus loading of the thumb MCP or, more commonly, from a sudden hyperextension or hyperabduction force to the thumb. In our investigation, we applied a longitudinal tensile force on the UCL. We adapted this method of testing because we wanted to ensure that the tensile load was distributed over the entire cross-section of both the proper and accessory UCLs. Third, our study does not account for the healing that occurs post-operatively. Fourth, although our study was underpowered to compare displacement in the repair and control groups, power analysis revealed that the power was 99% for detecting differences in yield load, maximum load and stiffness.

Our results suggest that the strength of the repair with the 2-anchor technique does not initially restore the strength of the intact UCL. Therefore, it is critical to protect the UCL until the ligament has adequately healed after repair.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

This is not a clinic investigation.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References

1. Arranz López J, Alzaga F, Molina J. Acute ulnar collateral ligament injuries of the thumb metacarpophalangeal joint: an anatomical and clinical study. *Acta Orthop Belg.* 1998;64(4):378-384.
2. Chuter GSJ, Muwanga CL, Irwin LR. Ulnar collateral ligament injuries of the thumb: 10 years of surgical experience. *Injury.* 2009;40(6):652-656.
3. Dinowitz M, Trumble T, Hanel D, et al. Failure of cast immobilization for thumb ulnar collateral ligament avulsion fractures. *J Hand Surg Am.* 1997;22(6):1057-1063.
4. Downey DJ, Moneim MS, Omer GE. Acute gamekeeper's thumb. Quantitative outcome of surgical repair. *Am J Sports Med.* 1995;23(2):222-226.
5. Firoozbakhsh K, Yi IS, Moneim MS, et al. A study of ulnar collateral ligament of the thumb metacarpophalangeal joint. *Clin Orthop Relat Res.* 2002;403:240-247.
6. Fleming BC, Spindler KP, Palmer MP, et al. Collagen-platelet composites improve the biomechanical properties of healing anterior cruciate ligament grafts in a porcine model. *Am J Sports Med.* 2009;37(8):1554-1563.
7. Harley BJ, Werner FW, Green JK. A biomechanical modeling of injury, repair, and rehabilitation of ulnar collateral ligament injuries of the thumb. *J Hand Surg Am.* 2004;29(5):915-920.
8. Heyman P, Gelberman RH, Duncan K, et al. Injuries of the ulnar collateral ligament of the thumb metacarpophalangeal joint: biomechanical and prospective clinical studies on the usefulness of valgus stress testing. *Clin Orthop Relat Res.* 1993;(292):165-171.
9. Kozin SH. Treatment of thumb ulnar collateral ligament ruptures with the Mitek bone anchor. *Ann Plast Surg.* 1995;35(1):1-5.
10. Kozin SH, Bishop AT. Gamekeeper's thumb. Early diagnosis and treatment. *Orthop Rev.* 1994;23(10):797-804.
11. Lee AT, Carlson MG. Thumb metacarpophalangeal joint collateral ligament injury management. *Hand Clin.* 2012;28(3):361-370.
12. Murray MM, Magarian E, Zurakowski D, et al. Bone-to-bone fixation enhances functional healing of the porcine anterior cruciate ligament using a collagen-platelet composite. *Arthroscopy.* 2010;26(9)(suppl):S49-S57.
13. Ritting AW, Baldwin PC, Rodner CM. Ulnar collateral ligament injury of the thumb metacarpophalangeal joint. *Clin J Sport Med.* 2010;20(2):106-112.
14. Samora JB, Harris JD, Griesser MJ, et al. Outcomes after injury to the thumb ulnar collateral ligament—a systematic review. *Clin J Sport Med.* 2013;23(4):247-254.
15. Werner BC, Hadeed MM, Lyons ML, et al. Return to football and long-term clinical outcomes after thumb ulnar collateral ligament suture anchor repair in collegiate athletes. *J Hand Surg Am.* 2014;39(10):1992-1998.
16. Zeman C, Hunter RE, Freeman JR, et al. Acute skier's thumb repaired with a proximal phalanx suture anchor. *Am J Sports Med.* 1998;26(5):644-650.