A New Technique for Volar Capsulodesis for Isolated Palmar Scapholunate Interosseous Ligament Injuries: A Cadaveric Study and Case Report

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Abstract

Introduction Most surgical techniques for scapholunate interosseous ligament (SLIL) repair address only the dorsal component of the ligament, potentially leading to high surgical failure rates. We introduce a new technique to reconstruct the volar SLIL using a portion of the long radiolunate ligament (LRL). A biomechanical evaluation was performed to evaluate the rupture strength of this repair, and a subsequent anatomic study was performed to verify that this repair would not compromise the blood supply to either the scaphoid or the lunate.

Methods A reconstruction of the volar SLIL was developed utilizing a lunate-based strip of the LRL. Fourteen cadaver arms were injected with red-colored epoxide and latex. The blood supply of the volar wrist capsule was dissected. The vascular supply to the ligaments, scaphoid, and lunate were investigated. The biomechanical strength of this reconstruction was tested on five cadaver arms by potting the scaphoid, lunate, and radius and subjecting the repair to a tensile load using a servohydraulic vertical displacement testing machine.

Results In all arms, a branch of the radial artery or radiocarpal arch supplied the radioscapolunate ligament at the medial border of the LRL. The proximal half of the scaphoid was supplied by dorsal branches of the radial artery. In all cases, a vessel entered the lunate on its ulnar volar side, away from the repair. The average strength of the intact LRL strip was 97.4 N, and the average strength of the ligament-suture interface used for the capsulodesis was 43.5 N.

Conclusion This volar approach to the SLIL does not compromise the vascularity of the scaphoid or the lunate. This approach allows the possibility of repairing or augmenting the volar SLIL. The strength of this repair appears to be less than the strength of the native SLIL. Further clinical studies are warranted.

Keywords

- scapholunate instability
- scapholunate injury
- wrist pain
- capsulodesis

Scapholunate (SL) instability has been recognized as the most common ligamentous injury of the carpus. If left untreated, the dissociation between the scaphoid and the lunate will ultimately lead to further collapse of the proximal and distal

carpal rows and subsequent degenerative change.^{1,2} The cause of injury to the SL interosseous ligament (SLIL) is typically a fall on the outstretched, ulnarly deviated hand.³ It is presumed that this mechanism results in elongation and

tearing of the volar SLIL, followed by elongation and tearing of the membranous and dorsal portions of the SLIL. Progression of ligamentous damage causes SL diastasis and rotatory subluxation of the scaphoid. The altered carpal kinematics cause increased stress on the articular contact surfaces of the radial fossa, capitate, and trapezium, leading to degenerative changes.^{4,5}

The dorsal SLIL has been shown to be an important stabilizer of the SL joint,^{6–8} but the volar radiocarpal ligaments also play a major role in scaphoid stability.^{3,9–12} Unfortunately, most surgical reconstructions address only the dorsal component of the SLIL. A common example is SLIL reconstruction via a dorsal capsulodesis utilizing the dorsal intercarpal ligament. Although short-term results appear satisfactory, long-term studies suggest that loss of SL reduction and radiographic deterioration are common.^{13–15}

Several authors have recognized the importance of the volar ligaments on SLIL repair. Various volar or combined volar and dorsal approaches have been described, with good or promising results.^{16–18} Some require an invasive midcarpal approach and are technically demanding.¹⁸ Other potential hazards of a dorsal and volar approach include the potential compromise of the blood supply to the lunate and the scaphoid, potentially compromising or preventing SLIL healing. We have developed a new technique utilizing a less invasive modified Henry approach to expose the volar SL interval. This technique involves the use of the long radiolunate (LRL) ligament to repair or reinforce the volar SLIL if injured. We report the results of an anatomical and biomechanical investigation of our technique, together with a preliminary case report.

Materials and Methods

Surgical Technique

A volar SLIL capsulodesis utilizing a lunate-based strip of the long radiolunate ligament (LRL) was developed based on previous anatomic dissection of the volar carpus (►Fig. 1a,b). This reconstruction was performed on five fresh frozen cadaver wrists. The volar capsule was visualized through a small modified Henry approach. A longitudinal incision over the flexor carpi radialis (FCR) tendon was carried proximally for 3 cm proximal to the scaphoid tubercle. Care was taken to identify the palmar cutaneous branch of the median nerve, which was retracted ulnarly with the flexor tendons and median nerve. Care was also taken to protect the radial artery and its venae comitantes on the radial aspect of the FCR tendon sheath. The FCR tendon sheath is incised longitudinally to expose the FCR tendon, and the FCR tendon was retracted radially to reveal the floor of the FCR tendon sheath. A longitudinal incision was made through the floor of the FCR tendon sheath to reveal the distal margin of the pronator quadratus muscle. An incision was made along its distal margin, exposing the volar radiocarpal wrist capsule. The space of Poirier was opened to separate the LRL and radioscapocapitate (RSC) ligaments (►Fig. 2a,b). The LRL was divided in half, in line with the transverse fibers (►Fig. 3). The distal half was cut laterally from its attachment to the radius, allowing for inspection and débridement of the SL joint. The SL joint was then reduced and pinned percutaneously. The distal LRL strip that was previously separated from the radius was rotated distally toward the scaphoid. It was then sutured under tension to a titanium suture anchor

Fig. 1 Artist rendition of the technique for LRL ligament capsulodesis for augmentation or repair of volar SLIL. (a) The distal half of the LRL ligament is left attached to the lunate and split in line with its fibers. (b) The distal portion of the ligament is then attached to the scaphoid via suture anchor to recreate the vector pull of the volar SL ligament.

Fig. 2 Cadaveric images showing the surgical approach to the volar carpus. (a) Pronator (proximally) and the volar margin of the distal radius. The lunate lies in the left central aspect of the image. The fibers of the LRL ligament can be found just distal to the volar lip of the radius. (b) Branch of the radial artery, which often pierces the volar capsule at the level of the SL interval. Clinically this branch of the artery helps the surgeon identify the fibers of the LRL ligament. The relationship between the RSC ligament and LRL ligament can be seen in this dissection. FCR, flexor carpi radialis; L, lunate; LRL, long radiolunate ligament; RSC, radioscaphocapitate ligament; S, scaphoid.

(Arthrex Inc, Naples, FL, USA) placed in the proximal pole of the scaphoid (►Fig. 4).

Anatomic Evaluation

Ten cadaveric upper extremities were amputated at the mid-humerus (six fresh frozen, four embalmed). None of the specimens utilized in this study had a history of upper extremity trauma or surgery. In each specimen, the brachial artery was cannulated and irrigated with tap water until backflow was achieved. Fabric softener was added to the tap water to increase patency of the arteries. The brachial arteries

were then injected with colored Araldite CY 221 epoxy resin mixture (Huntsman Advanced Materials, The Woodlands, Texas, USA) until the palm and fingertips displayed a red appearance. The upper extremities were then refrigerated for 24 hours.

Under loupe magnification, the radial artery and its branches to the volar wrist capsule were carefully dissected. In addition, the contributions of the anterior interosseus artery and ulnar artery to the volar wrist capsule were investigated. A window in the volar wrist capsule was created to allow visualization of the arterial contributions to the SL

Fig. 3 Cadaveric dissection showing the split created in line with the LRL ligament fibers. The lunate and scaphoid can be seen immediately below the ligament. The distal half of the LRL ligament is divided and left attached to the lunate.

Fig. 4 The LRL ligament is split and the distal half is cut laterally and sutured to the proximal pole of the scaphoid (Sc) with a suture anchor. L, lunate.

Fig. 5 Anatomic dissection of carpal ligaments with preservation of volar blood supply. Image shows typical representation from cadaveric dissections. The blood supply to the volar aspect of the scaphoid and lunate were not compromised by dissecting the distal half of the LRL ligament.

ligament. This was achieved by sharply dissecting and separating the LRL and RSC ligaments.

Four additional fresh frozen cadaveric upper extremities amputated at the mid-humerus underwent brachial artery cannulation and irrigation with tap water until backflow was achieved. The brachial arteries were then injected with Red Latex (Wards Natural Science, Rochester, NY, USA) until the palm and fingertips displayed a red appearance. The upper extremities were then stored in the freezer for 2–3 days.

After thawing, a superficial dissection of the main branches of the radial artery to the volar wrist capsule was performed under loupe magnification. Following identification of the radial artery and its branches, the skin, subcutaneous tissue, muscles, and tendons were removed, and the hands were submerged in a bleach bath to digest the surrounding soft tissue. In this way, the capsular and ligamentous vasculature could be visualized directly without overlying soft tissue (►Fig. 5).

Biomechanical Testing

To evaluate the strength of the repair, all superficial skin, subcutaneous tissue, muscle, and tendons were removed, revealing the wrist capsule, ligaments, and carpal bones below. The lunate, scaphoid, and a portion of the radius connected to the intact half of the LRL were separated from the remaining carpus and forearm bones and potted in polycarbonate cylinders with polymethyl methacrylate (PMMA). The cylinders were mounted in a servohydraulic vertical displacement testing machine (MTS 858 Mini Bionix II, MTS Systems, Inc., Eden Prairie, MN, USA) with a 100-lb load-cell, allowing a tensile load to be placed directly at the SL articulation at the ligamentous reconstruction

site. The repair was tested load-to-failure at 5 mm/s. (►Fig. 6)

Results

In all dissected cadaver upper extremities, the radial artery was found to contribute to the volar radiocarpal arch, which lay within the wrist capsule. The radial artery consistently supplied a vascular branch that coursed between the short and long radiolunate ligaments to supply the radioscapholunate ligament (ligament of Testut) (►Fig. 5). Arterial blood supply to the radiocarpal ligaments was found to originate proximally from the volar radiocarpal arch and distally from the intercarpal arch. The scaphoid was observed to receive its blood supply from the dorsal carpal branch of the radial artery dorsally and the superficial palmar branch of the radial artery volar-laterally. No branches were seen on the volar aspect of the proximal scaphoid (►Fig. 5). The lunate was found to have a volar supplying branch that originated from the radiocarpal arch at the level of the anterior interosseous artery. None of the aforementioned branches were violated with the modified volar Henry approach to the carpus or our palmar SLIL reconstruction utilizing a proximal strip of the LRL.

The average strength of the proximal intact strip of the LRL ligament was 97.4 N (range 60.9–178.6). The bone anchor failed in two occasions, in which case the anchor was clamped and the test was repeated. The average strength of the ligament-suture interface was 43.5 N (range 26.8–81.3).

Clinical Example

A 20-year-old male collegiate American football offensive lineman presented with wrist pain at extremes of flexion and extension and a feeling of wrist instability with pushing and lifting activities. Pain was present over the SL interval dorsally with wrist flexion, and the Watson maneuver was painful and suggested increased laxity compared with the

Fig. 6 Servohydraulic vertical displacement testing machine with 100-lb load cell before test load-to-failure at volar SL reconstruction site.

contralateral wrist. Magnetic resonance imaging (MRI) was suggestive of volar SL tear. Plain radiographs were not suggestive of static SL injury (►Fig. 7a,b). Arthroscopy revealed a Geissler III instability pattern with hemorrhage and a tear seen within the volar portion of the ligament (►Fig. 7c). The wrist was surgically approached dorsally, verifying that the dorsal ligament was intact but the scaphoid and lunate were seen to gap volarly when an elevator was placed into the SL interval. The volar approach and elevation of the LRL flap were performed as described (►Fig. 7d). The volar ligament was found to be disrupted (►Fig. 7e). A single suture anchor was used to attach the LRL to the waist of the scaphoid. The dorsal capsule was repaired with suture anchors (►Fig. 7f,g). The patient had the SL joint pinned for 6 weeks. The patient maintained excellent motion with wrist flexion of 60 degrees and extension of 70 degrees (►Fig. 7h,i). He was able to

complete his collegiate career and continues to have no wrist pain 36 months after surgery.

Discussion

SL dissociation remains a difficult clinical problem. Despite many proposed surgical interventions, the ideal treatment remains elusive. Many soft tissue reconstructions initially achieve near-anatomic restoration of carpal alignment and have satisfactory short-term results; unfortunately, with long-term follow-up, these same patients show signs of recurrent instability. Currently, it is unknown what the effects of this radiographic instability are on clinical outcome; however, given the fact that a large number of these patients are young and active adults, it is concerning that many may develop painful arthritis later in life.

Fig. 7 A clinical case of a volar repair using the LRL capsulodesis in a 20-year-old male patient. (a,b) Anteroposterior (AP) and lateral radiographs showing no sign of static SLIL instability. (c) Arthroscopic view of the SL interval through the radial midcarpal portal, showing increased gapping at volar margin of the ligament. (d) Surgical incision used to expose the volar carpus. (e) Tear in volar SL ligament with capsular flap elevated. (f,g) AP and lateral radiographs showing the patient's wrist at 3 years following surgery with stable SL angle and no diastasis. The volar anchor can be seen on the lateral radiograph. Additional suture anchors can be seen in the ulnar head from a concomitant triangular fibrocartilage complex (TFCC) repair as well as the lunate and triquetrum, which were placed to repair the dorsal capsule. (h,i) Evidence of excellent wrist function and no pain. Abbreviations: L, lunate; S, scaphoid.

The majority of soft tissue procedures used to treat SLIL injury primarily focus on the repair of the dorsal SLIL and are performed through a dorsal approach to the carpus. Although the dorsal component of the SLIL has the greatest yield strength and functions as an important constraint against translation and rotation, the volar SLIL is also an important contributor to the rotational stability of the SL joint.¹⁹ Furthermore, although biomechanical studies have demonstrated the SLIL to be the primary stabilizer of the SL joint,^{6–8} the SLIL does not perform this role in isolation. Several secondary stabilizers of the SL joint are important for the maintenance of SL kinematics. The “V” arrangement of the dorsal intercarpal (DIC) and dorsal radiocarpal (DRC) ligaments has been shown to help stabilize the scaphoid and lunate during repetitive wrist motion.⁸ The palmar ligamentous structures also contribute to secondary SL stability.^{3,9–12}

In a study by Meade et al,¹¹ selective sectioning of cadaveric carpal ligaments revealed a larger radiographic change in SL angle and SL interval after sectioning of the radiocarpal ligament (RCL), compared with the dorsal and volar SL ligaments. Interestingly, comparable increases in SL angle and SL interval were observed after sectioning of the volar and dorsal SLIL.¹¹ Short et al demonstrated that static instability can exist with an intact DIC ligament when the SLIL and RSC and scaphotrapeziotrapezoid (STT) ligaments have been sectioned.⁷ It has also been shown that after sectioning the SLIL and DRC ligament, an isolated dorsal capsulodesis utilizing the DIC ligament does not provide adequate stabilization.⁸ These findings suggest that a dorsal reconstruction alone may not be sufficient to restore and maintain carpal kinematics.

Brunelli and Brunelli²⁰ described a tenodesis technique that utilizes a slip of the FCR tendon that is tunneled through the distal scaphoid and secured to the dorsal distal radius. More recently, triligament tenodeses have been introduced to reconstruct the dorsal SL ligament, scaphotrapeziotrapezoid (STT) ligament, and DRC ligament with a strip of the FCR tendon.²¹ The radiographic results of this reconstruction suggest that it is more durable than dorsal capsulodesis.²² In our experience, diastasis can recur after this reconstruction. It is possible that this more rigorous reconstruction allows for better maintenance of carpal alignment in the short term but that the material properties of the tendon graft allow it to degenerate and stretch over time.

In efforts to circumvent problems with dorsal repairs, several authors have recognized the importance of reconstruction of the volar ligaments. Conyers¹⁶ used an extended carpal tunnel incision to repair the palmar SLIL and imbricate the extrinsic radiocarpal ligaments. The dorsal SLIL was not repaired. At an average follow-up of 1.6 years, 22 of 28 patients had an SL gap of less than 3 mm, an increase in SL angle of less than 10 degrees, and minimal or absent pain.¹⁶ Dunn and Johnson¹⁸ proposed reconstruction of the volar SLIL, LRL ligament, and RSC ligament with FCR autograft, combined with direct repair of the dorsal SLIL. Although no clinical results have been published on this reconstruction, the authors report improvements in scapholunate diastasis and scapholunate angle in a cadaveric model.¹⁸ They believe that reconstruction of the RSC ligament prevents dorsal

migration of the capitate and acts as a sling that restricts scaphoid flexion. They also believe that reconstruction of the volar SLIL and LRL ligament may prevent lunate extension.²⁰ In a series of six patients, Marcuzzi et al¹⁷ used combined volar and dorsal approaches to directly repair the volar and dorsal SLIL. They report good clinical and radiographic outcome in five patients at an average follow-up of 32 months. One patient who did not follow the post-operative rehabilitation protocol had a poor outcome.

As observed with static scapholunate dissociation, we believe that predynamic and dynamic scapholunate dissociation can also lead to pain, disability, and progress to radiocarpal and midcarpal arthritis. Although changes are often difficult to detect on plain radiographs, the absence of palmar ligamentous connections between the scaphoid and the lunate may allow the volar SL joint to become wedged open by the proximal force of the capitate. A step-off may be present at the midcarpal joint during various phases of wrist motion, causing abnormal stresses at the articular surfaces. The altered carpal contact kinematics can lead to degenerative change.

In our technique, the radiocarpal ligaments were tightened and the volar SL ligament was reconstructed. We found the average strength of the proximal intact strip of the LRL ligament to be 97.4 N. This is comparable to previously reported yield strength of the intact palmar SLIL of 117.9 N from our institution.¹⁹ While the strength of a separate ligament strip appears to be less than the strength of the native volar SLIL reported in literature, we believe that our repair functions to restrict the dorsal translation of the scaphoid proximal pole within the scaphoid fossa, prevents gapping at the volar SL joint, and may prevent progressive dissociation of the scaphoid and lunate.

As supported by previous anatomical investigations,^{23–25} we observed that the intraosseous blood supply to the scaphoid originates principally from the dorsal carpal branch of the radial artery dorsally and the superficial palmar branch of the radial artery volar-laterally. Arterial blood supply to the lunate was found to originate volarly from the radiocarpal arch, while the radiocarpal ligaments were supplied by the volar radiocarpal and intercarpal arches. None of these branches were violated with our palmar SLIL reconstruction utilizing a proximal strip of the LRL. We believe our approach does not jeopardize the vascularity to the scaphoid or lunate.

We emphasize the importance of anatomic restoration. Our technique utilizes a less extensive volar approach without sectioning of the transverse carpal ligament. This technique can be used for all stages of SL instability: in isolation for patients with a volar SLIL tear to prevent progression of instability, or combined with a dorsal reconstruction in more advanced stages. The same volar incision is used as is described for the triligament tenodesis, providing an ideal situation for combining the two procedures. We are currently testing the volar SLIL reconstruction in vivo, both for isolated volar SL ligament tears and in combination with dorsal reconstruction for complete ruptures. We would caution against using this repair in cases where there is a fixed dorsal

intercalated segment instability (DISI) deformity, as the integrity of the LRL ligament may be compromised.

Conflict of Interest

None

References

- 1 Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. *J Hand Surg Am* 1984; 9(3):358–365
- 2 Taleisnik J. Current concepts review. Carpal instability. *J Bone Joint Surg Am* 1988;70(8):1262–1268
- 3 Mayfield JK. Patterns of injury to carpal ligaments. A spectrum. *Clin Orthop Relat Res* 1984;(187):36–42
- 4 Blevens AD, Light TR, Jablonsky WS, et al. Radiocarpal articular contact characteristics with scaphoid instability. *J Hand Surg Am* 1989;14(5):781–790
- 5 Watson HK, Weinzwieg J, Zeppieri J. The natural progression of scaphoid instability. *Hand Clin* 1997;13(1):39–49
- 6 Short WH, Werner FW, Green JK, Masaoka S. Biomechanical evaluation of ligamentous stabilizers of the scaphoid and lunate. *J Hand Surg Am* 2002;27(6):991–1002
- 7 Short WH, Werner FW, Green JK, Masaoka S. Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate: part II. *J Hand Surg Am* 2005;30(1):24–34
- 8 Short WH, Werner FW, Green JK, Sutton LG, Brutus JP. Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate: part III. *J Hand Surg Am* 2007;32(3):297–309
- 9 Berger RA, Blair WF, Crowninshield RD, Flatt AE. The scapholunate ligament. *J Hand Surg Am* 1982;7(1):87–91
- 10 Mitsuyasu H, Patterson RM, Shah MA, Buford WL, Iwamoto Y, Viegas SF. The role of the dorsal intercarpal ligament in dynamic and static scapholunate instability. *J Hand Surg Am* 2004;29(2):279–288
- 11 Meade TD, Schneider LH, Cherry K. Radiographic analysis of selective ligament sectioning at the carpal scaphoid: a cadaver study. *J Hand Surg Am* 1990;15(6):855–862
- 12 Garcia-Elias M, Vall A, Salo JM, Lluch AL. Carpal alignment after different surgical approaches to the scaphoid: a comparative study. *J Hand Surg Am* 1988;13(4):604–612
- 13 Gajendran VK, Peterson B, Slater RR Jr, Szabo RM. Long-term outcomes of dorsal intercarpal ligament capsulodesis for chronic scapholunate dissociation. *J Hand Surg Am* 2007;32(9):1323–1333
- 14 Szabo RM, Slater RR Jr, Palumbo CF, Gerlach T. Dorsal intercarpal ligament capsulodesis for chronic, static scapholunate dissociation: clinical results. *J Hand Surg Am* 2002;27(6):978–984
- 15 Moran SL, Cooney WP, Berger RA, Strickland J. Capsulodesis for the treatment of chronic scapholunate instability. *J Hand Surg Am* 2005;30(1):16–23
- 16 Conyers DJ. Scapholunate interosseous reconstruction and imbrication of palmar ligaments. *J Hand Surg Am* 1990;15(5): 690–700
- 17 Marcuzzi A, Leti Acciaro A, Caserta G, Landi A. Ligamentous reconstruction of scapholunate dislocation through a double dorsal and palmar approach. *J Hand Surg [Br]* 2006;31(4):445–449
- 18 Dunn MJ, Johnson C. Static scapholunate dissociation: a new reconstruction technique using a volar and dorsal approach in a cadaver model. *J Hand Surg Am* 2001;26(4):749–754
- 19 Berger RA, Imeada T, Berglund L, An KN. Constraint and material properties of the subregions of the scapholunate interosseous ligament. *J Hand Surg Am* 1999;24(5):953–962
- 20 Brunelli GA, Brunelli GR. A new surgical technique for carpal instability with scapho-lunar dislocation. (Eleven cases) [in French]. *Ann Chir Main Memb Super* 1995;14(4-5):207–213
- 21 Van Den Abbeele KLS, Loh YC, Stanley JK, Trail IA. Early results of a modified Brunelli procedure for scapholunate instability. *J Hand Surg [Br]* 1998;23(2):258–261
- 22 Moran SL, Ford KS, Wulf CA, Cooney WP. Outcomes of dorsal capsulodesis and tenodesis for treatment of scapholunate instability. *J Hand Surg Am* 2006;31(9):1438–1446
- 23 Berger RA, Kauer JMG, Landsmeer JMF. Radioscapholunate ligament: a gross anatomic and histologic study of fetal and adult wrists. *J Hand Surg Am* 1991;16(2):350–355
- 24 Freedman DM, Botte MJ, Gelberman RH. Vascularity of the carpus. *Clin Orthop Relat Res* 2001;(383):47–59
- 25 Kuhlmann JN, Guérin-Surville H, Boabighi A. Vascularisation of the carpus, a systematic study. *Surg Radiol Anat* 1988;10(1):21–28