Assessment of Flexion Elongation Relation and Type of Failure after Capsulodesis

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J Wrist Surg 2020;9:382–387.

Abstract

Background Injury of the scapholunate interosseous ligament is the most frequently diagnosed cause of carpal instability and can be treated with a Mayo capsulodesis procedure. During this procedure, a radially based flap of the dorsal radiocarpal complex is attached to the lunate. The procedure attempts to reduce flexion of the scaphoid and restore the scapholunate relationship by crossing the scapholunate interval. To obtain a better understanding of the biomechanical properties and possibly improve the postoperative rehabilitation process, a better understanding of the reconstructions biomechanics is needed.

Methods Ten dorsal intercarpal ligament capsulodesis were performed on embalmed wrists to assess the flexion elongation relation at the dorsal intercarpal reconstruction, the dorsal intercarpal complex, and the type of failure during flexion of the wrist.

Results The mean elongation of the dorsal intercarpal reconstruction at 70-degree flexion was 0.8 mm. During flexion, the dorsal intercarpal reconstruction showed no ligament tears or failure of the bone anchor. The mean elongation of the dorsal intercarpal complex was 3.9 mm at 70 degrees. During subsequent repeated flexion, four sutures to connect the dorsal intercarpal complex to the surrounding tissue loosened between 55 and 60 degrees.

Conclusions These findings suggest that capsulodesis can safely withstand flexion of the wrist until 50 degrees.

Clinical Relevance Clinicians should consider the opportunity to start early with controlled active motion.

Level of Evidence Not applicable.

Keywords
- biomechanics
- capsulodesis
- scapholunate interosseous ligament (SLIL)
- SL-ligament

Injuries of the scapholunate interosseous ligament (SLIL) are the most frequently diagnosed cause of carpal instability.[1] Usually, this injury is the result of a fall onto an outstretched hand with the wrist in extension, ulnar deviation, and intercarpal supination.[2] The SLIL ruptures can result in painful carpal instability and progression into a predictable pattern of degenerative osteoarthritis better known as scapholunate advanced collapse (SLAC).[3] To treat pain and

received
July 14, 2019
accepted
February 13, 2020
published online
April 16, 2020

DOI https://doi.org/10.1055/s-0040-1708861.
ISSN 2163-3916.

instability and prevent progression into a SLAC wrist, numerous surgical methods have been proposed.[4–6] In 1987, Blatt introduced a method using a part of the dorsal intercarpal capsule to attach on the radius.[7] This capsulodesis method has been modified by attaching the dorsal intercarpal reconstruction (DIR) at the surface of the lunate, also known as the Mayo capsulodesis.[8,9] The capsulodesis attempts to limit scaphoid flexion and restore the relationship between the scaphoid and lunate by attaching the distal pole to the lunate by a dorsal capsule flap.

Previous studies showed improvement in pain and stability after capsulodesis and 58% patient's satisfaction rate over 5 years follow-up.[10,11] Nevertheless, disadvantages of capsulodesis are postoperative lack of wrist flexion, minimal improvement in radiographic parameters, and the inability to preserve radiographic improvement at long-term follow-up.[10,12]

Patients are generally immobilized in cast to protect the capsulodesis, while immobilization of the wrist results in stiffness and atrophy. However, if movement of the wrist does not damage the surgical reconstruction, early active motion after surgery might be possible.

Therefore, the surgical reconstruction needs to be studied.

The aim of this study on anatomic specimens was to determine the palmar flexion elongation relation of the DIR and the dorsal intercarpal complex (DIC), and, to study the ability of the capsulodesis to withstand flexion without failing.

Methods

Ten wrists were embalmed according to the AnubiFiX (AnubiFiX, Rotterdam, The Netherlands) method. This method preserves tissue and joint flexibility and can therefore be a representation of normal biomechanics.[13,14] Three female and seven male wrists with a mean age of 86.8 years (range: 72–100) were used, of which three were left and seven right. All specimens were visually examined by an orthopaedic surgeon for evidence of pre-existing lesions or prior surgery of the wrist. All arms were disarticulated at the elbow joint. Ten dorsal intercarpal ligament capsulodesis procedures were performed by one orthopaedic surgeon according to the same surgical protocol.

Surgical Technique

During the entire surgical procedure, the wrist was placed in neutral position.

A longitudinal incision of 4 cm starting 1 cm ulnar of Lister's tubercle was made. The extensor retinaculum was opened following the course of the third extensor compartment. Then the fourth extensor compartment was opened (►**Fig. 1A**). The carpal bones were exposed following the Berger et al's approach[8] the incision started at the scaphotrapeziotrapezoid joint and moved ulnar until the dorsal ridge of the triquetrum. At the triquetrum, the incision took a proximal oblique course following the fibers of the dorsal radiocarpal ligament until the center of the lunate fossa. The radially based flap of capsule was tangentially elevated and released from the dorsal surfaces of the lunate and proximal scaphoid (►**Fig. 1B**). The SLIL was identified and sectioned (►**Fig. 1C**). A JuggerKnot Soft Suture Anchor (Biomet, Inc., Warsaw, IN) was inserted into the lunate (►**Fig. 1D**). A radially based 0.5 cm wide flap of dorsal intercarpal ligament was developed from the elevated capsular flap (►**Fig. 1E**). This 0.5 cm DIR was fixed with tension onto the lunate to reconstruct the SLIL ►**Fig. 1F**). The remaining radially based flap of capsule was sutured with Vicryl absorbable sutures 3.0 over the DIR to restore the DIC (►**Fig. 1G** and **H**).

Measurement Technique

Each forearm was mounted into a testing apparatus to simulate palmar flexion (►**Fig. 2**). For the assessment of elongation, a differential variable reluctance transducer (DVRT) (LORD Sensing, Williston, VT) was used. A DVRT sensor measures linear displacement between two sites. To record elongation of the DIR, the DVRT was mounted at the location where the bone anchor was fixed at the lunate and the radial origin of the DIR (►**Fig. 1I**). To quantify the elongation of the DIC, the transducer was placed at the location where the JuggerKnot was fixed onto the lunate and Lister's tubercle (►**Fig. 1J**).

A Caperlan wire (Solognac-Caperlan, Cestas, France) was sutured around the third metacarpal, and through two fixed pulleys attached to a universal testing machine (Testometric Co, Rochdale, United Kingdom). The machine moved vertically at a speed of 5.0 mm/s, resulting in palmar flexion of the wrist. Data extraction started when the universal testing machine reached a 0.5 N preload. To quantify palmar flexion, a digital goniometer was attached at the dorsal aspect of the hand.

To assess the elongation of the DIR, ten wrists were tested five times from neutral position to 70-degree flexion. After testing the DIR, the DIC was tested. The test stopped if either the DIR or DIC failed, or the suture or the anchor was pulled out. Data was represented as the mean and standard deviation (SD) in a flexion elongation curve.

Results

No pre-existing lesions or evidence for prior wrist surgery were found on the anatomic specimen.

The mean elongation of the DIR at 70-degree palmar flexion was 0.8 mm (SD: 0.6) (►**Fig. 3**). The mean elongation of the DIC was 0.03 mm (SD: 0.1) at 5 degrees and 3.9 mm (SD: 1.7) at 70 degrees (►**Fig. 4**).

Visually, the DIR showed no bone anchor failure during the repeated flexion tests until 70 degrees. In four arms sutures to connect the proximal DIC to the surrounding tissue loosened at 55- and 60-degree palmar flexion.

Discussion

Symptomatic scapholunate instability can surgically be treated by a capsulodesis. In this study, the capsulodesis reconstruction was tested during 0- to 70-degree palmar flexion without failing of the bone anchor. The DIR and DIC showed minimal elongation during early flexion. Sutures to connect the proximal

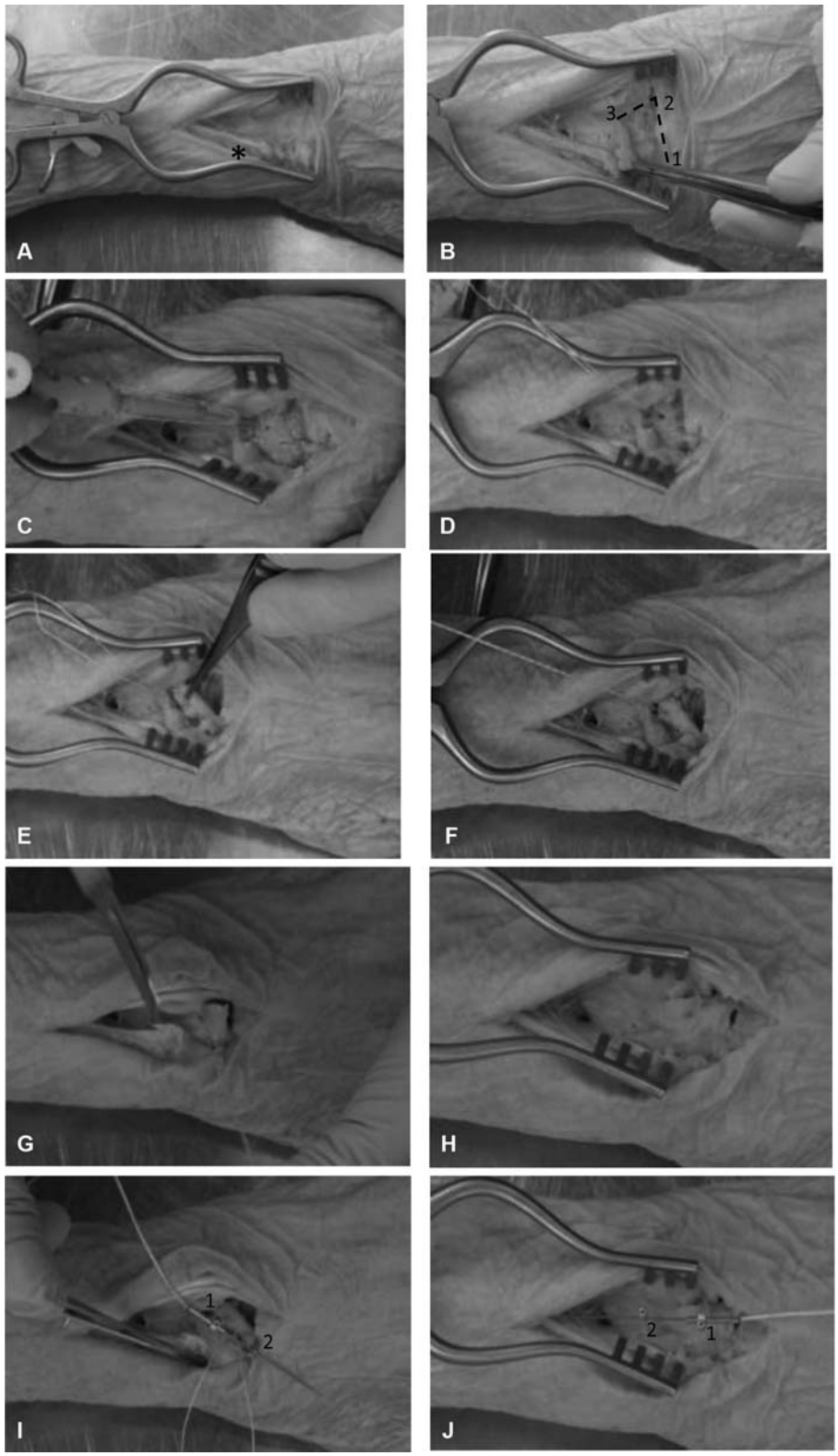

Fig. 1 Surgical approach of the dorsal intercarpal ligament capsulodesis with a bone-anchor. (**A**) An incision of 1 cm ulnar from Lister's tubercle (*) was made. The extensor retinaculum was opened. (**B**) A radially based flap was created. The incision started at the scaphotrapeziotrapezoid joint (1) and moved ulnar until the dorsal ridge of the triquetrum (2). At the triquetrum, the incision took a proximal oblique course following the fibers of the dorsal radiocarpal ligament until the lunate fossa (3). (**C**) The scapholunate interosseous ligament was identified and sectioned. A JuggerKnot Soft Suture bone Anchor was used. (**D**) The bone anchor was inserted into the lunate. (**E**) From the radially based flap, a smaller flap (dorsal intercarpal reconstruction, DIR) was created. (**F**) The DIR was fixed onto the lunate using the bone anchor. (**G**) The bone anchor was sutured in the center of the overlaying radially based flap. (**H**) The remaining radially based flap connected to the surrounding tissue to restore the dorsal intercarpal complex (DIC). (**I**) For measuring the elongation of the DIR, the differential variable reluctance transducer (DVRT)-sensor was placed at the bone anchor in the lunate (1) and at the radial origin of the DIR (2). (**J**) For measuring the elongation of the dorsal intercarpal complex, the DVRT-sensor was placed at the bone anchor in the lunate (1) and Lister's tubercle (2).

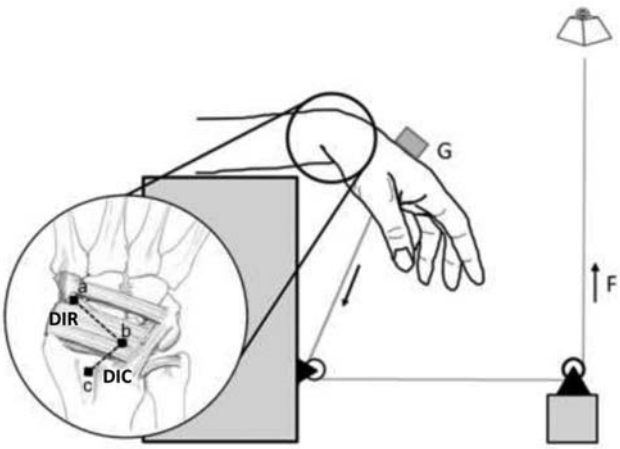

Fig. 2 Schematic overview of testing apparatus. The universal testing machine is moving vertically (F), resulting in palmar flexion of the wrist. The differential variable reluctance transducer sensor was placed at the radial side of the dorsal intercarpal reconstruction (DIR) (**A**) and at the bone anchor (**B**) to measure the elongation of the DIR, and from the bone anchor (**B**) to Listers tubercle (**C**) to measure the elongation of the dorsal intercarpal complex (DIC). A digital goniometer (G) at the dorsal aspect of the hand was used to quantify the palmar flexion.

side of the DIC to the surrounding tissue loosened at 55 and 60 degrees. These results might indicate controlled early active motion is safe until 50-degree palmar flexion.

The SLIL is not the only ligament involved in stabilizing the scapholunate interval. At the volar side of the wrist, the palmar radiocarpal ligament, radioscaphocapitate ligament, and the scaphotrapeziotrapezoid ligament contribute to stability. At the dorsal side, the dorsal intercarpal ligament and the dorsal radiocarpal ligament stabilize the interval.

Previous biomechanical studies categorized the wrist ligaments in primary and secondary stabilizers.[15–17] Only after sectioning the SLIL, significant changes in movement of the lunate and scaphoid were observed. These results suggested the SLIL ligament is the primary stabilizer. When carpal instability occurs in patients, more stabilizers might be torn. To limit the effect of multiple variables, this study observed reconstruction elongation with a sectioned SLIL only.

Capsulodesis reconstructions resulted in significant reduction in pain and increase in grip strength.[18,19] However, flexion of the wrist can be reduced significantly to 45 degrees.[10,11,20] Although improvements in scapholunate angle and scapholunate gap were found in short-term follow-up, the alignment

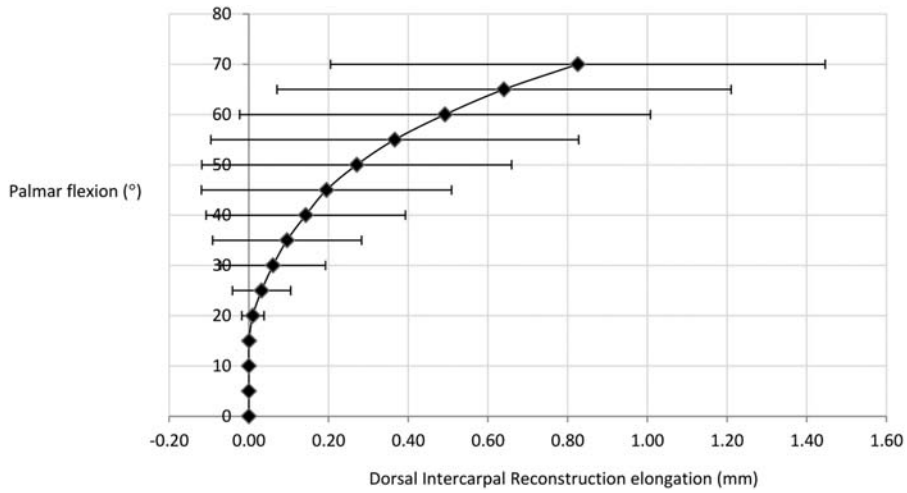

Fig. 3 Linear elongation to palmar flexion on the dorsal intercarpal reconstruction.

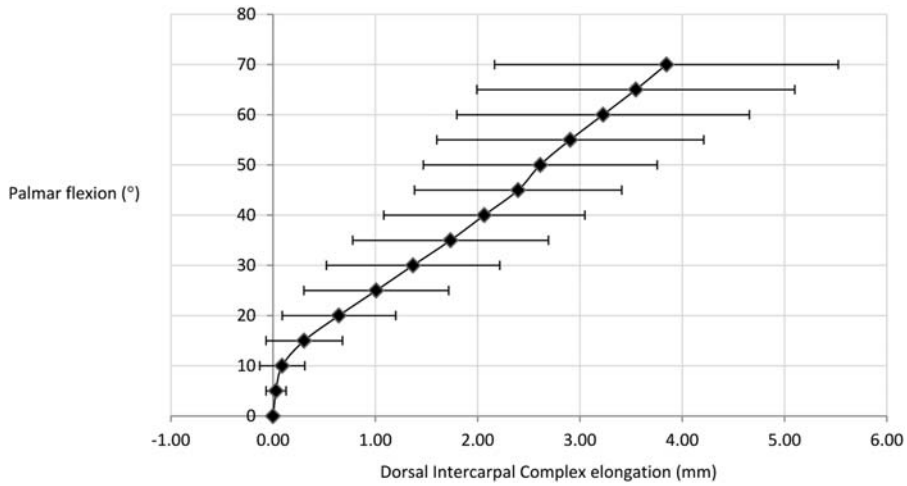

Fig. 4 Linear elongation to palmar flexion on the dorsal intercarpal complex.

seems not to be maintained at longer follow-up.[11] Still, most patients treated with capsulodesis were asymptomatic and none needed further treatment.

To protect the capsulodesis, patients are generally immobilized allowing the tissues to heal. However, immobilization of a joint results in stiffness and atrophy. The balance between protection and prevention of motion loss is considered difficult. The results of this study indicate capsulodesis create a reconstruction that can withstand 50-degree palmar flexion with minimal amounts of elongation during early flexion. Furthermore, no failure of the bone anchor was seen. In four arms, the suture knots were loosening at the proximal side of the DIC between 55- and 60-degree palmar flexion. At the time the suture loosening occurred, the mean DIC elongation of the four wrists was 3.8 mm. The mean DIC elongation of all wrists was 3.9 mm. This difference is presumably caused by differences in soft tissue stiffness of the used upper limbs, indicating the wrists in which loosening occurred was less stiff. No tissue ruptures or suture tears were observed. This observation implies extra attention is needed in suturing the proximal side of the DIC.

This study has several limitations. First, only palmar flexion was tested. Although postoperative palmar flexion is reduced most, it would be thorough to examine extension, ulnar and radial deviation as well.

Second, this study used a limited number of embalmed upper limbs of older people and a limited number of tests on the same upper limb. Because embalming can cause shrinkage of anatomical structures, the measurements might have influenced the size and quality of the ligaments. Furthermore, flexion greater than 45 degrees might have caused distraction of the wrist and stretch the DIC repair. This might have affected the results. Although the absolute displacements and angulations may include uncertainties, the trends of the measurements are helpful because the results have always been interpreted in relation to displacement in the same structure. This type of surgery leads to stiffness and scarring of patient wrists capsule, which influences the range of motion and provides more stability. Because we used embalmed upper limbs, this process could not occur and may have influenced our results. The nearest to the human in vivo situation would be to perform measurements on unembalmed human bodies. Because we used human bodies of older age, we had to cope with inferior soft tissue and absence of scar tissue. This suggests that the capsulodesis, which is normally performed on younger patients, might withstand more flexion.

Third, this study focused on one surgical intervention, while several techniques are reported for injuries of the SLIL, including tenodesis. The Brunelli tenodesis and its modifications attempt to correct scaphoid dissociation and flexion by tunneling a tendon graft through the scaphoid and connecting it to the lunate.[4,5] Like the capsulodesis, tenodesis is associated with a decrease in postoperative range of motion and grip strength.[5] It would be valuable to know more about the biomechanics to improve postoperative results.

Conclusions

Despite the limitations, this study showed that during early palmar flexion the elongation of the reconstruction is minimal and the bone anchor showed no failure. The capsulodesis creates a reconstruction that can withstand 50-degree palmar flexion with minimal amounts of elongation. This supports the hypothesis that a controlled early rehabilitation might be possible.

Funding
The JuggerKnot Soft Suture Anchors (Biomet, Inc., Warsaw, IN) were funded by Zimmer Biomet.

Conflict of Interest
None declared.

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