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Efficacy of a Radial-Based Thumb Metacarpophalangeal-Stabilizing Orthosis for Protecting the Thumb Metacarpophalangeal Joint Ulnar Collateral Ligament

Joseph A. Gil, MD^a, Kerry Ebert, M.Ed., OTR/L, CHT^b, Keri Blanchard, OTR/L, CHT^b, Avi D. Goodman, MD^a, Joseph J. Crisco, PhD^a, and Julia A. Katarincic, MD^a

^aBrown University, Warren Alpert Medical School, Department of Orthopaedic Surgery. 593 Eddy Street, Providence, Rhode Island, 02903

^bUniversity Orthopedics, Hand Therapy. 2 Dudley Street, Providence, Rhode Island, 02905

Abstract

Study design: Basic research (biomechanics)

Introduction: The high degree of motion that occurs at the thumb metacarpophalangeal (MCP) joint must be taken into account when immobilizing a partially torn or repaired thumb ulnar collateral ligament (UCL).

Purpose of the Study: To determine the efficacy of a low-profile functional orthosis in resisting abduction across the thumb UCL.

Methods: Ten fresh cadaveric hands were mounted to a custom board. An anteroposterior (AP) radiograph of the thumb was obtained with a 2 N preload valgus force applied to the thumb, and the angle between the K-wires was measured as a baseline. Subsequently, 20 N, 40 N, 60 N, 80 N and 100 N valgus forces were applied 15 mm distal to the MCP joint. AP radiographs of the thumb were obtained after each force was applied. The angle of displacement between the wires was measured and compared to the baseline angle. The angles were measured with an imaging processing tool. A custom low-profile functional orthosis was fashioned for each cadaveric thumb by a certified hand therapist. The above loading protocol was then repeated.

Results: The low-profile functional orthosis significantly reduced mean abduction angles at each applied load.

Conclusions: This investigation provides objective evidence that our low-profile functional orthosis effectively reduces the degree of abduction that occurs at the thumb metacarpophalangeal joint up to at least 100 N.

Keywords

orthosis; thumb ulnar collateral ligament; thumb ulnar collateral ligament repair; thumb ulnar collateral ligament injury; prevention

1. Introduction

An incidence of 50 thumb ulnar collateral ligament (UCL) injuries per 100,000 thumbs per year has been reported.¹ Thumb UCL injuries account for 86% of all traumatic injuries that occur at the base of the thumb.² In 1955, C.S. Campbell coined the term “gamekeeper’s thumb” when he attributed the attritional wear of the thumb UCL to the repetitive valgus loading of the thumb MCP that occurs during the execution of wounded rabbits.³ Another term used to describe an acute thumb UCL injury is “skier’s thumb”, because skiers have been found to be at an increased risk for sustaining this injury during falls.² More recently, acute thumb UCL injuries have been more generally associated with a hyperabduction force to the thumb MCP that occurs in athletes.^{4–12}

Persistent thumb MCP instability resulting from a UCL injury results in decreased pinch strength and pain, and leads to degenerative arthritis.^{4,13} Partial injuries are often diagnosed with a firm endpoint on valgus stress testing, and can often be successfully managed non-operatively, with approximately 4 weeks of immobilization in a thumb spica cast or orthosis, followed by a course of hand therapy.² In contrast, complete UCL injuries are best managed with surgical repair and postoperative immobilization because conservative management often results in persistent thumb pain.¹

Surgical repair of acute complete thumb UCL injuries within 3–4 weeks after injury has been associated with excellent functional outcomes.^{2,14,15} However, the repaired ligament lacks the strength of native tissue until the ligament is healed. A thumb UCL repaired with one suture anchor has been demonstrated to be significantly weaker compared to the intact UCL.¹⁶ Therefore, UCL repairs are often protected, with full return to activity avoided until adequate ligament to bone healing, which occurs at approximately 10 to 12 weeks.^{2,17} A recent investigation of a two-anchor thumb ulnar collateral ligament repair reported that players returned to football between 4 to 7 weeks after surgery without a orthosis.⁴ If adequately immobilized in a cast or orthosis, patients could potentially return to play immediately. However, skill position players, including wide receivers and quarterback in football, often cannot return with the thumb immobilized. At our institution, we allow these skill position players to return to sport at 6 weeks with a hand-based low profile functional orthosis (Figure 1).

The thumb MCP joint is a combined condyloid and ginglymus joint that allows flexion and extension, ulnar and radial deviation, and rotation.¹⁸ The high degree of motion that occurs at this joint must be taken into account when immobilizing a partially torn or repaired thumb UCL. Low profile functional orthoses have been popularized by evidence that demonstrates that allowing the thumb interphalangeal (IP) joint to remain free decreases the risk of extensor pollicis longus adhesion formation and promotes early healing ligament healing.^{19,20} The orthosis is custom made to each patient. The orthosis immobilized the MCP joint, while leaving the interphalangeal joint and thumb carpometacarpal joint (CMC) free, thereby preserving motion at these joints. In theory, the orthosis protects the repaired thumb UCL while preserving a degree of hand function. Previous investigations have examined the efficacy of thumb UCL immobilization with a forearm-based thumb UCL orthosis.²¹ However, no similar investigation has been performed to determine if using a low-profile

functional orthosis compromises the ability of the orthosis to reduce thumb UCL strain with valgus forces applied to the thumb. Accordingly, the purpose of our study was to determine the efficacy of a low-profile functional orthosis in resisting abduction across the thumb ulnar collateral ligament (UCL) and protecting it from reinjury.

2.1 Material and Methods

Ten fresh cadaveric hands (3 females, 7 males; average age 52.6 ± 14.9 years) were frozen and stored in a freezer at -40° Fahrenheit. The specimens were thawed to room temperature and the hands were harvested at the level of the proximal one-third of the forearm. An anteroposterior (AP) radiograph of the thumb was obtained in order to exclude cadaveric thumbs with preexisting arthritis.

The cadaver thumbs were prepared for testing by implanting a threaded 0.062 mm Kirschner wire (K-wire) into the proximal phalanx of the thumb. After flexing the interphalangeal joint to uncover the head of the proximal phalanx, the K-wire was percutaneously inserted from distal to proximal along its longitudinal axis. The K-wire was advanced until the K-wire just engaged, but did not breach, the base of the proximal phalanx, and left the distal aspect protruding from the first phalanx. A second 0.045 K-wire was implanted into the thumb metacarpal for reference. A wire driver was used to advance this K-wire percutaneously into the thumb metacarpal along its longitudinal axis from proximal to distal. The K-wire was advanced to the level of the metacarpal head taking care not to breach the cortex (Figure 2).

The distal radius and ulna were mounted to a custom board (Figure 3). The hand was positioned such that the dorsal surface of the thumb MCP was parallel to the board. The metacarpal heads of the index, middle, ring and small fingers were positioned such that they were stabilized while a load was applied to the thumb. A hook was mounted to the K-wire protruding from the distal end of the proximal phalanx 15 mm away from the thumb MCP joint to ensure that each load applied to the thumb generated consistent torque. Loads were applied to the MCP by attaching weights to a cable hanging over a pulley. By placing a block underneath the K-wire protruding from the distal end of the proximal phalanx, the MCP was forced to abduct in one plane of motion.

After preloading the thumb UCL with a static 100 N force for 1 minute to eliminate inherent ligament laxity, the 100 N force was removed and an anteroposterior (AP) radiograph of the thumb was obtained with a 2 N preload valgus force applied to the thumb, and the angle between the K-wires was measured as a baseline. Subsequently, 20 N, 40 N, 60 N, 80 N and 100 N valgus forces were applied to the distal K-wire. At these forces, the estimated torques applied across the MCP joint were 0.3 N-m, 0.6 N-m, 0.9 N-m, 1.2 N-m, and 1.5 N-m, respectively. AP radiographs of the thumb were obtained after each force was applied. The angle of displacement between the wires was measured and compared to the baseline angle. The angles were measured with ImageJ (<https://imagej.nih.gov/ij/>), an imaging processing tool made available by the National Institutes of Health. A custom low-profile functional orthosis, fabricated with 1/16" non-perforated thermoplastic material (Rolyan Aquaplast Thermoplastic Material, Patterson Medical, Warrenville, IL) immobilizing the thumb MCP but leaving the carpometacarpal and interphalangeal joints free, was fashioned for each

cadaveric thumb by a certified hand therapist. The orthosis material was heated in a orthosis pan with water temperature at approximately 154° F until material was pliable, and then molded to each cadaveric hand. The orthosis was secured to the hand with KinesioTape. The above loading protocol was then repeated. There were no ligament failures in any of the control or immobilized specimens.

2.2 Statistical Methods

A repeated measures 2-way (load x condition) ANOVA with a post-hoc Sidak's multiple comparisons test was performed to assess mean differences in the abduction angle between the control and immobilized specimens at each applied load. A *p* value of <0.05 was defined as statistically significant, *a priori*. Statistical analysis was performed utilizing Stata SE 14 (College Station, Texas).

3. Results

The mean thumb MCP abduction of the control group was 15.9 ± 9.2 degrees with a 2 N force, 25.6 ± 12.5 degrees at a 20 N force, 28.1 ± 13.0 degrees at a 40 N force, 31.0 ± 12.4 degrees at a 60 N force, 32.0 ± 12.8 degrees at an 80 N force, and a 33.0 ± 13.2 degrees at a 100 N force (Table 1). The mean normalized thumb MCP abduction of the immobilized group was 6.6 ± 6.8 degrees at a 2 N force, 14.7 ± 7.2 degrees at a 20 N force, 18.1 ± 8.0 degrees at a 40 N force, 21.0 ± 8.0 degrees at a 60 N force, 22.0 ± 8.0 degrees at an 80 N force, and 24.0 ± 8.2 degrees at a 100 N force (Table 1). No ligament failures occurred in either the control or immobilized groups.

The low-profile functional orthosis significantly reduced mean abduction angles at each applied load ($P < 0.05$). There was 41% reduction in abduction angle at 20 N, 35% reduction at 40 N, 31% reduction at 60 N, 30% reduction at 80 N, and 25% reduction at 100N (Figure 4).

4. Discussion

The primary objective of this investigation was to determine if a low-profile functional orthosis significantly reduces abduction, and thereby indirectly reduces strain, of the thumb MCP UCL up to 100 N. We found that our orthosis, despite being hand-based and leaving the thumb IP and CMC joints free, significantly reduced mean abduction angles at each applied load. We have previously demonstrated that the maximum load to failure of a repaired UCL is 84 N; therefore, this orthosis effectively protects the UCL up to at least 100 N after UCL repair. This investigation provides objective evidence that our low-profile functional orthosis provides a protective effect at the thumb MCP UCL. Additionally, the protective effect conferred by applying a functional orthosis may allow early return to work and sport; however, this must be verified with additional investigations that examine how thumb UCL strain corresponds to the thumb MCP abduction angle.

There are several limitations of this investigation. First, repeating loading of the thumb UCL could have stretched the ligament. To minimize this effect, each thumb UCL was preloaded with 100 N for 1 minute prior to testing. In this initial investigation, the maximum force that

was applied to the thumb MCP joint was 100 N. We have previously demonstrated that the maximum load to failure of a repaired UCL is 84N; therefore, we can infer that this orthosis effectively protects the repaired UCL up to at least 100 N. Nevertheless, future research needs to be performed to determine the force at which the orthosis fails to provide a protective effect. Third, this cadaveric model does not account for additional strength generated by the healing process. Fourth, our model forces the thumb to abduct in one plane of motion; however, this is consistent with the mechanism of injury for UCL ruptures.

Immediate return to play after a thumb UCL repair is allowed in a thumb spica cast or orthosis.² In contrast, if the player's position requires a orthosis-free hand, return to play is delayed three months, which allows sufficient time for ligament-to-bone healing. This population of athletes includes skill position players, including quarterbacks and wide receivers, who often cannot return to sports with a bulky orthosis or cast, but may be allowed to return to sport earlier than the full healing period with a low-profile orthosis. In these cases, players are taped, or, in our institution, immobilized with this low-profile orthosis and are allowed to return to sport at 6 weeks after injury.

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Figure 1:
Clinical photograph of the tested orthosis.

Figure 2:

The cadaver thumbs were prepared for testing by implanting a threaded 0.062 mm Kirschner wire (K-wire) into the proximal phalanx of the thumb (P1). A second 0.045 K-wire was implanted into the thumb metacarpal (MC) for reference.

Figure 3:

The distal radius and ulna were mounted to a custom board. The dorsal surface of the thumb MCP was parallel to the board. The metacarpal heads of the index, middle, ring and small fingers were positioned such that they were stabilized while a load was applied to the thumb. A hook was mounted to the K-wire protruding from the distal end of the proximal phalanx 15 mm away from the thumb MCP joint to ensure that each load applied to the thumb generated consistent torque.

Figure 4:

The low-profile functional orthosis significantly reduced mean abduction angles at each applied load ($P < 0.05$). There was 41% reduction in abduction angle at 20 N, 35% reduction at 40 N, 31% reduction at 60 N, 30% reduction at 80 N, and 25% reduction at 100 N (Figure 3).

Table 1:

Degrees of Abduction with each force applied.

	2 N	20 N	40 N	60 N	80 N	100 N
Unsplinted						
Test 1	10.5	17.7	21.6	22.8	24.1	24.8
Test 2	14.7	27.0	30.2	30.9	29.7	27.7
Test 3	16.7	27.3	31.1	32.3	30.1	31.4
Test 4	4.3	12.8	12.6	30.0	35.1	36.7
Test 5	19.6	27.7	27.6	29.9	30.2	30.5
Test 6	7.7	11.0	14.1	14.2	13.9	14.2
Test 7	5.6	10.4	12.2	12.7	14.3	14.7
Test 8	21.6	37.3	39.4	40.5	42.4	43.2
Test 9	30.8	43.8	47.2	50.1	51.7	52.6
Test10	28.3	41.3	44.6	46.5	48.3	49.8
Average±SD (95% CI)	16.0±9.2 (10.3–21.7)	12.5±12.5 (17.9–33.3)	28.1±13.0 (20.0–36.1)	31.0±12.4 (23.3–38.7)	32.0±12.8 (24.0–39.9)	32.6±13.2 (24.4–40.8)
Splinted						
Test 1	2.8	10.9	13.9	17.3	16.8	19.8
Test 2	2.6	7.7	12.3	17.1	17.3	21.7
Test 3	0.1	18.4	27.0	30.6	31.0	31.6
Test 4	0.1	5.7	6.0	10.9	13.2	14.4
Test 5	6.7	14.6	19.3	20.9	21.5	23.6
Test 6	10.1	13.6	15.1	14.6	16.8	17.2
Test 7	1.2	7.0	9.7	11.8	12.0	13.3
Test 8	20.0	25.9	27.6	29.9	31.8	34.3
Test 9	15.8	25.7	29.1	32.7	33.8	36.6
Test10	7.0	17.5	21.0	23.9	25.5	27.7
Average±SD (95% CI)	6.6±6.8 (2.4–10.9)	14.7±7.2 (10.2–19.2)	18.1±8.0 (13.1–23.1)	21.0±8.0 (16.0–25.9)	22.0±8.0 (17.0–26.9)	24.0±8.2 (18.9–29.1)